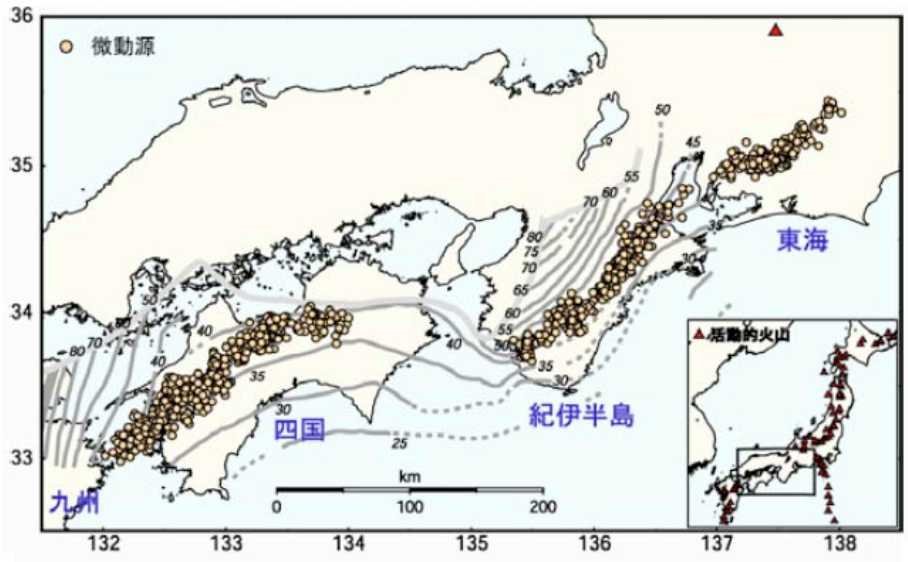
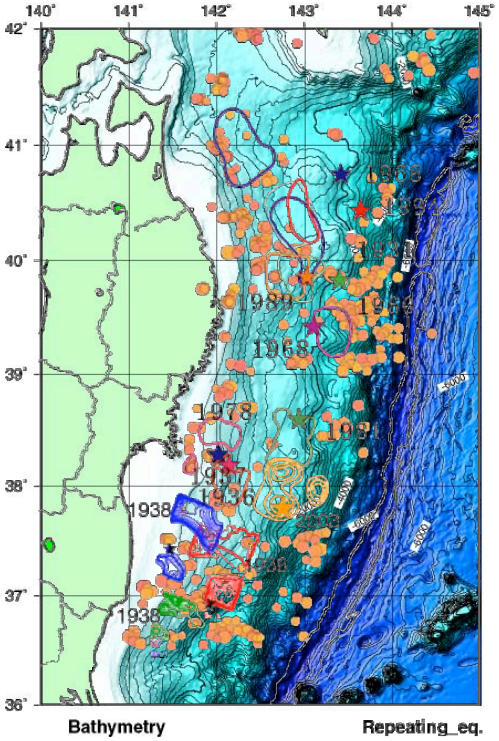
Nonvolcanic Tremor Beneath the San Andreas Fault: Why?

Bill Ellsworth
U.S. Geological Survey

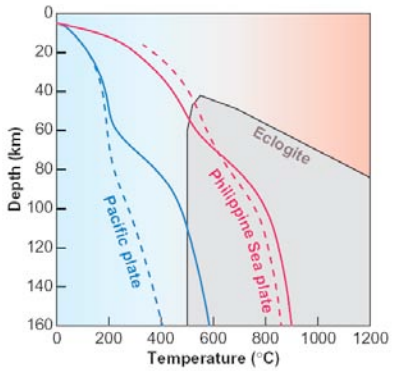
Nonvolcanic Tremor in Japan



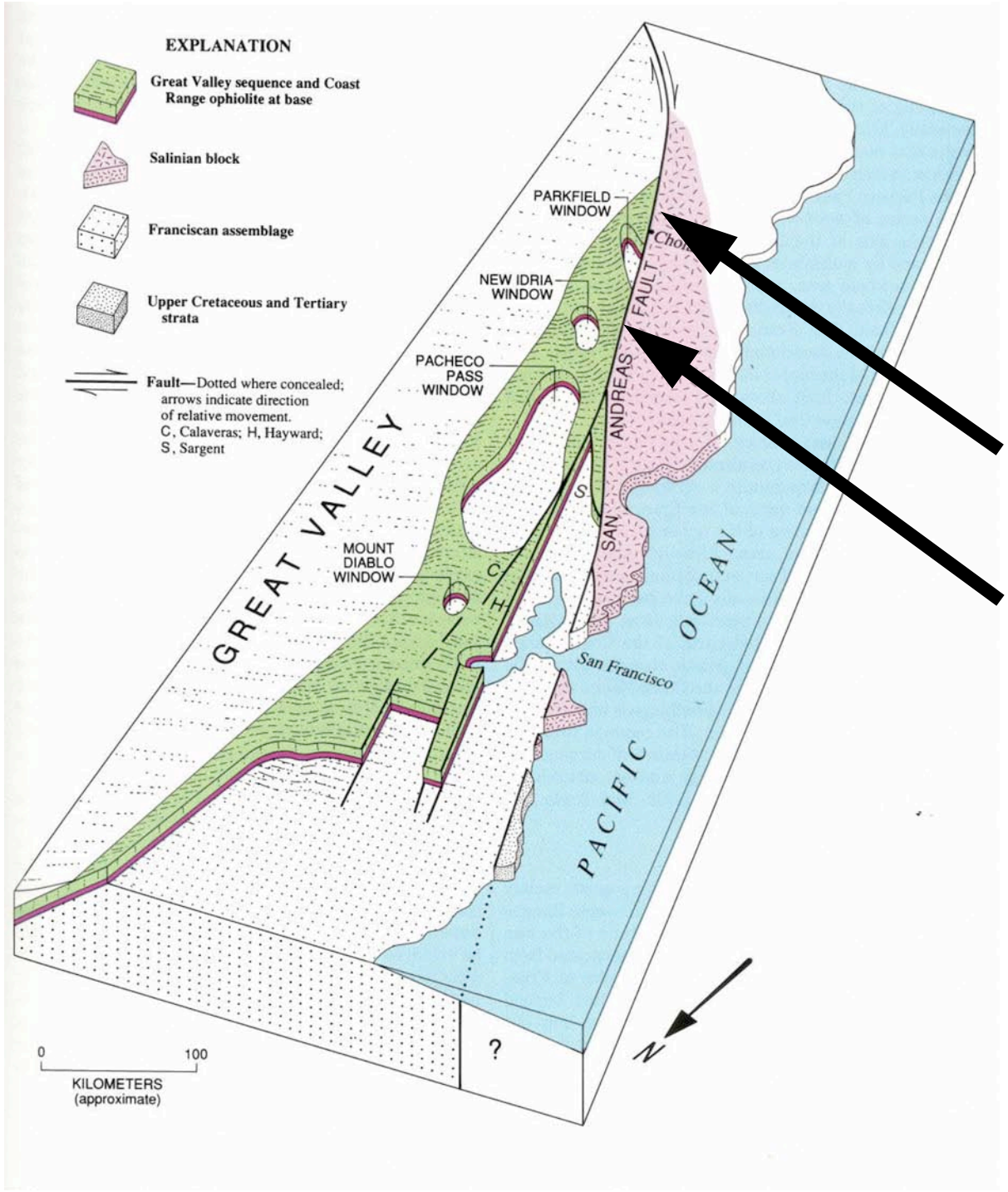
Obara (2002)



