

# Magma-Tectonic Interactions – Static Stress Triggering

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Penn State

# Outline

## Stress Triggering

- Dynamic, Quasi-Static & Static

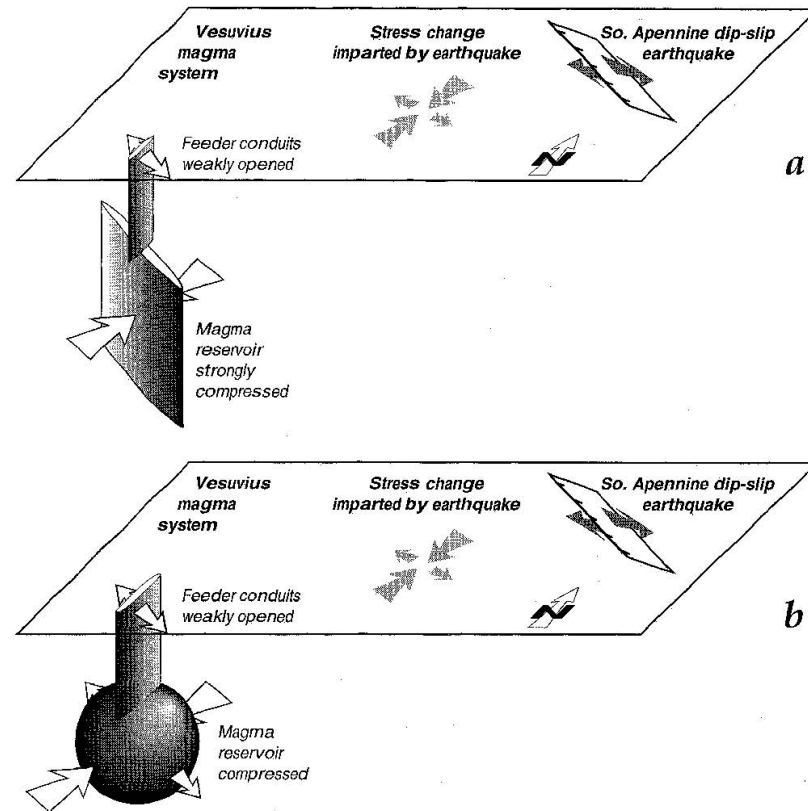
## Earthquake-Eruption Triggering Examples

- Vesuvius-Apennines
- Mt. Fuji & Nankai

## Earthquake-Earthquake Triggering

- Dynamic triggering
  - $1/r^2-1/r$  (body & surface waves)
  - Time lag = min. to hours
  - $r < 1200$  km
  - Magmatic processes: advective overpressure, rectified diffusion
- Quasi-Static triggering
  - $1/r^2-1/r$
  - Time lag = years to centuries
  - Dependant on effective viscosity of lower crust & upper mantle

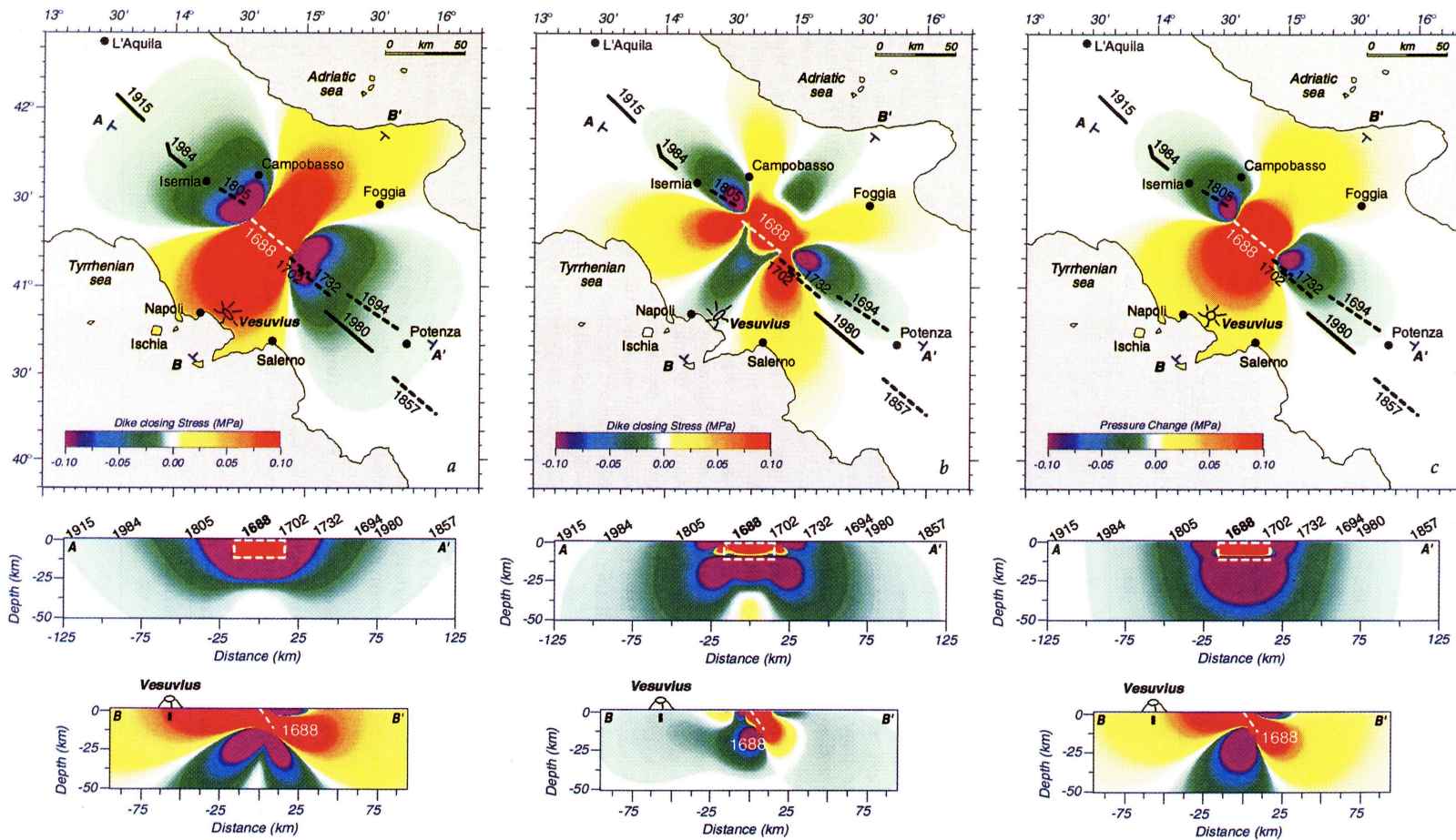
- Static triggering
  - $1/r^3$
  - Time lag = months to years
  - Limited to a few fault lengths
- Volcanism
  - Normal stress change – ‘unclamping’
  - Compressional stress – ‘squeeze’ magma chamber
- Stresses – Low!
  - Smaller than Earth tides (0.001 MPa)



**Figure 3.** Schematic illustration of the response of a hypothetical Vesuvius magmatic system to a southern Apennine normal-faulting earthquake for (a) a buried dike in which at least one fissure or feeder conduit strikes NE and (b) a buried spherical magma chamber with a NE striking fissure.