Courtesy of Naoki Uchida



Phase diagram from Julian (2002)
after Peacock and Wang (1999)

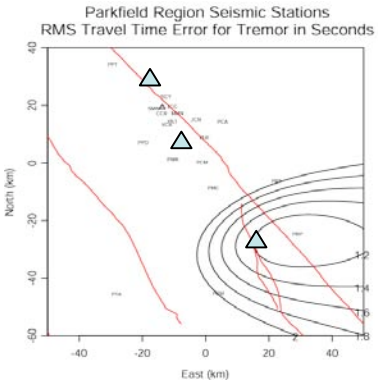


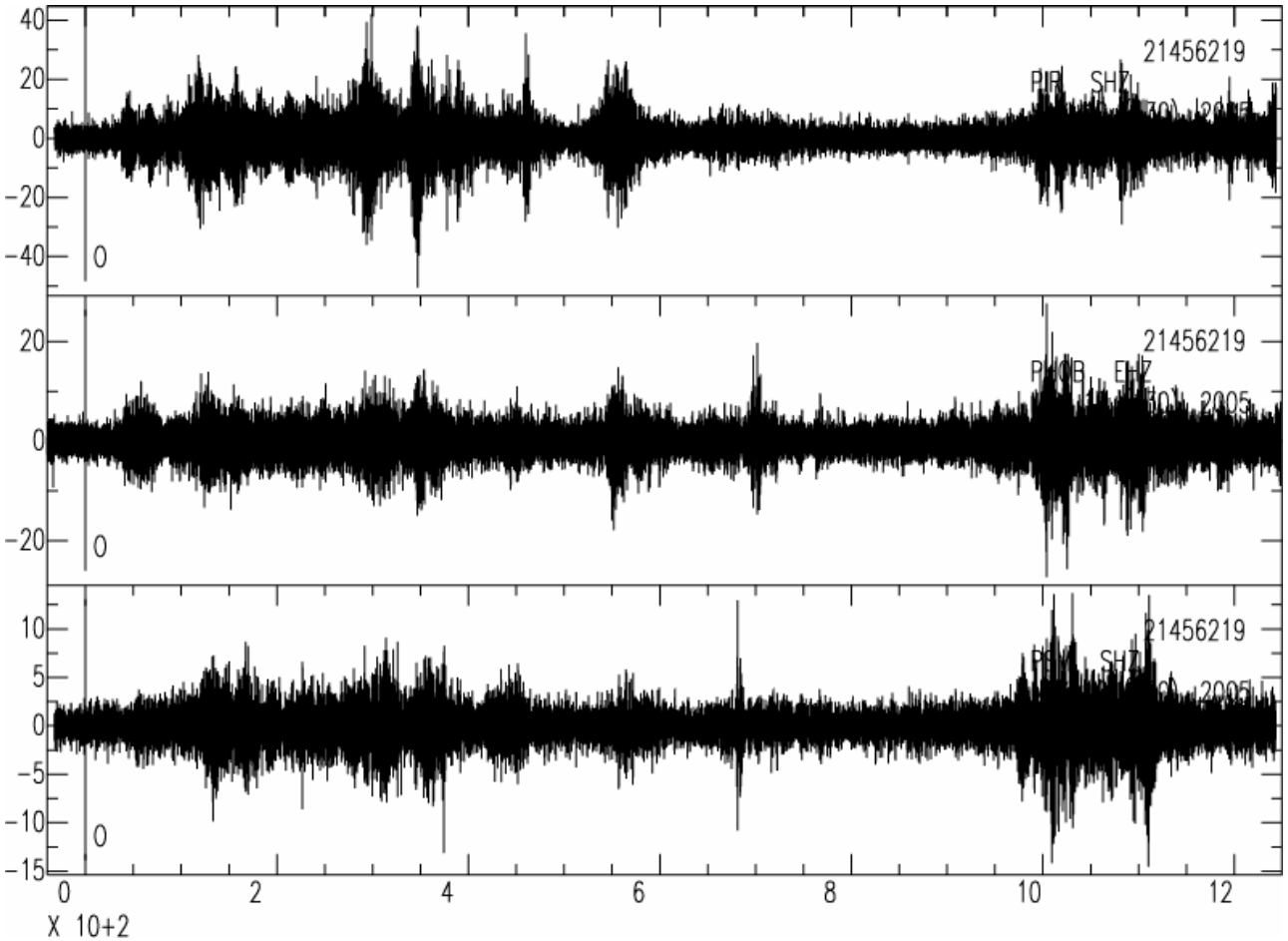
Discovered in 2004 by Nadeau and Dolenc (2005), spontaneous episodes of nonvolcanic tremor along the San Andreas Fault system have only been recognized along the northern end of the 1857 break beneath Palo Prieto Pass ("Cholame") and along the central creeping SAF beneath Monarch Peak.

Tremor episodes typically last a few minutes to _ hour and occur several times a week, year in and year out.

Focal depths are in the lower crust and upper mantle and below the brittle-ductile transition.

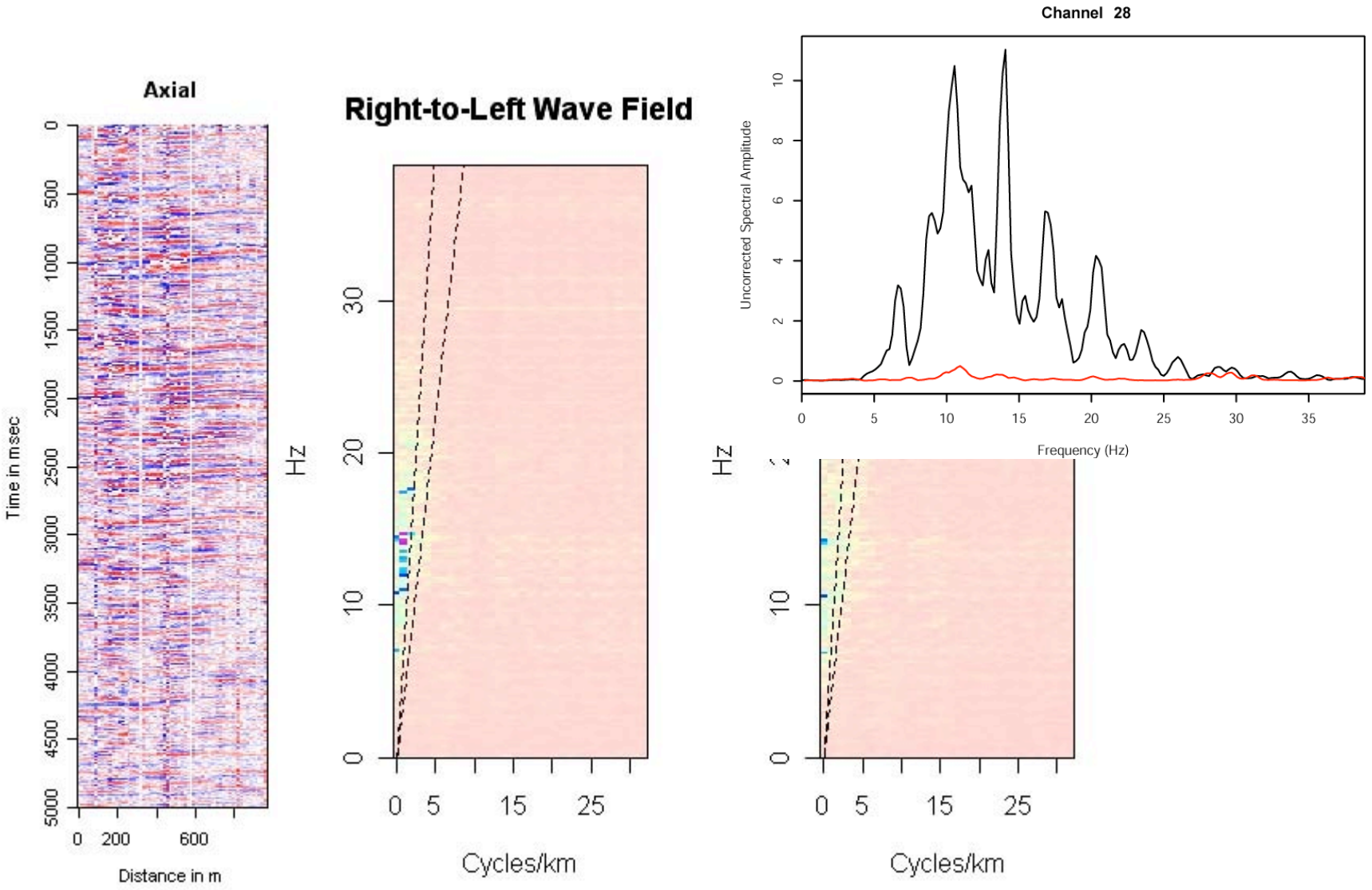
Palo Prieto Pass Nonvolcanic Tremor Episode in May 2005
NCSN Vertical Seismometers
2 – 8 Hz bandpass