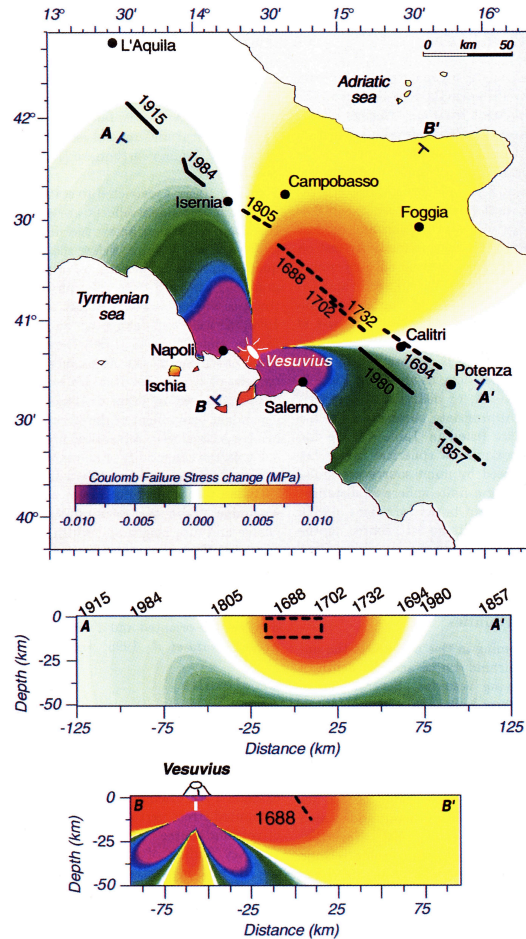
Nostro et al. (1998) JGR

# Vesuvius and Apennines



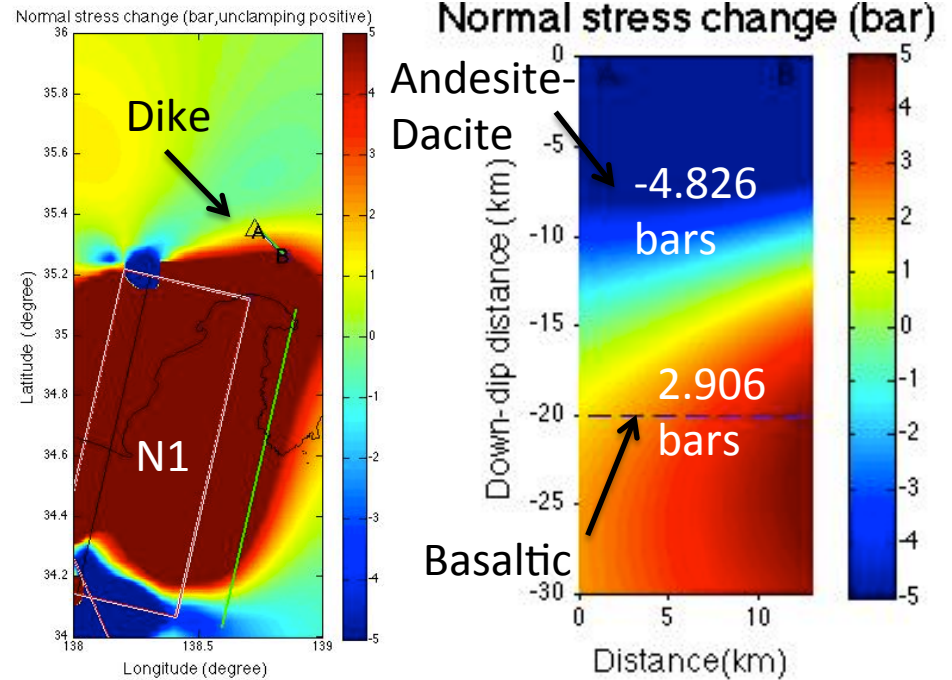
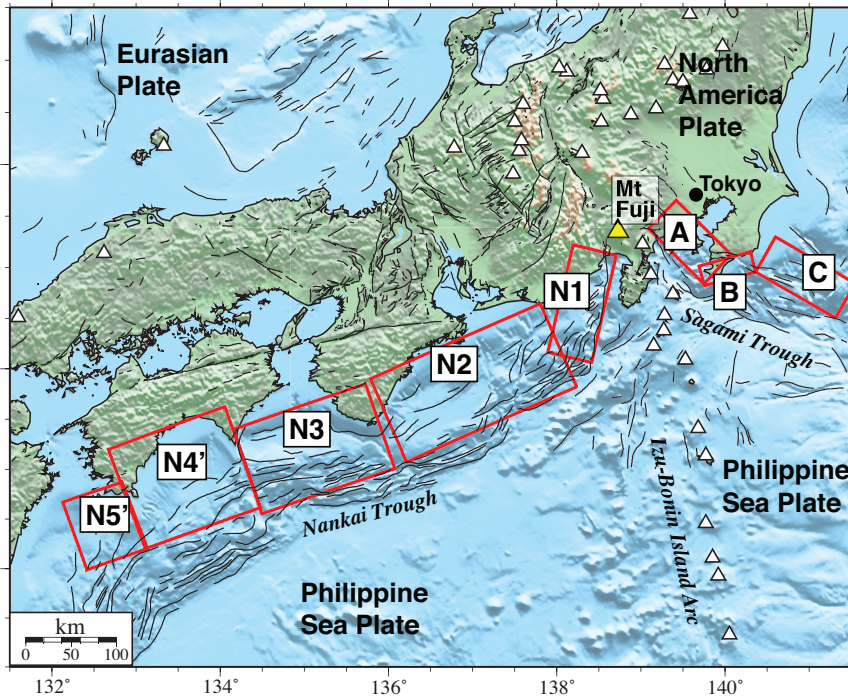
Nostro et al. (1998) JGR

# Vesuvius and Apennines



Nostro et al. (1998) JGR

# Mt. Fuji & Nankai



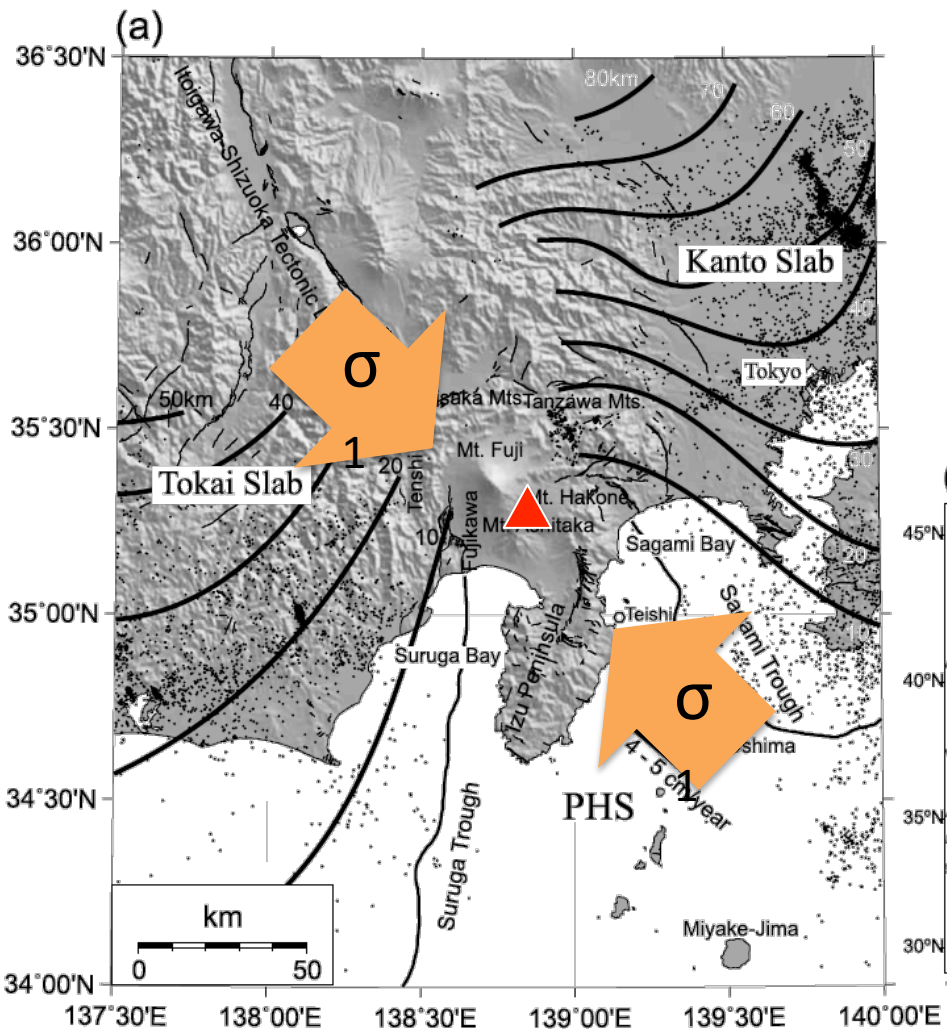
## 1707 Hiei Earthquake and Mt. Fuji Eruption

- $M_w$  8.7 earthquake followed 49 days later by VEI 5 eruption
- Investigate stress trigger; 1703 Genroku  $M_w$  8.2 & Mt. Fuji
- Magma mixing – andesitic & dacitic magmas; basaltic magmas later