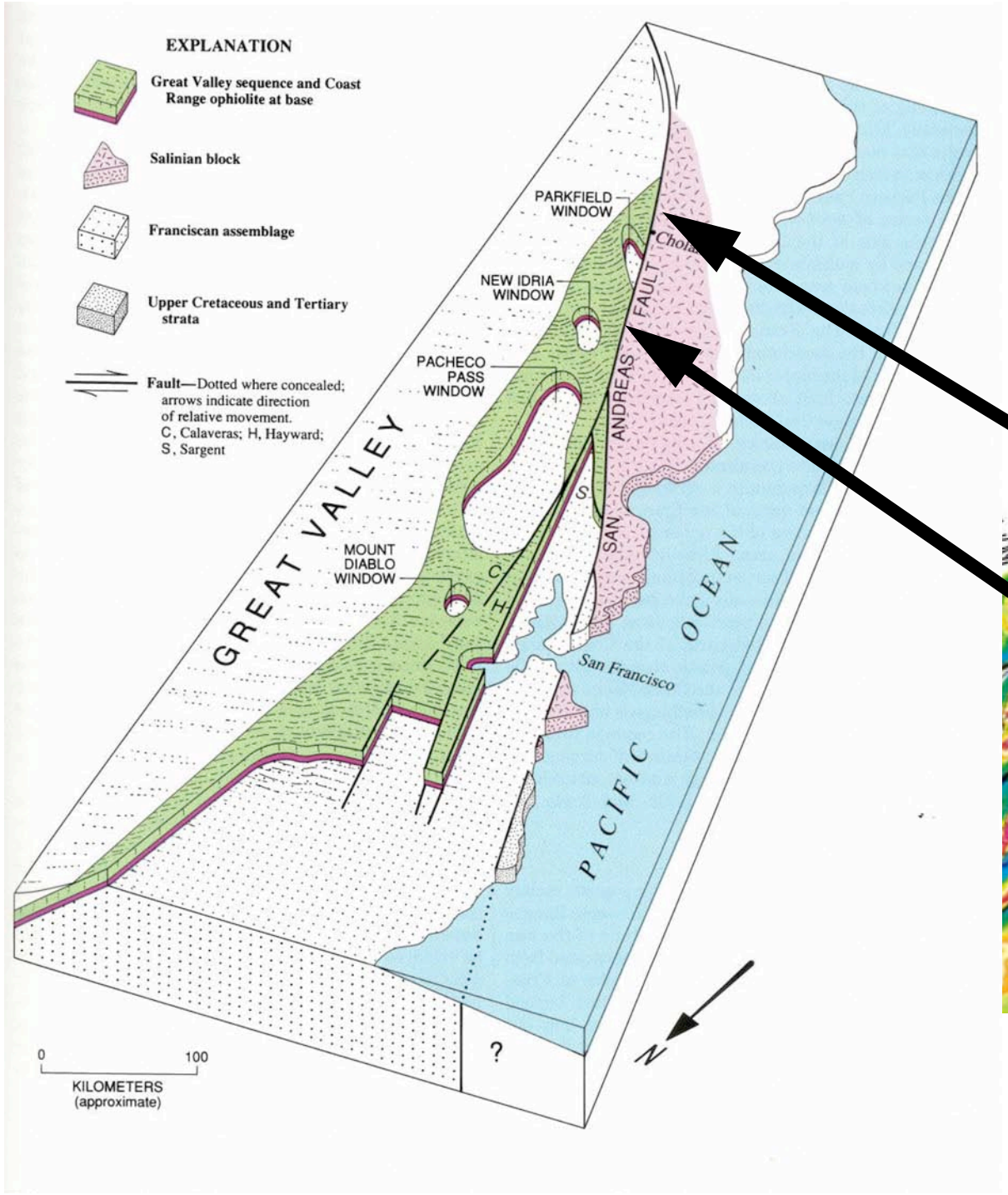




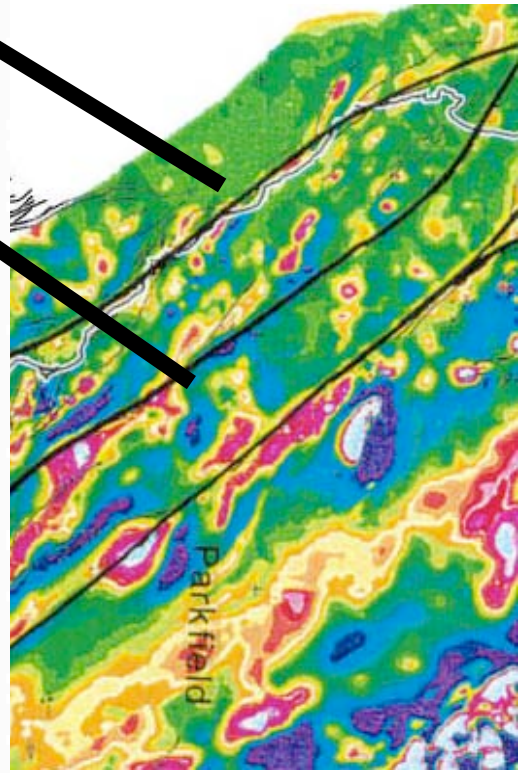
20 Minutes

Tremor Wave Field Observed in SAFOD on PGSI 80-level 3C Borehole Array

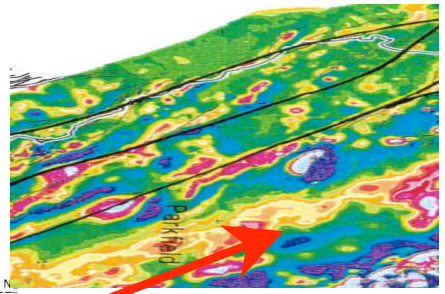


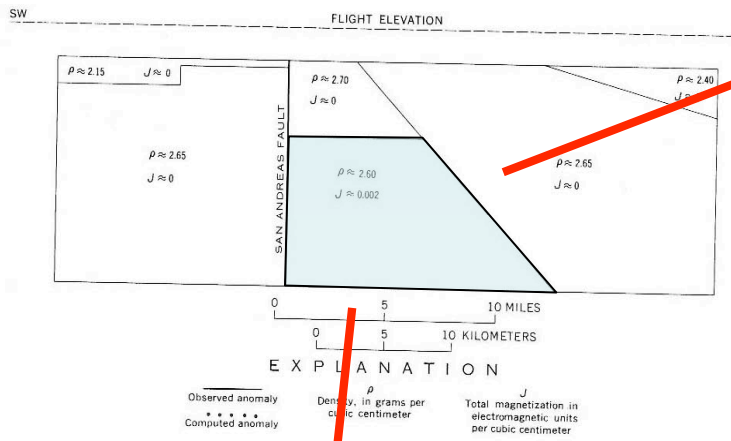


Both tremor sources are spatially correlated with pronounced magnetic highs.

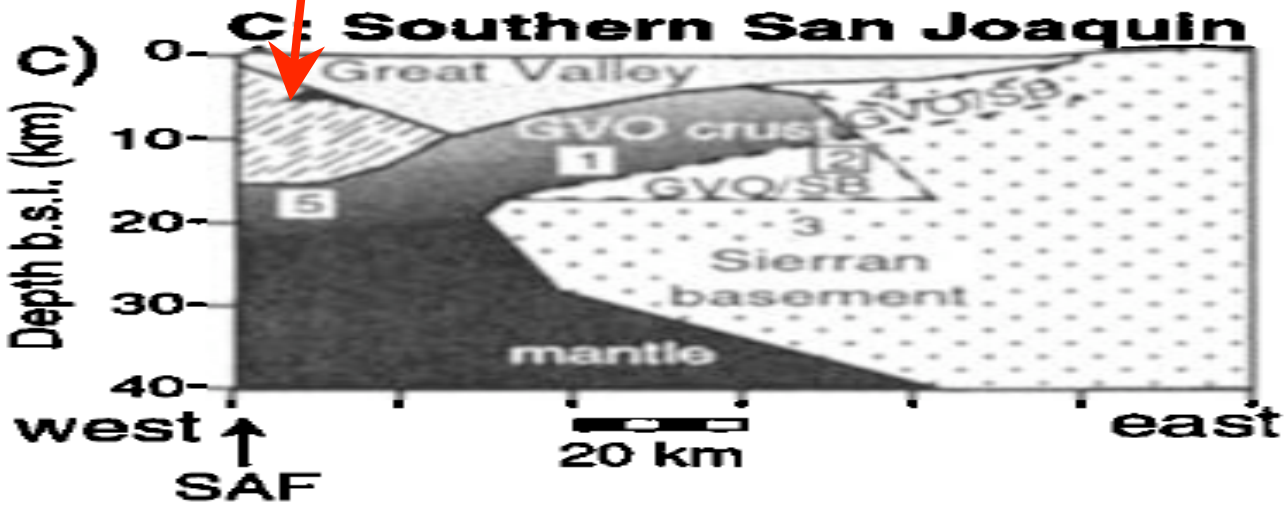


The Palo Prieto magnetic high has been interpreted by Hanna et al. (1972) as a partially serpentinized ultramafic body in the mid-crust.

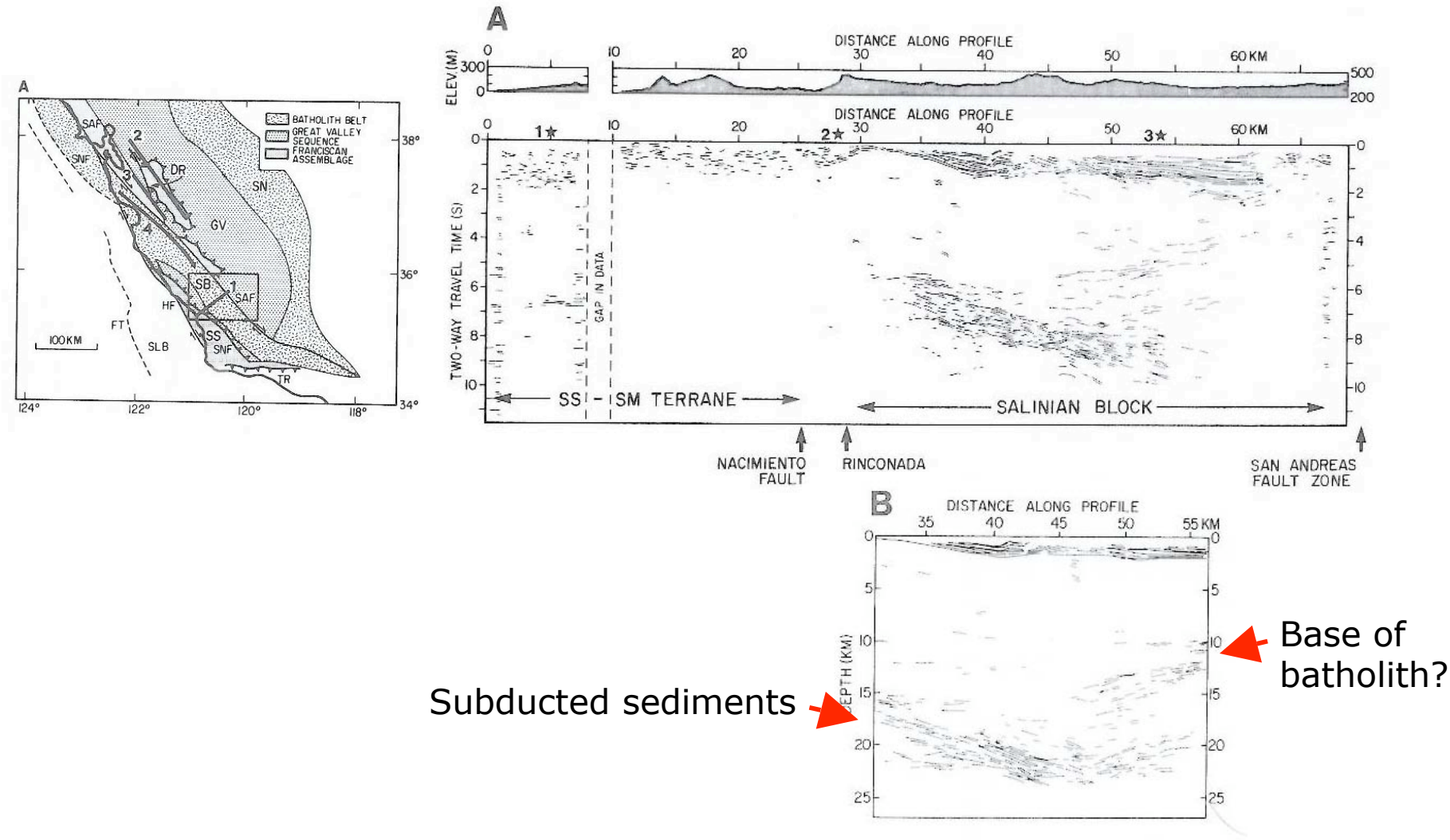




According to Godfrey & Klemperer (1998) it would correspond to either basal Franciscan or oceanic crust.

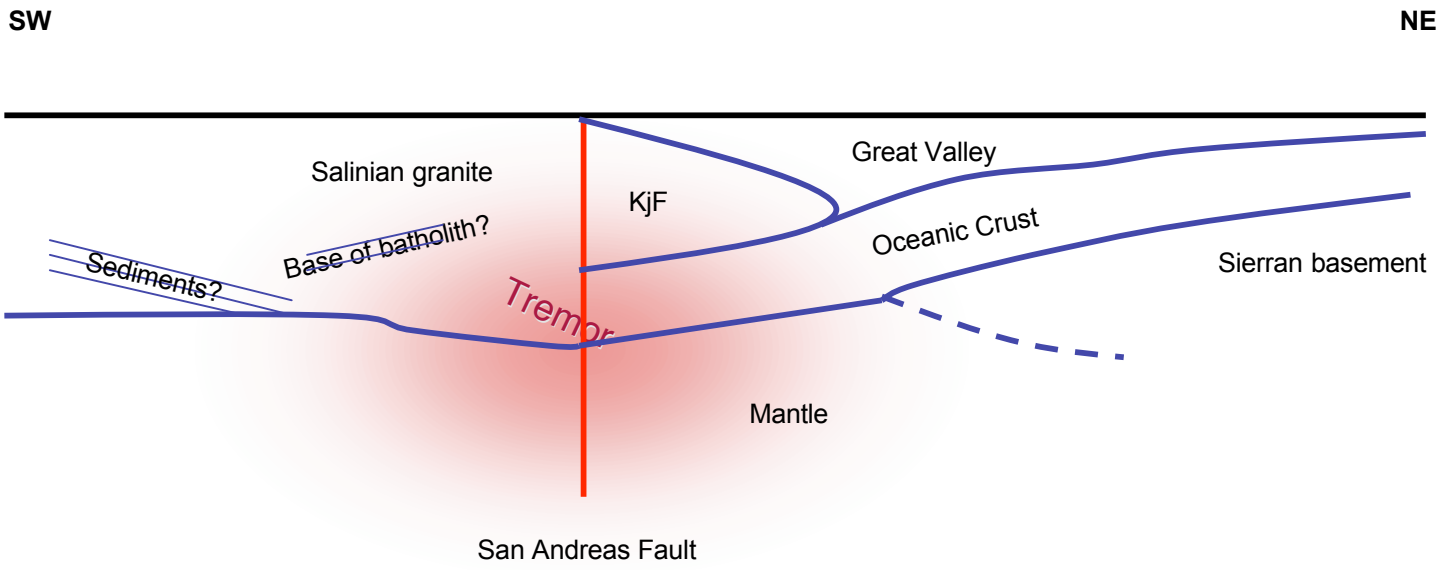


Crustal structure west of the San Andreas Fault
SJ-6 Profile (Trehu & Wheeler, 1987)