C. Chesley (UM-UNAVCO RECESS), C. Puskas (UNAVCO), D. Kobayashi (PSU)



# Mt. Fuji



Nakamichi et al. 2005

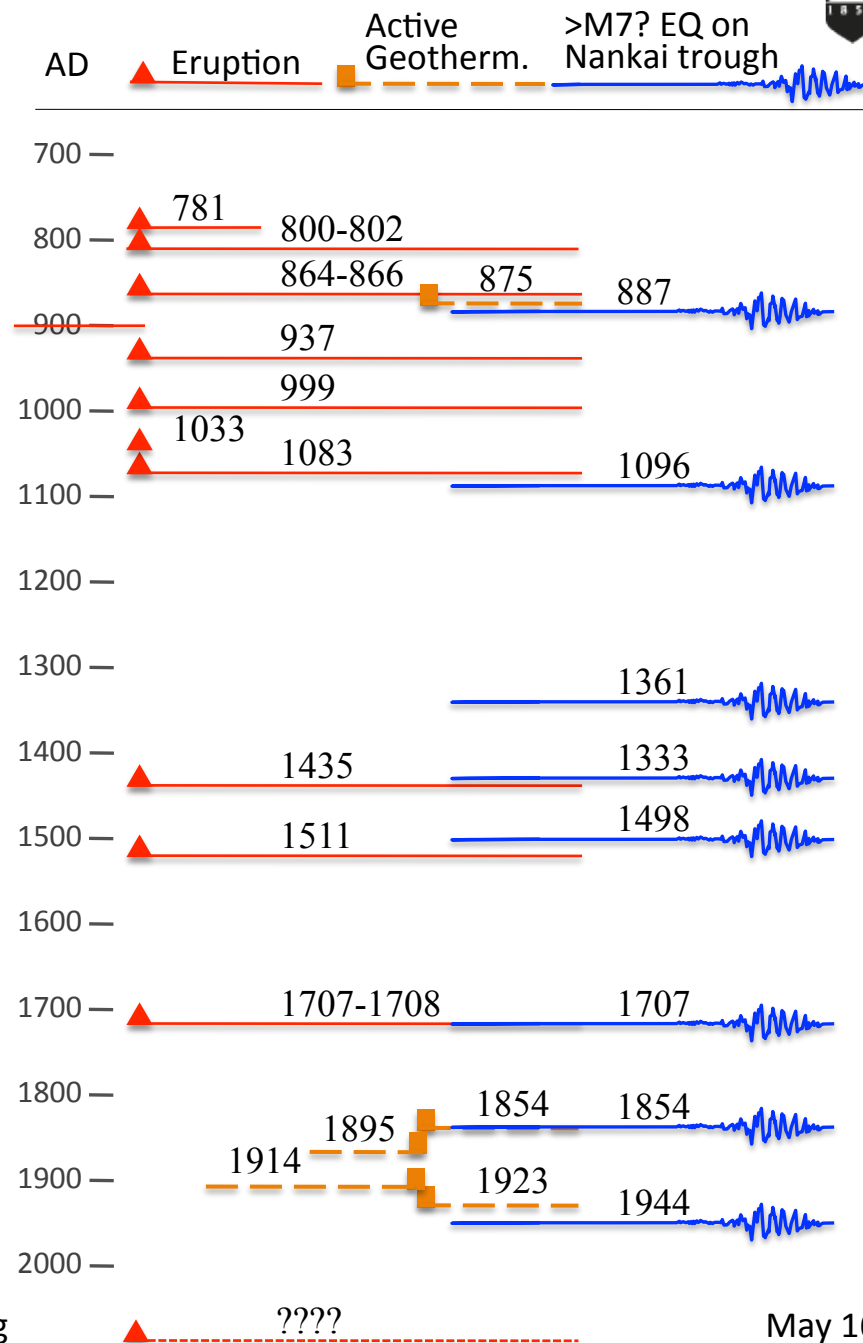


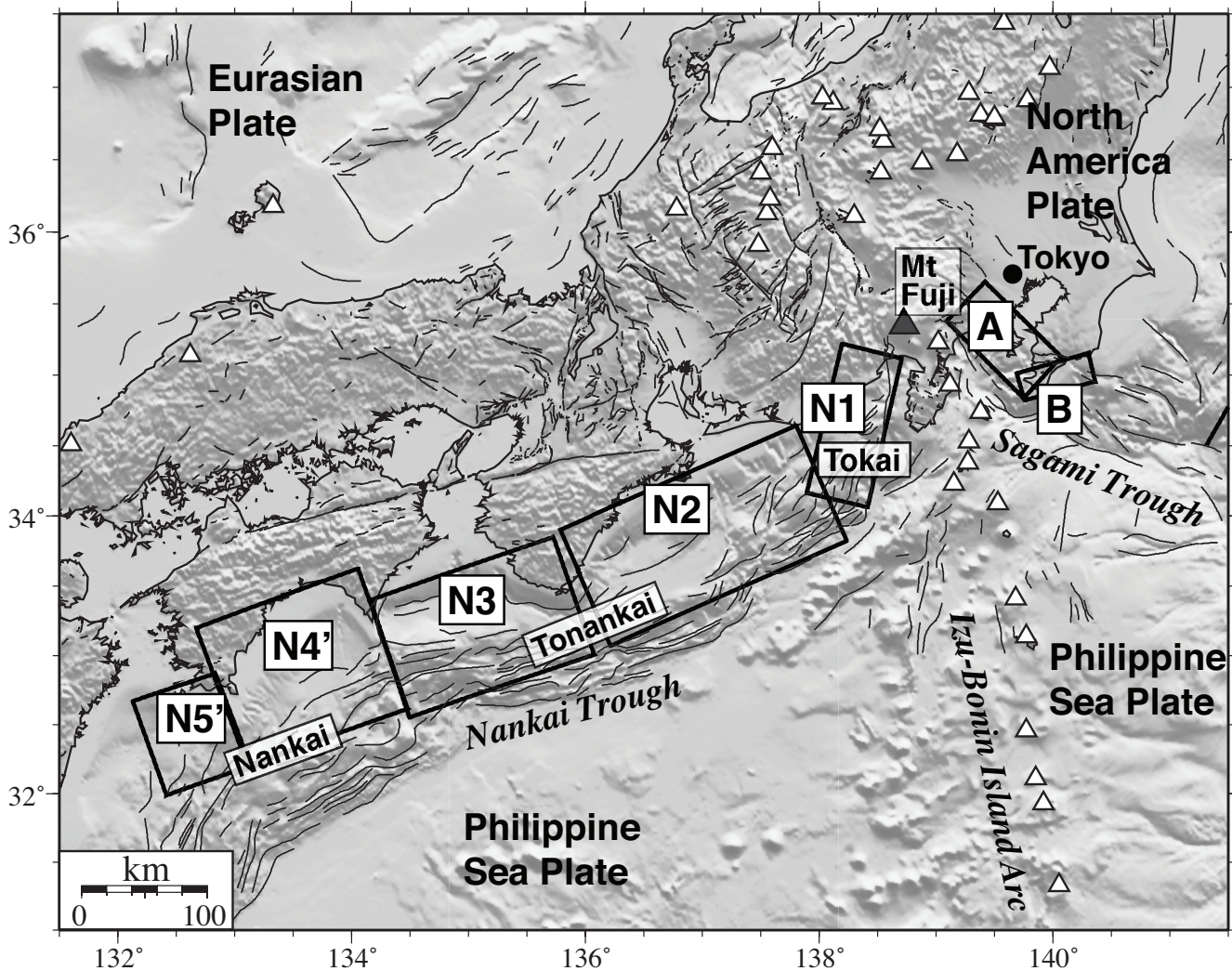
Vent distribution  
Modified from Nakamura 1976

# Mt. Fuji



## Mt. Fuji Eruptive History & Nankai Seismicity

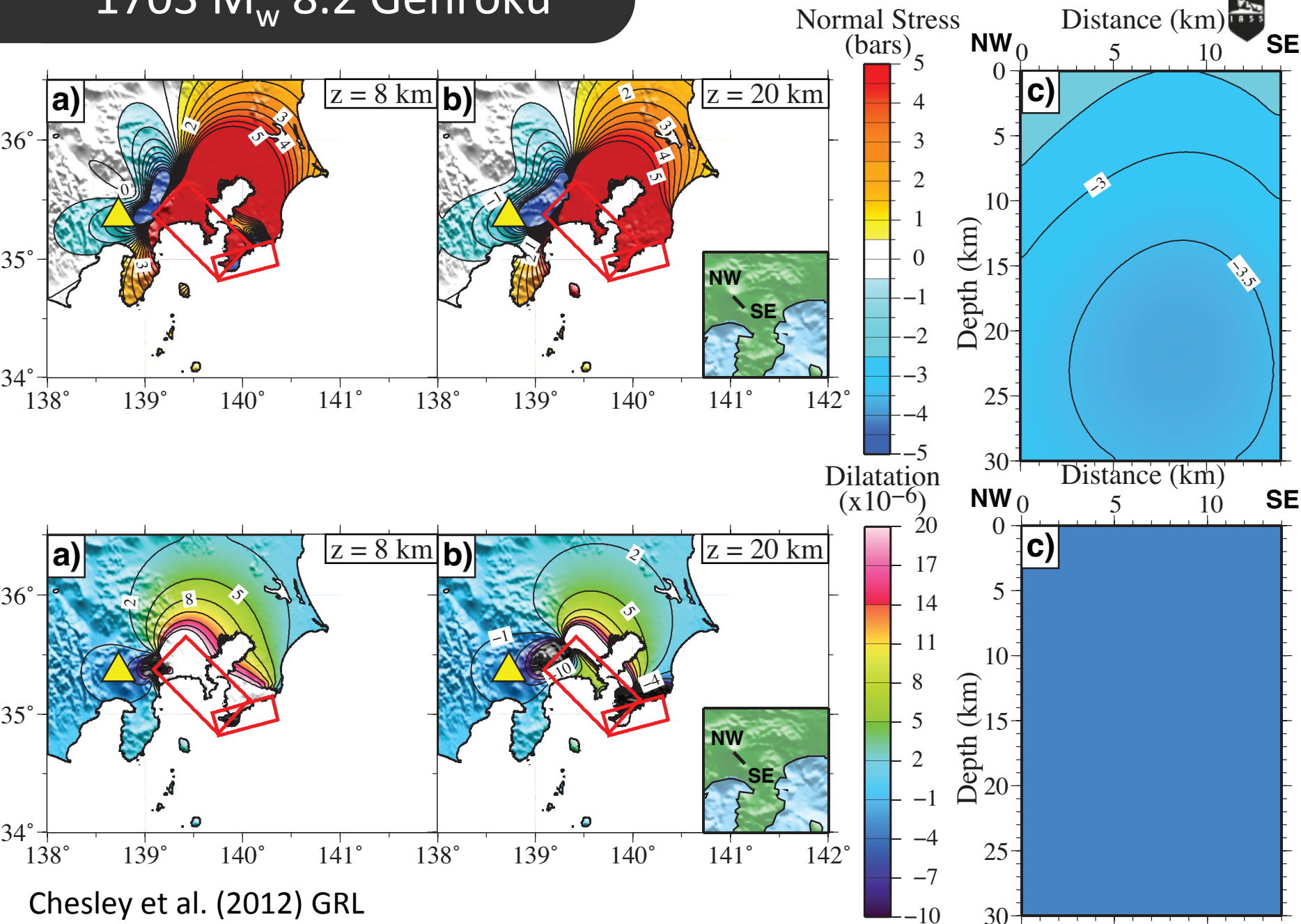




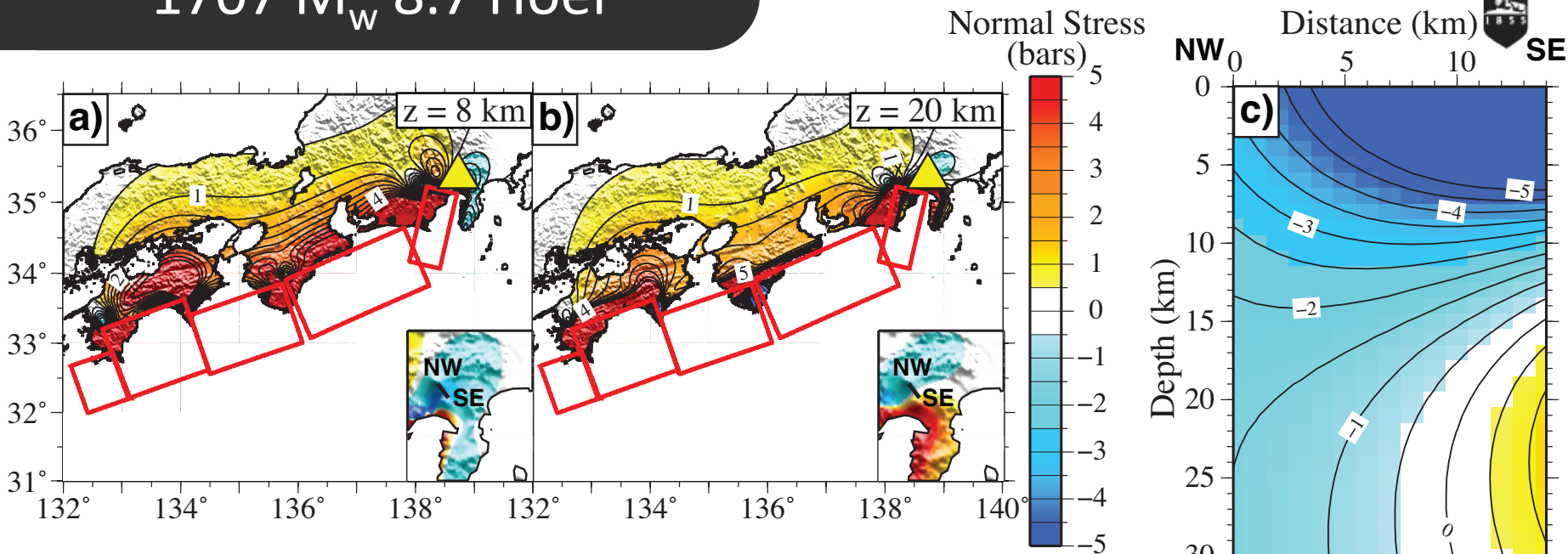
Chesley et al. (2012) GRL

1707  $M_w$  8.7 Hoi and 1703  $M_w$  8.2 Genroku earthquakes

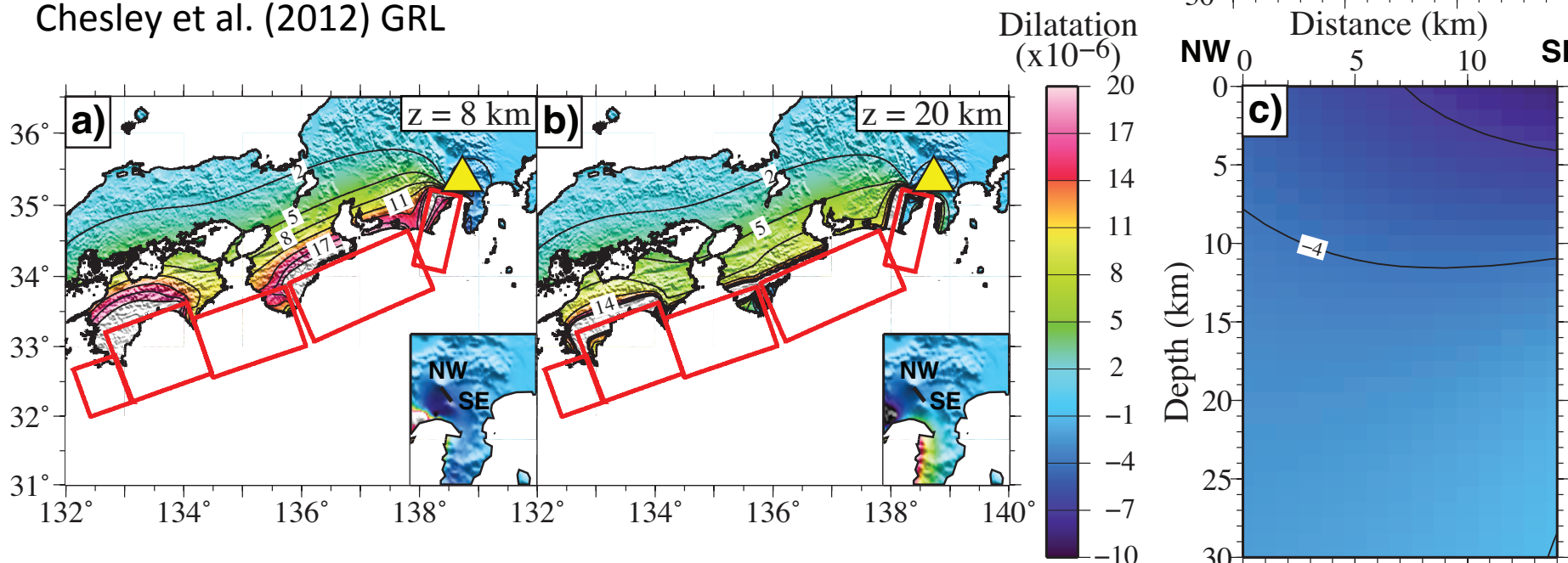
# 1703 M<sub>w</sub> 8.2 Genroku



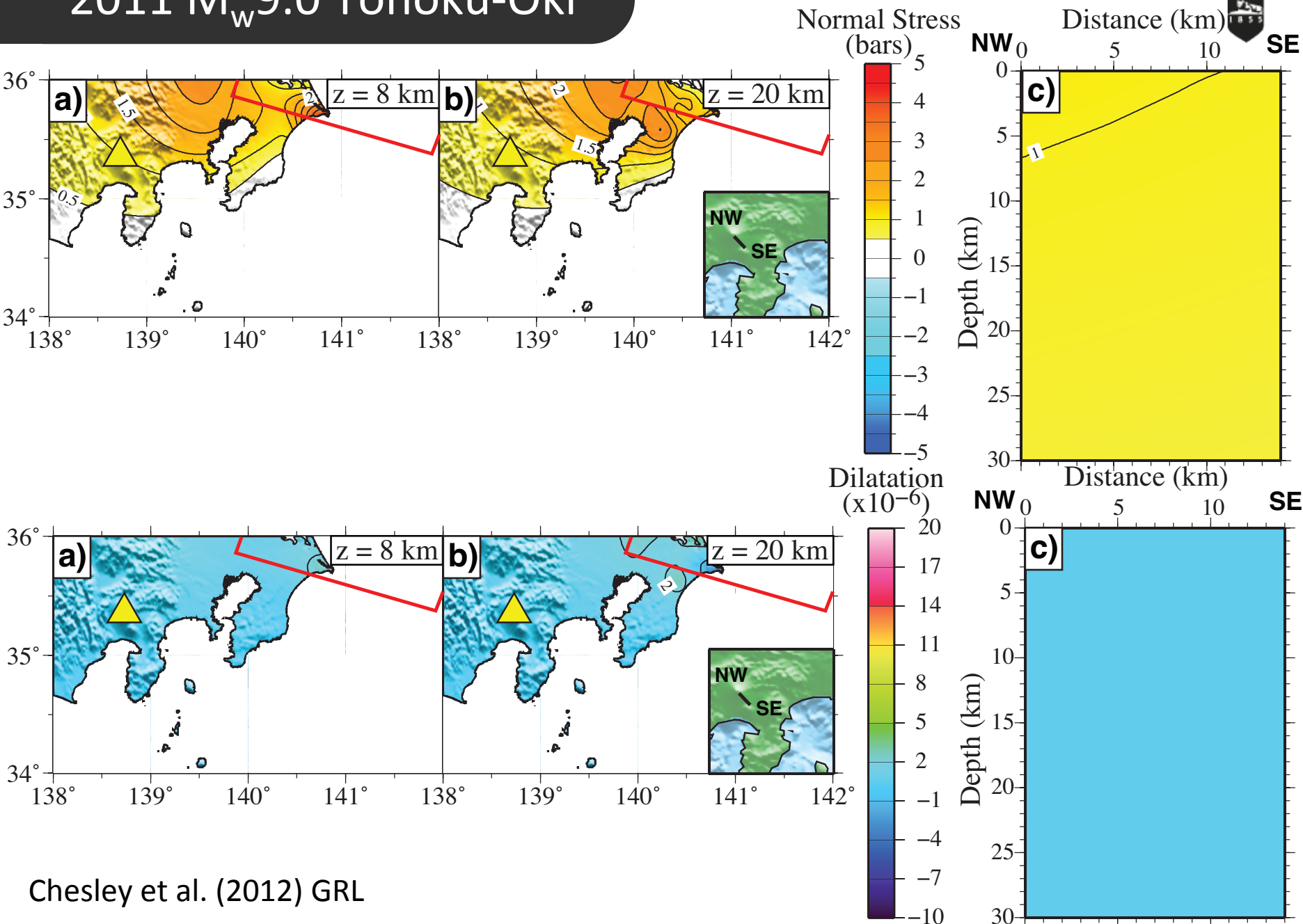
# 1707 $M_w$ 8.7 Hiei



Chesley et al. (2012) GRL

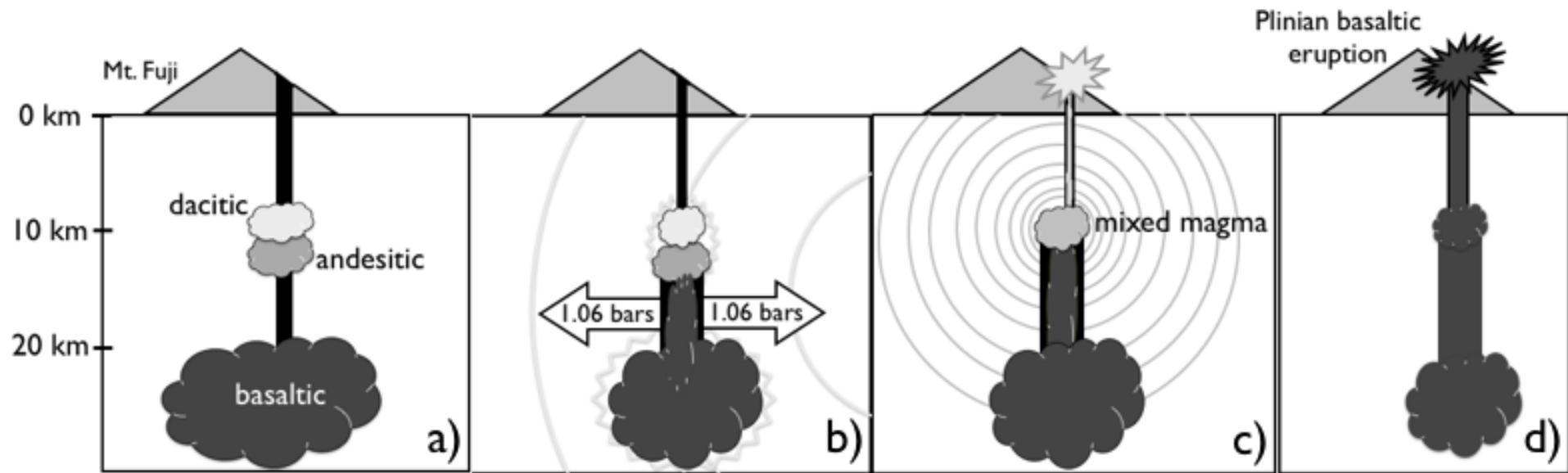


# 2011 $M_w$ 9.0 Tohoku-Oki



Chesley et al. (2012) GRL

# 1707 Hiei Eruption



## 1707 Hiei Earthquake and Mt. Fuji Eruption

- $M_w$  8.7 earthquake followed 49 days later by VEI 5 eruption
- Unclamping of dike at ~10 - 20 km depth
- Magma mixing – andesitic & dacitic magmas; basaltic magmas later