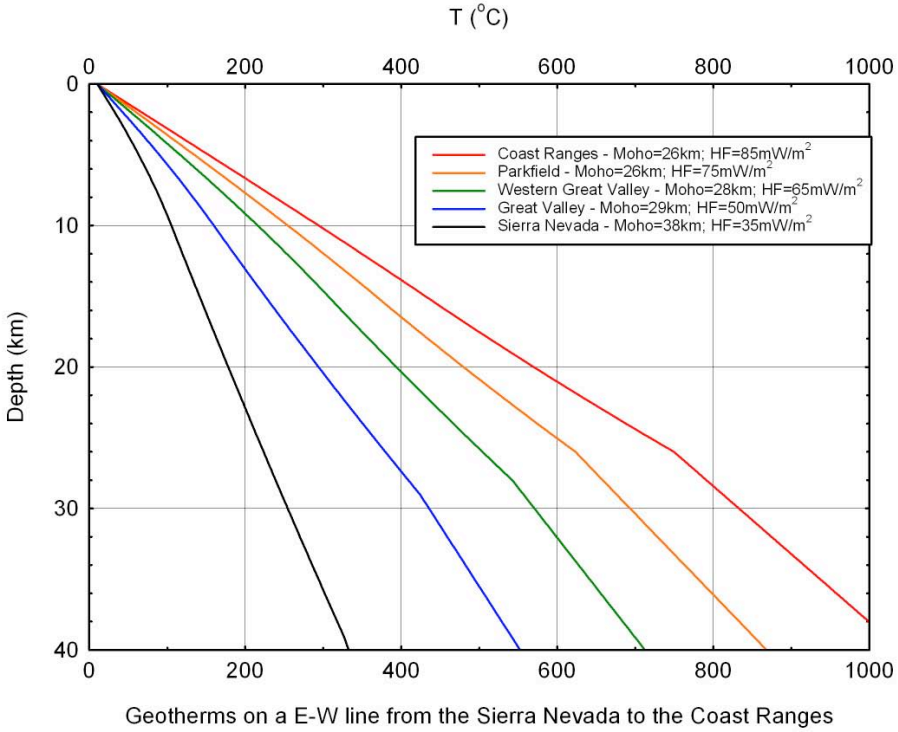


Subducted sediments

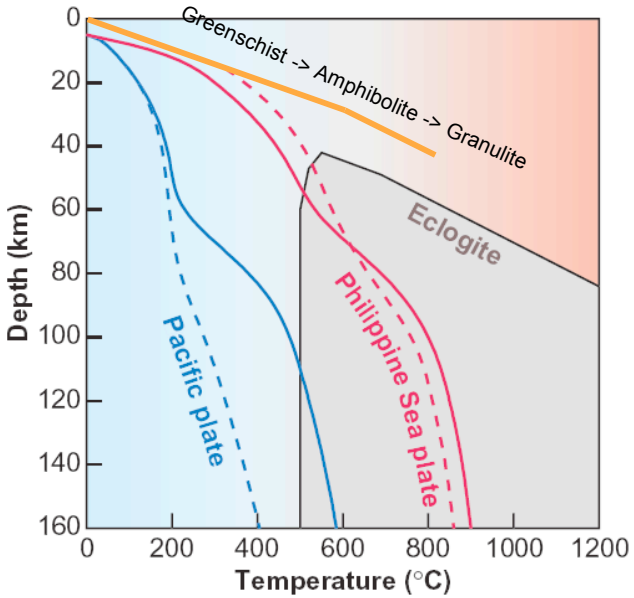
Base of batholith?


SW
NE
Salinian granite
KjF
Great Valley
Base of batholith?
Oceanic Crust
Sediments?
Sierran basement
Tremor
Mantle
San Andreas Fault

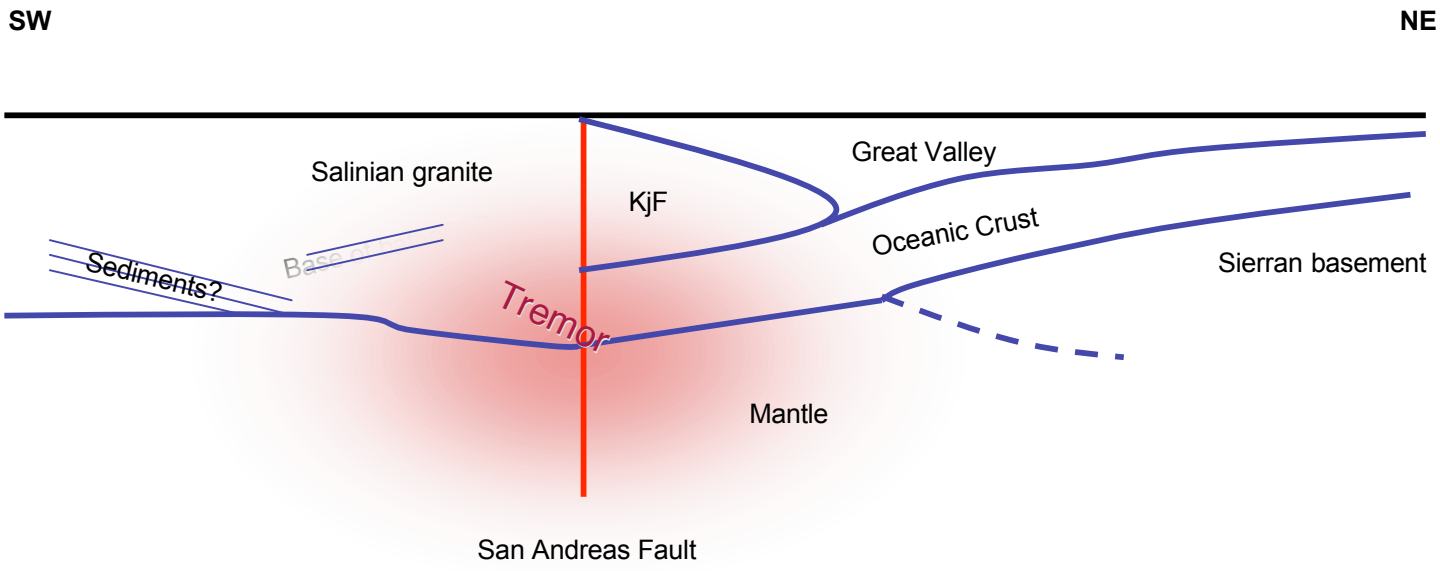
Temperatures beneath the San Andreas Fault and Coast Range are High