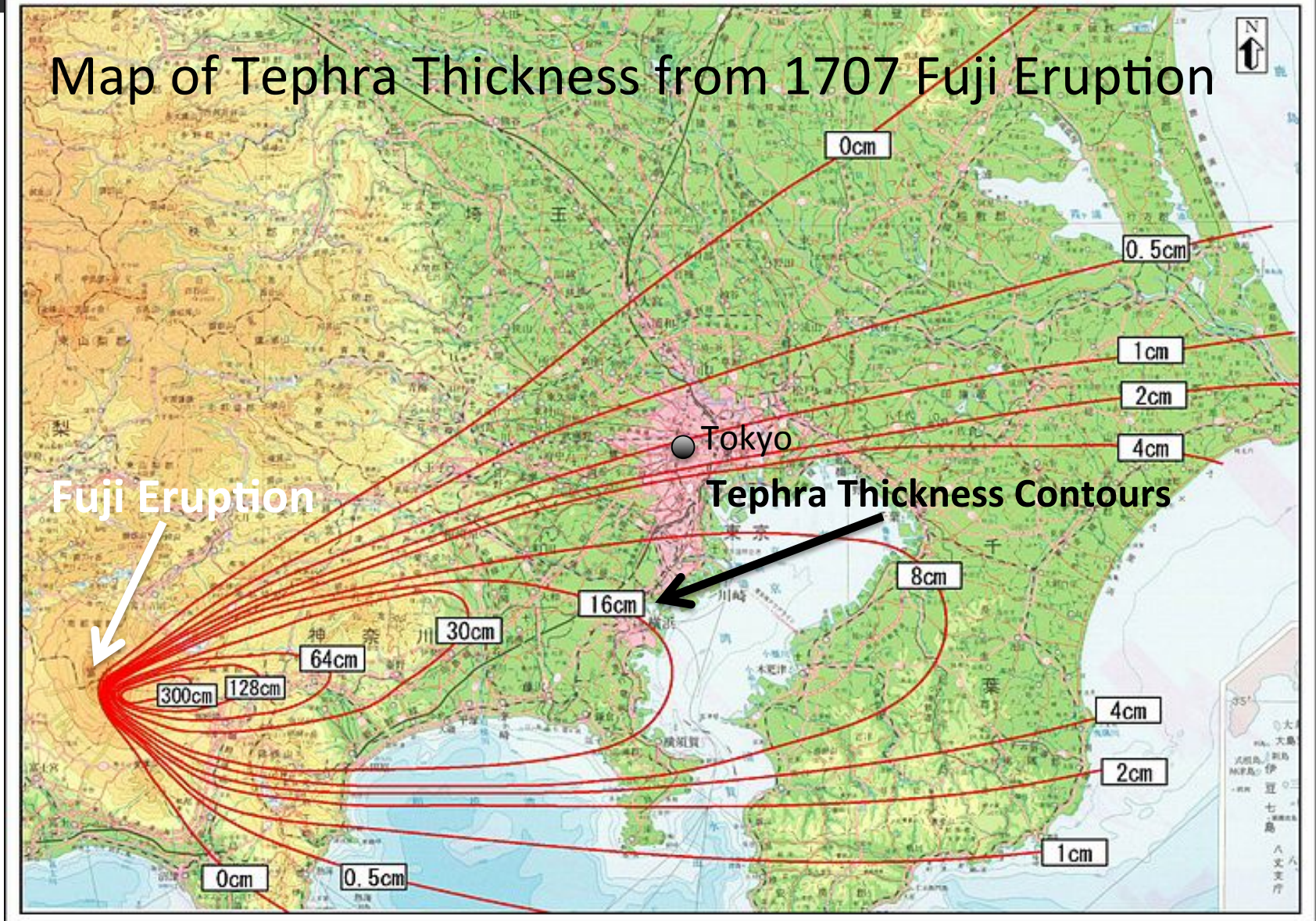
Chesley et al. (2012) GRL

# Mt. Fuji



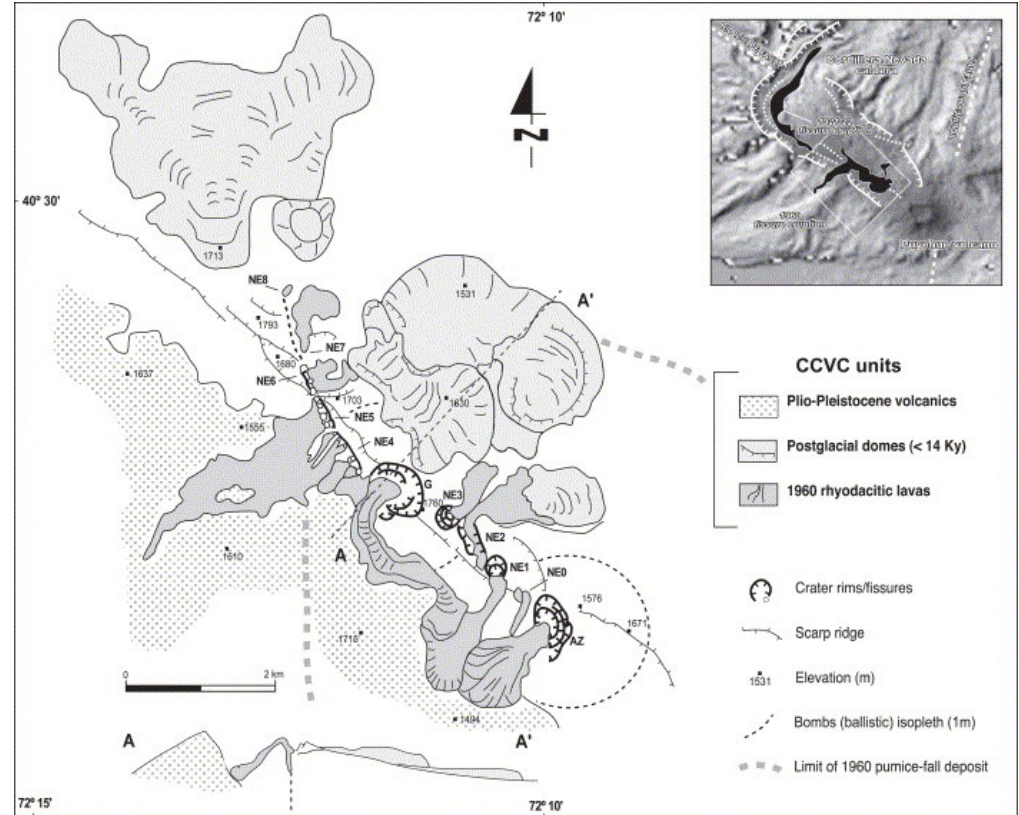
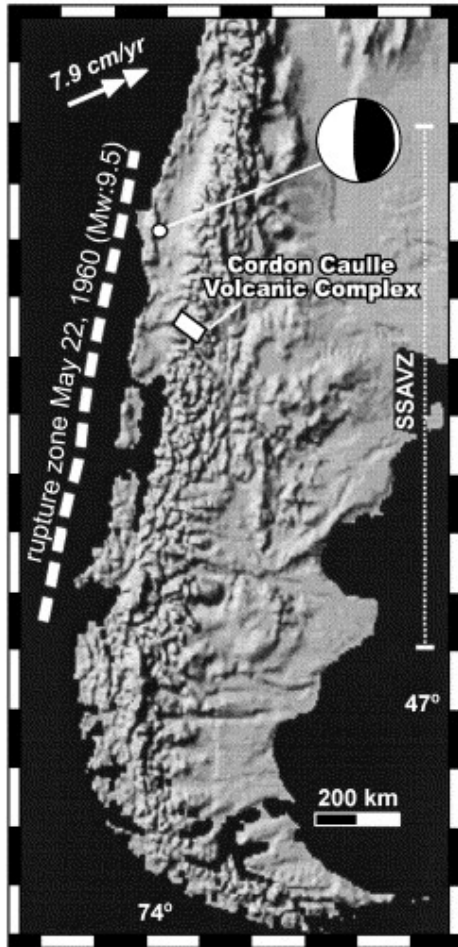


## Map of Tephra Thickness from 1707 Fuji Eruption



[http://upload.wikimedia.org/wikipedia/commons/thumb/3/31/Volcanic-ash-downfall\\_map\\_of\\_Mt.Fuji\\_Hoei-eruption01.jpg/774px-Volcanic-ash-downfall\\_map\\_of\\_Mt.Fuji\\_Hoei-eruption01.jpg](http://upload.wikimedia.org/wikipedia/commons/thumb/3/31/Volcanic-ash-downfall_map_of_Mt.Fuji_Hoei-eruption01.jpg/774px-Volcanic-ash-downfall_map_of_Mt.Fuji_Hoei-eruption01.jpg) <http://www.bousai.go.jp/fujisan-kyougkai/>

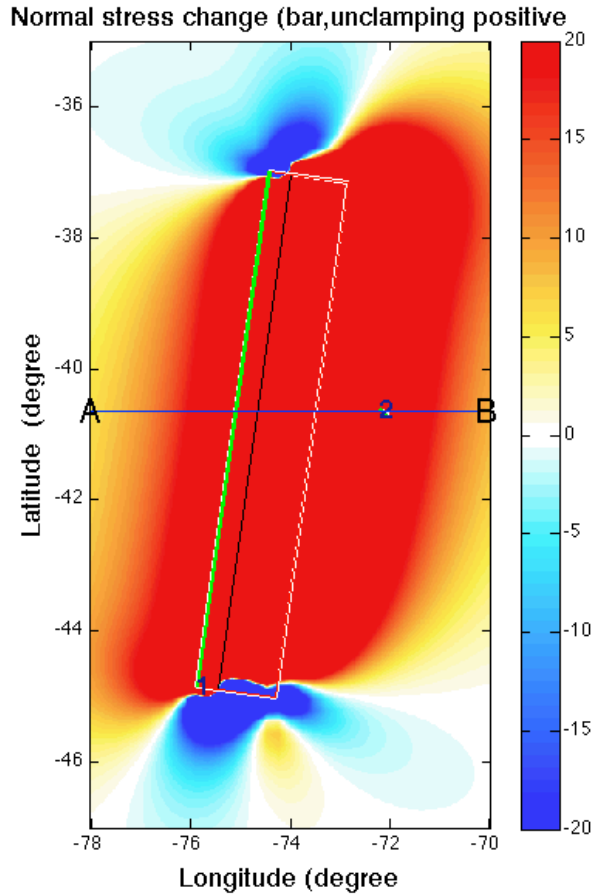
# 1960 $M_w$ 9.5 Valdivia, Chile



Lara et al. (2004)