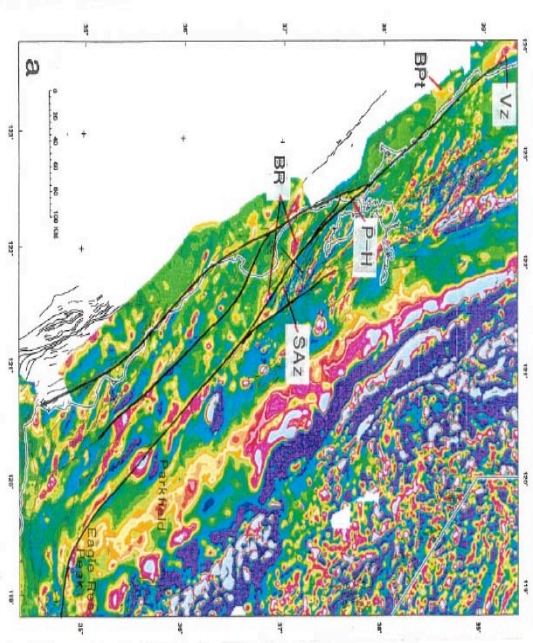
Colin Williams, personal communication (2008)



Phase diagram from Julian (2002) after Peacock and Wang (1999)

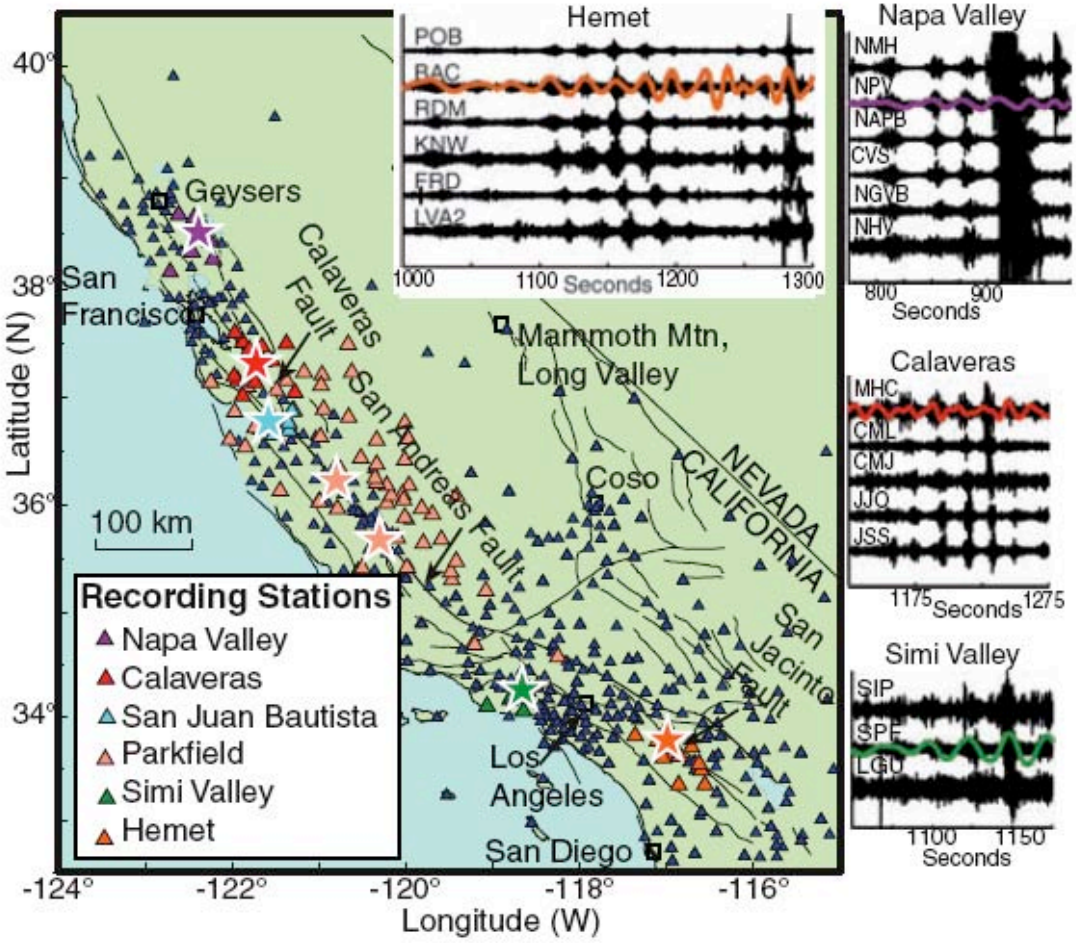

SW
NE
Salinian granite
KjF
Great Valley
Oceanic Crust
Sierran basement
Sediments?
Tremor
Mantle
San Andreas Fault

What about the loci of triggered nonvolcanic tremor?



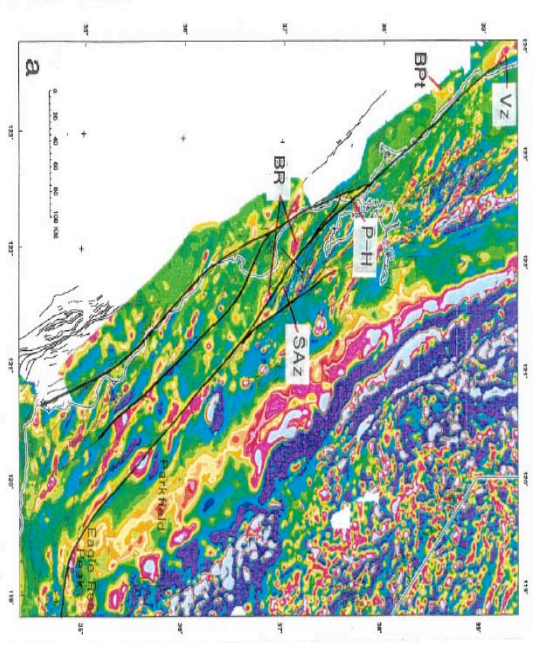
Jachens et al. (1998)