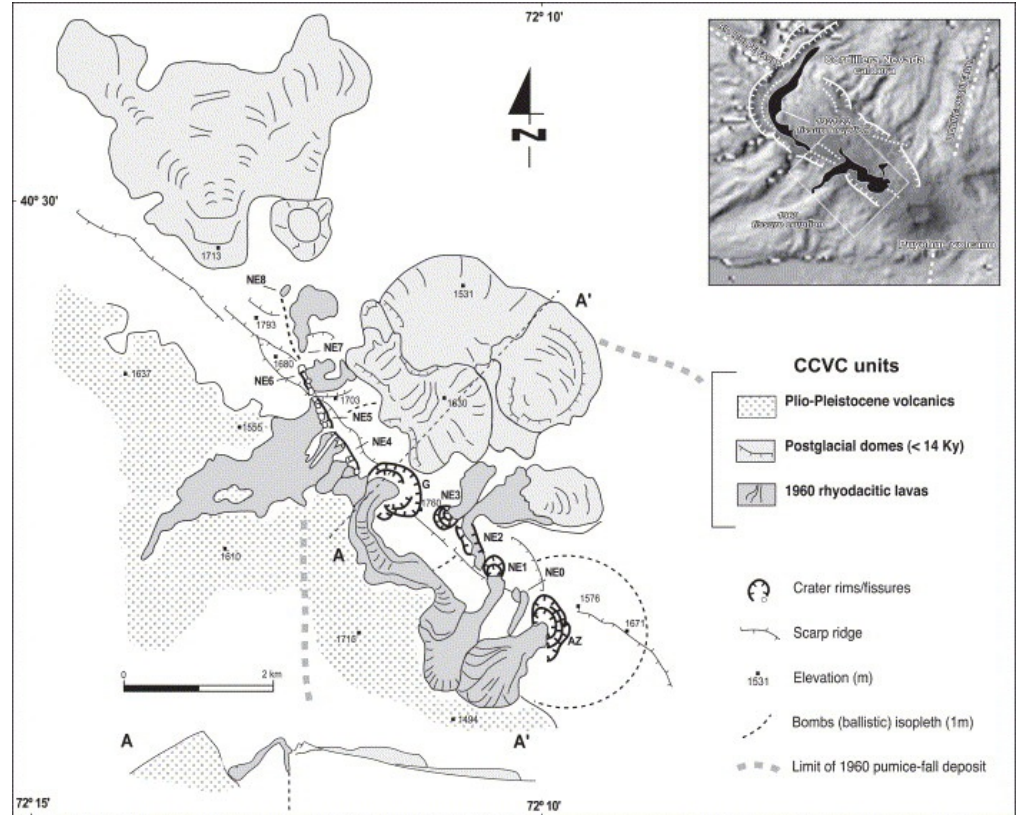
Chesley et al. (2012) GRL

# 1960 Cordon-Caulle



Coulomb 3.3.01 25-Apr-2013 23:54:55 Valdivia\_9.5\_rupture.inp  
 Specified faults: 130/90/90 Depth: 10.00 km Friction: 0.40

P. Hill (2013)

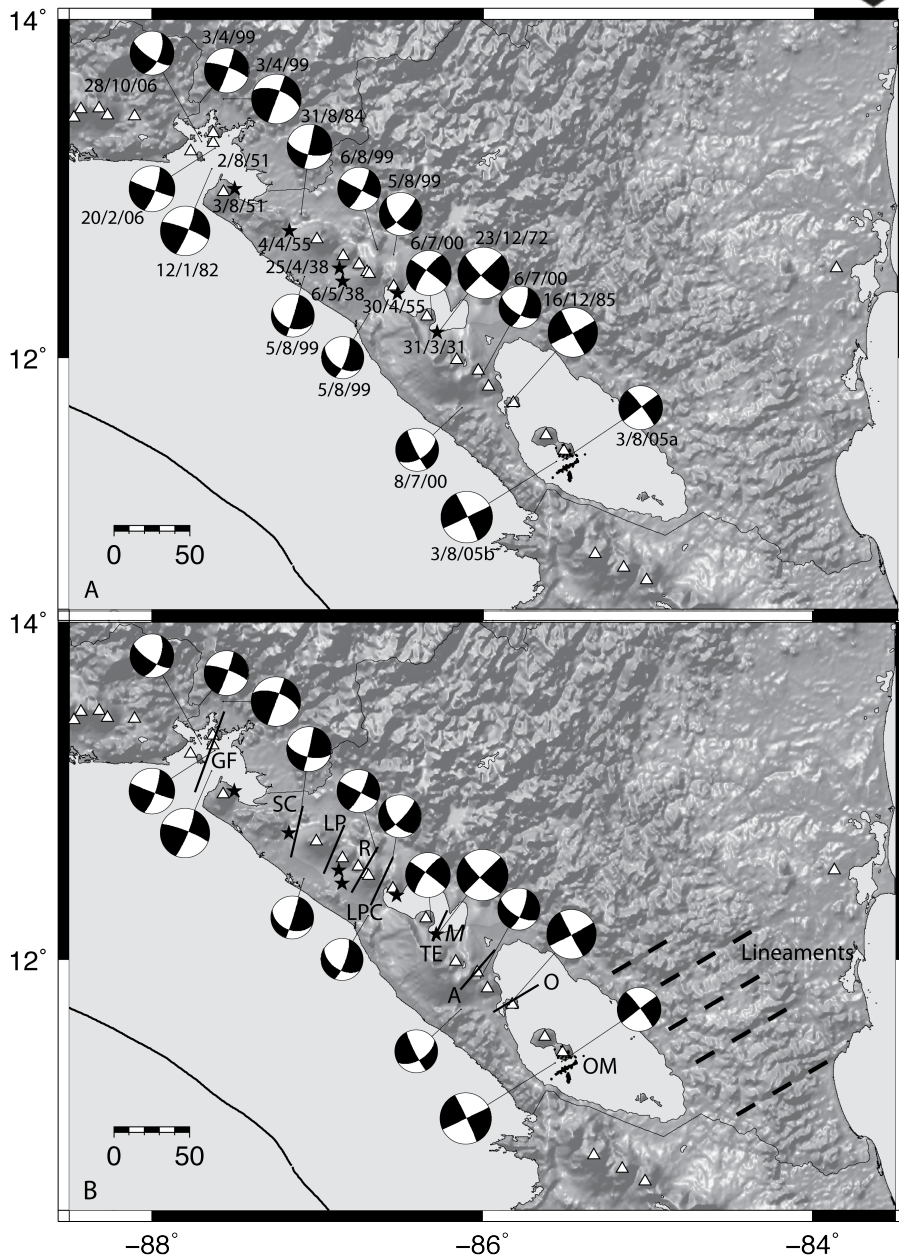


Lara et al. (2004)

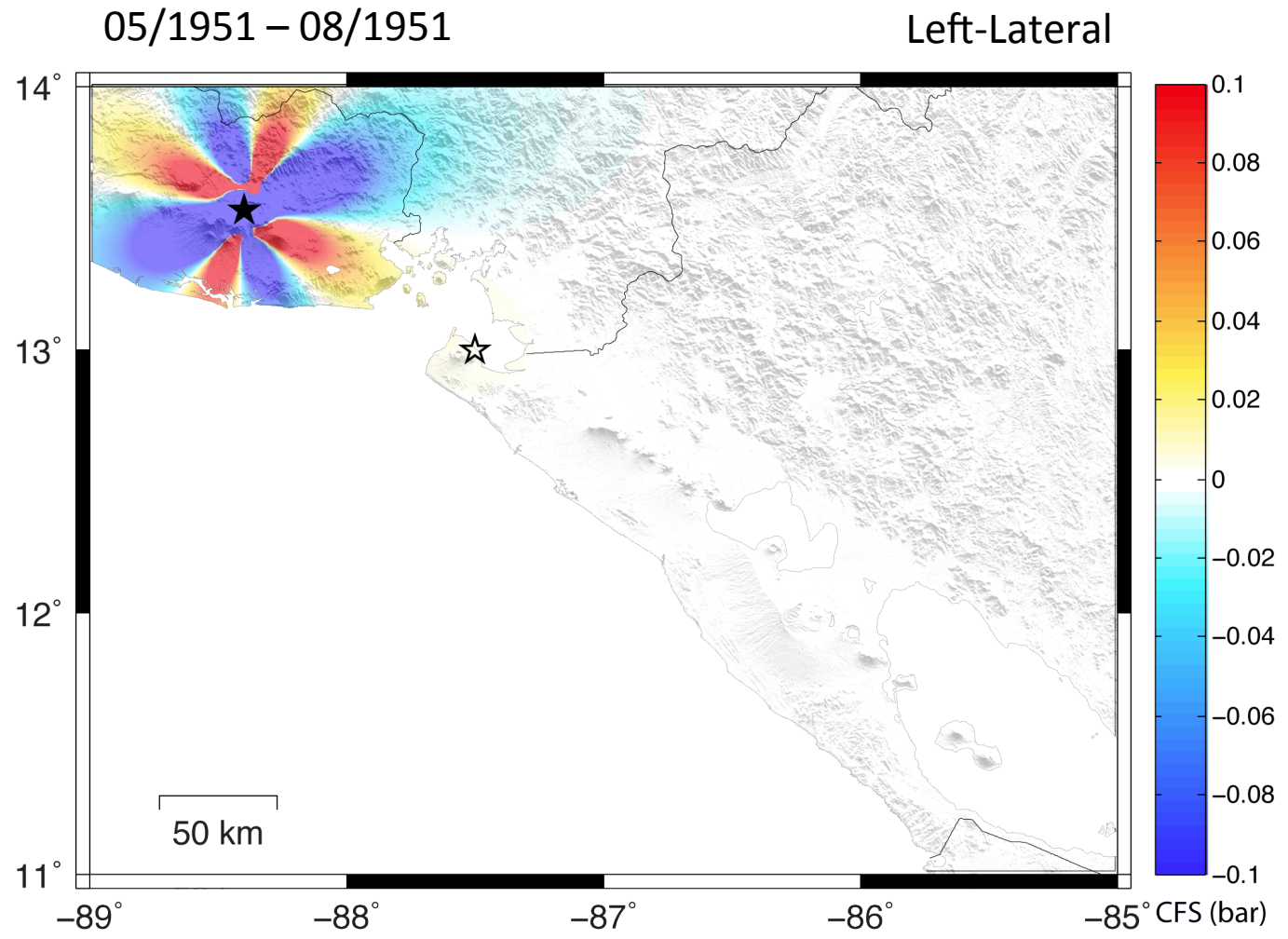


# Nicaragua Fore-Arc Motion

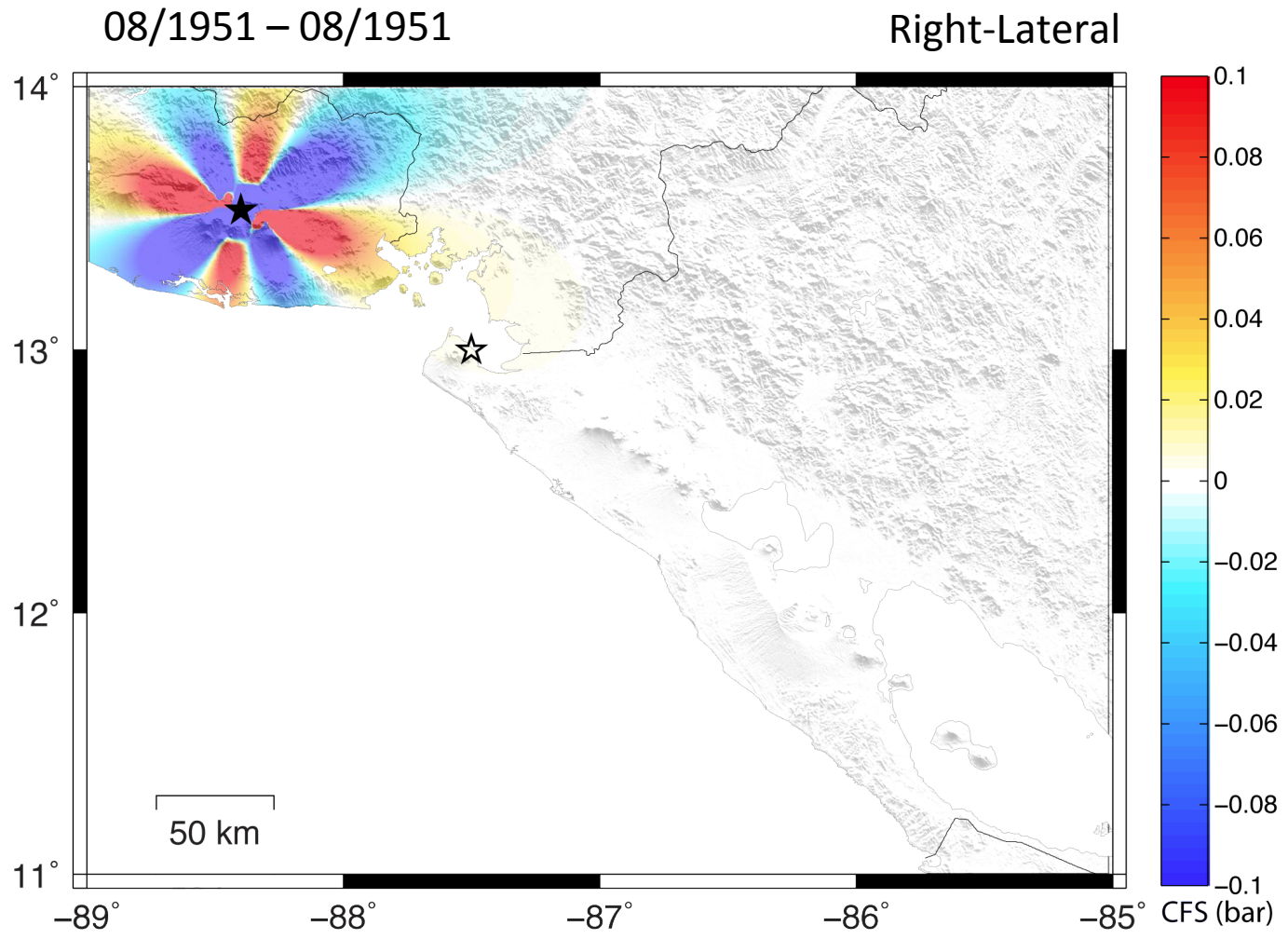
- Upper plate seismicity indicates northwest directed fore arc sliver transport
  - Central Costa Rica to Guatemala
- Diffuse deformation in CCRDB
- Shallow (<20 km) & located within 20 km of arc
- Focal mechanisms are consistent w/ NE or NW trending fault planes
- $M_s < 6.5$
- Elongated damage zones & focal mechanisms NW to NE
- Cluster & Migrate along strike
- Historically have caused greater damage and loss of life (e.g., 23/12/72 M6.2 Managua)