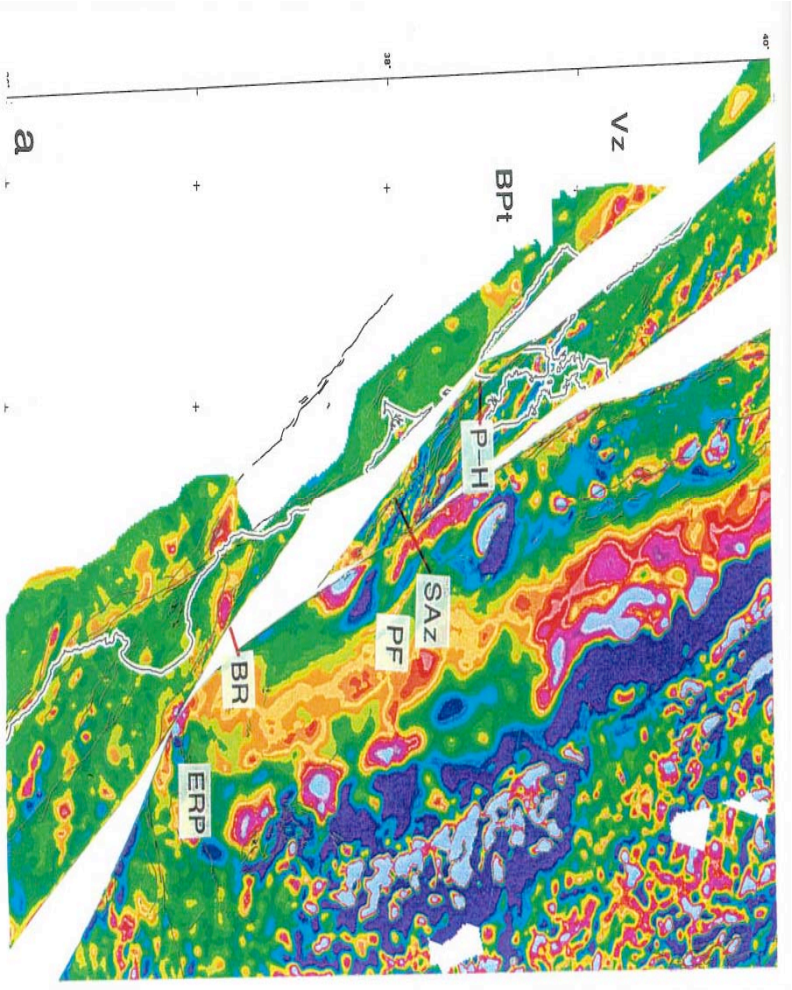
Tremor triggered by the Denali Earthquake



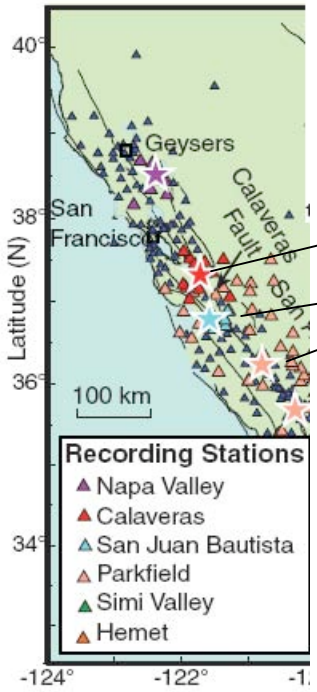
Gomberg et al. (2008)

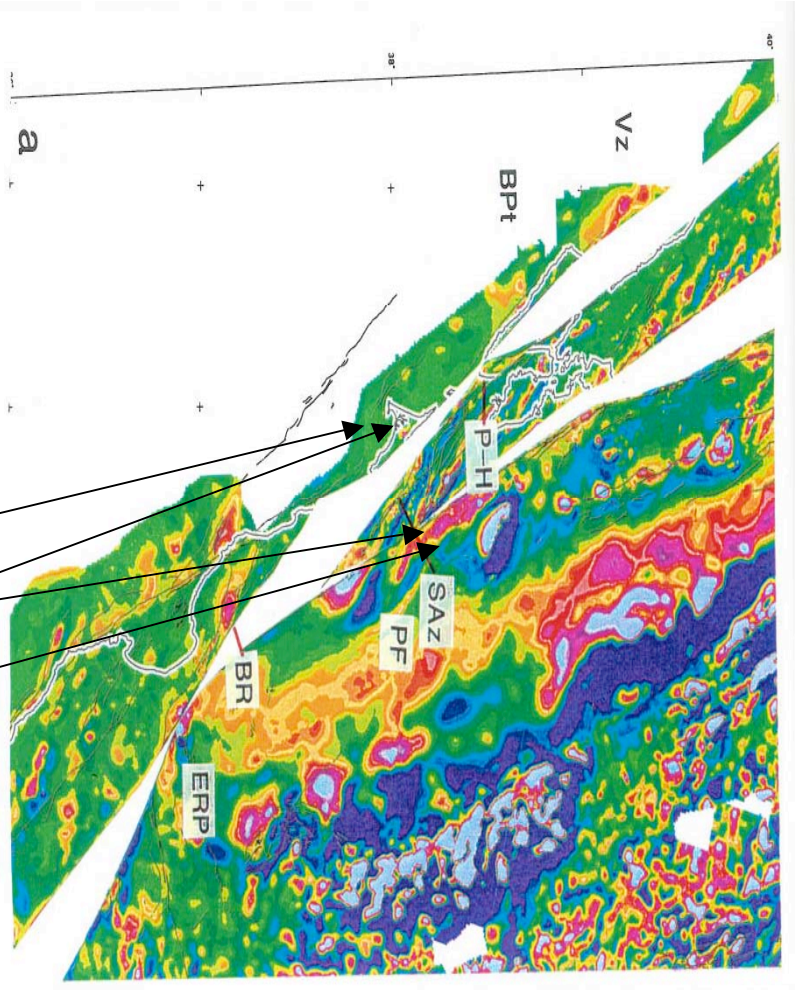
Jachens, Wentworth and McLaughlin (1998) restored the offset of well-established piercing points on the San Andreas Fault system (e.g. Eagle Rest Peak and Logan gabbros), and the magnetic anomalies truncated by the major faults.





After reconstruction, the source regions of the triggered tremor near the Calaveras Fault and San Juan Bautista align with the magnetic structures associated with the Monarch Peak and Palo Prieto Pass sources.





A Few Summary Observations on San Andreas Fault System Nonvolcanic Tremor

- Tremor occurs below the brittle-ductile transition.
  - Depths are shallower than in Japan and Cascadia (mostly).
  - Depth control is poor.
  - Hypocentral distribution most likely in a volume and not on a plane.
  - Temperatures are high (500 - 600^{o}C).

- Tremor activity occurs frequently.
  - Episodes are typically short, lasting only a few minutes to _ hour.
  - Preliminary array measurements by Ryberg indicate that the source migrates rapidly (~km/min) during an episode.
  - Activity level appears to be tidally correlated.

- Tremor sources spatially correlate with serptetinized oceanic crust.
  - Restoration of San Andreas system offsets suggests that triggered tremor has the same structural setting as the persistent source zones.
  - Not at all obvious why the process would be running today.

Outlook

Multiple Array Experiment – October 2007

A1, A2, A3: Trond Ryberg & Christian Haberland (GFZ)

A4: Bill Ellsworth (USGS) & David Shelly (UCB)