# Earthquake - Earthquake

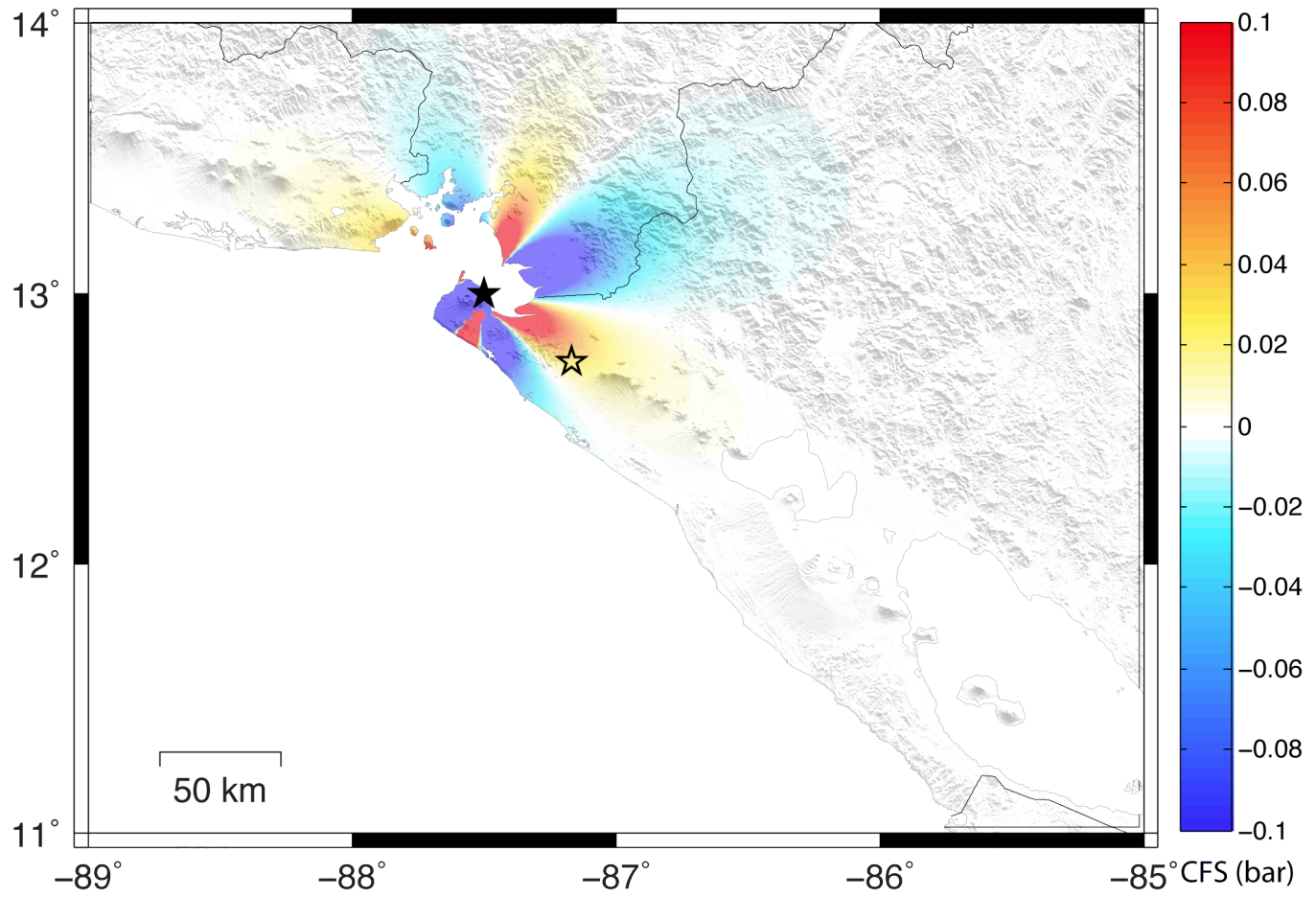


# Earthquake - Earthquake



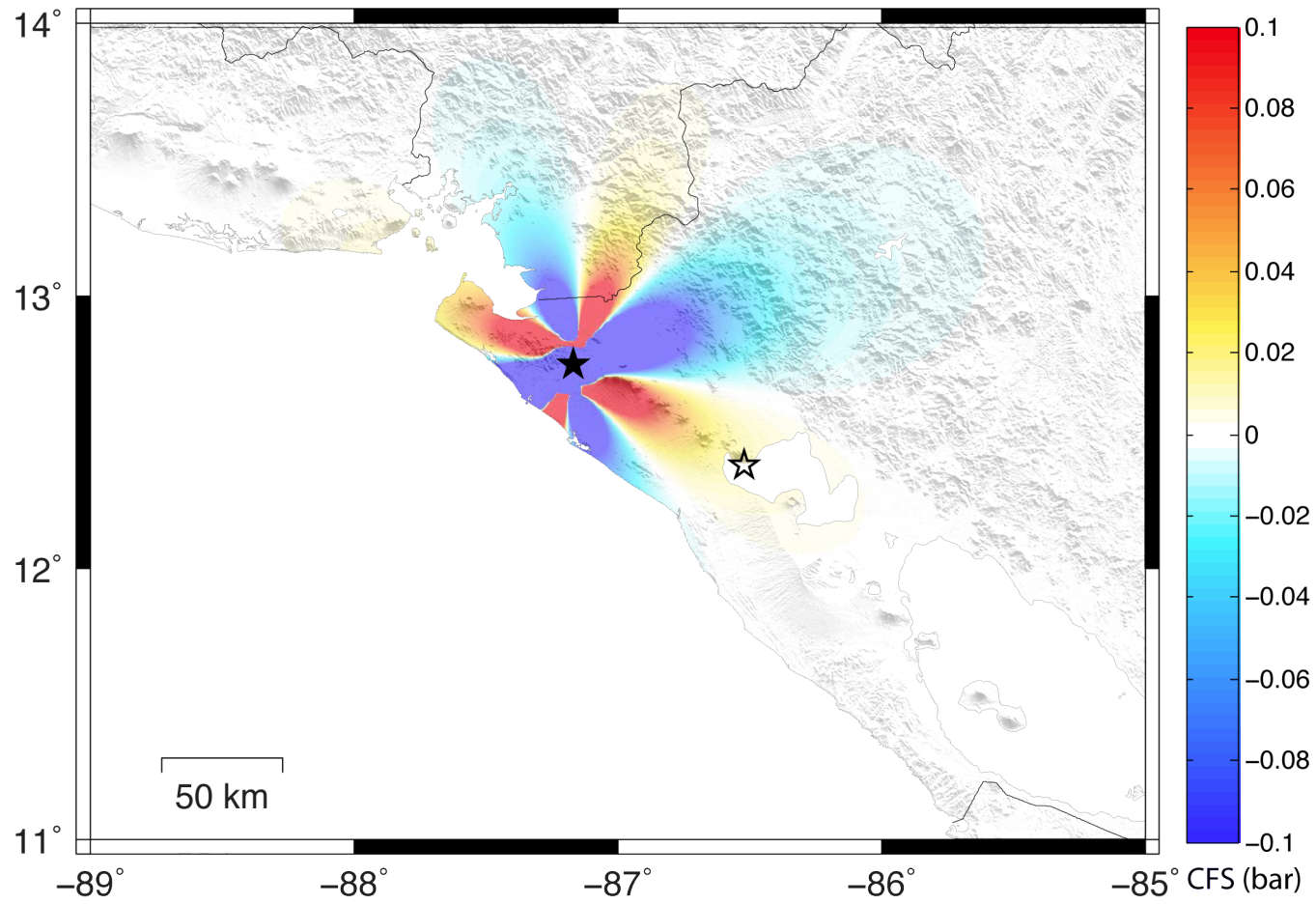
# Earthquake - Earthquake

08/1951 - 04/1955



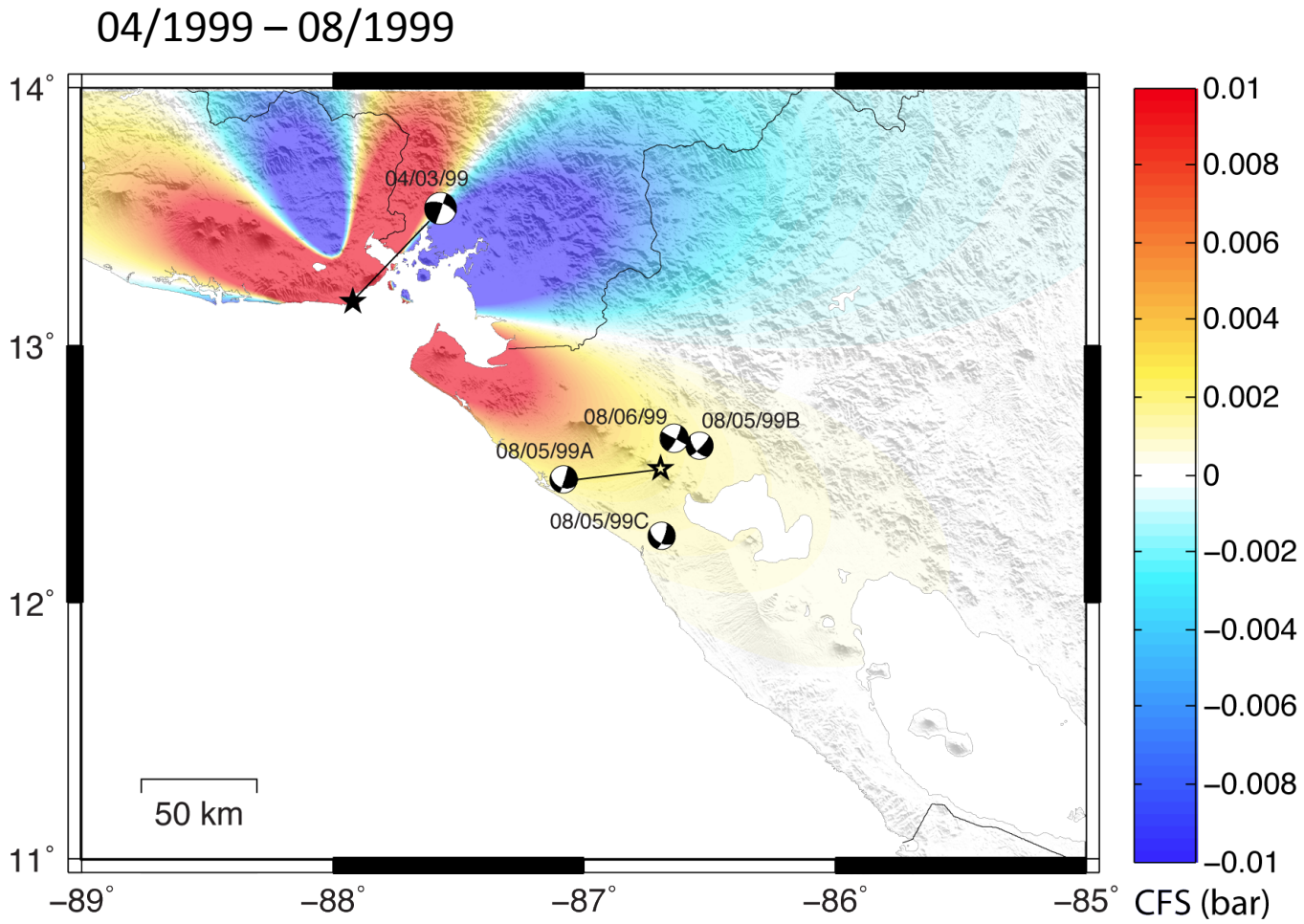
# Earthquake - Earthquake

04/04/1955 – 04/30/1955

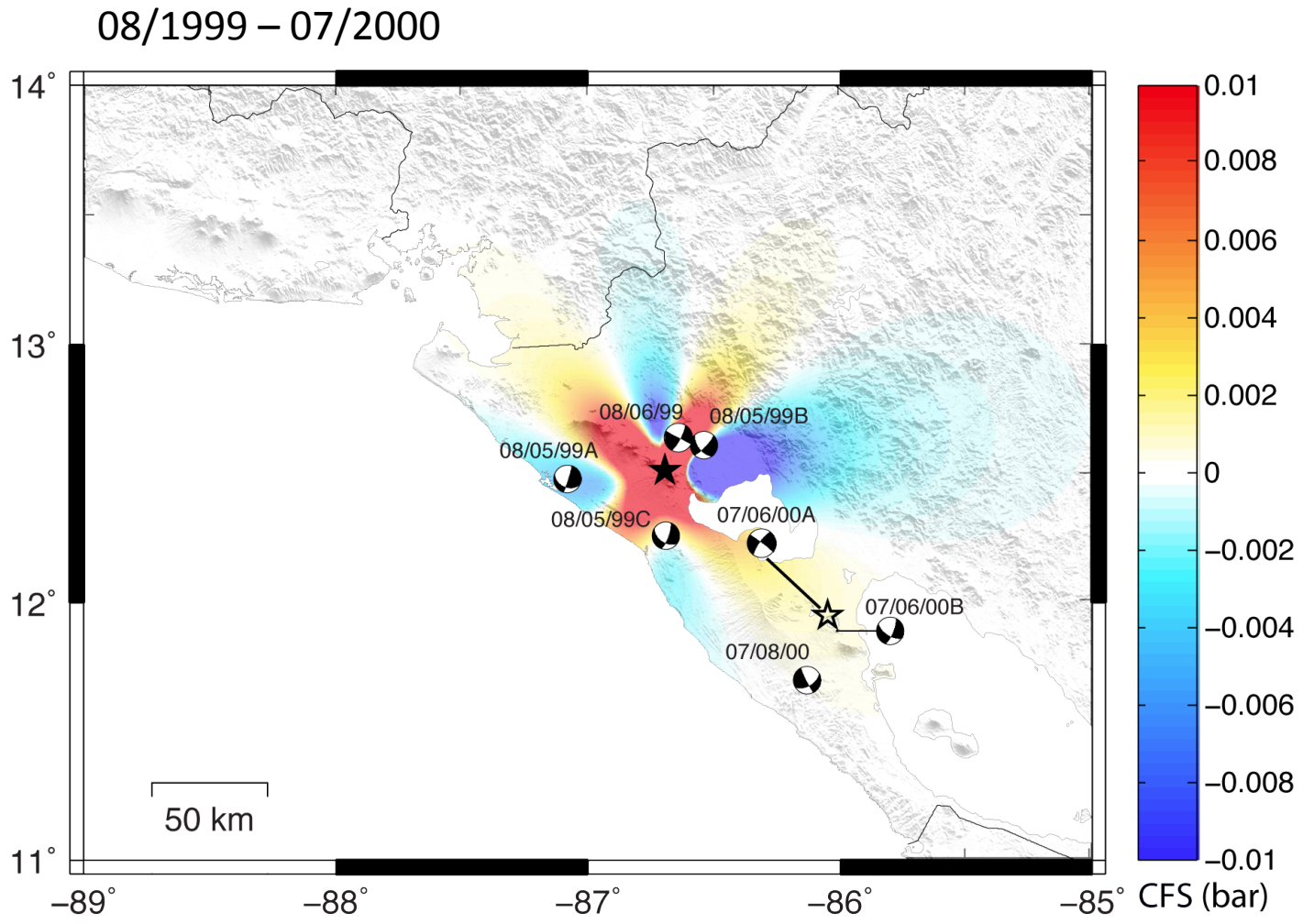




# Earthquake - Earthquake



# Earthquake - Earthquake



# Journey to the Center of the Earth: Thrinukagigar, Iceland



<http://youtu.be/Ganz9CJvCf0>