Using Earthquakes to Relate Magnetic and Electric Fields to Fault activity

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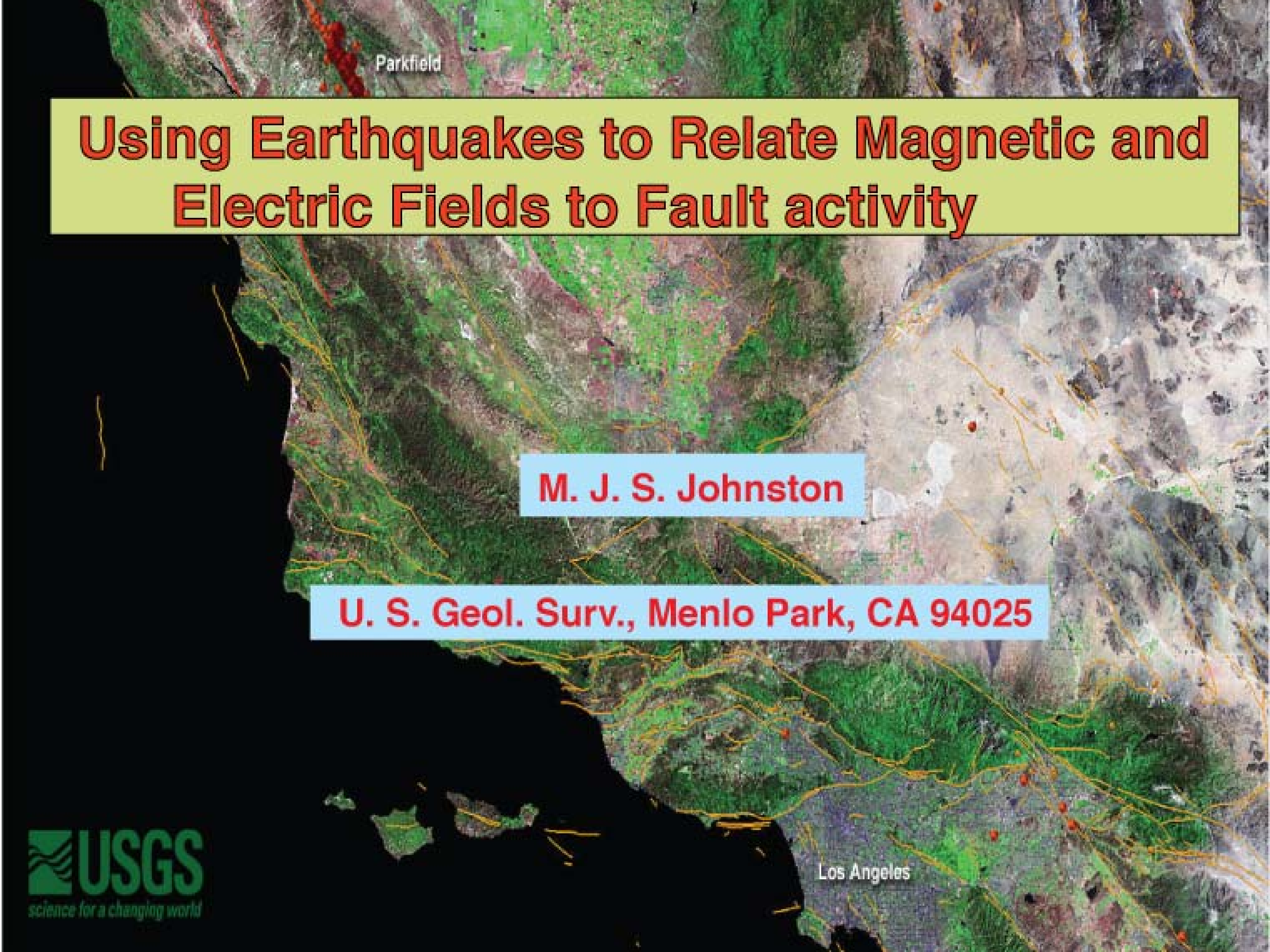

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OUTLINE

- EM and Earthquake Prediction
  - The Red Flag Problems

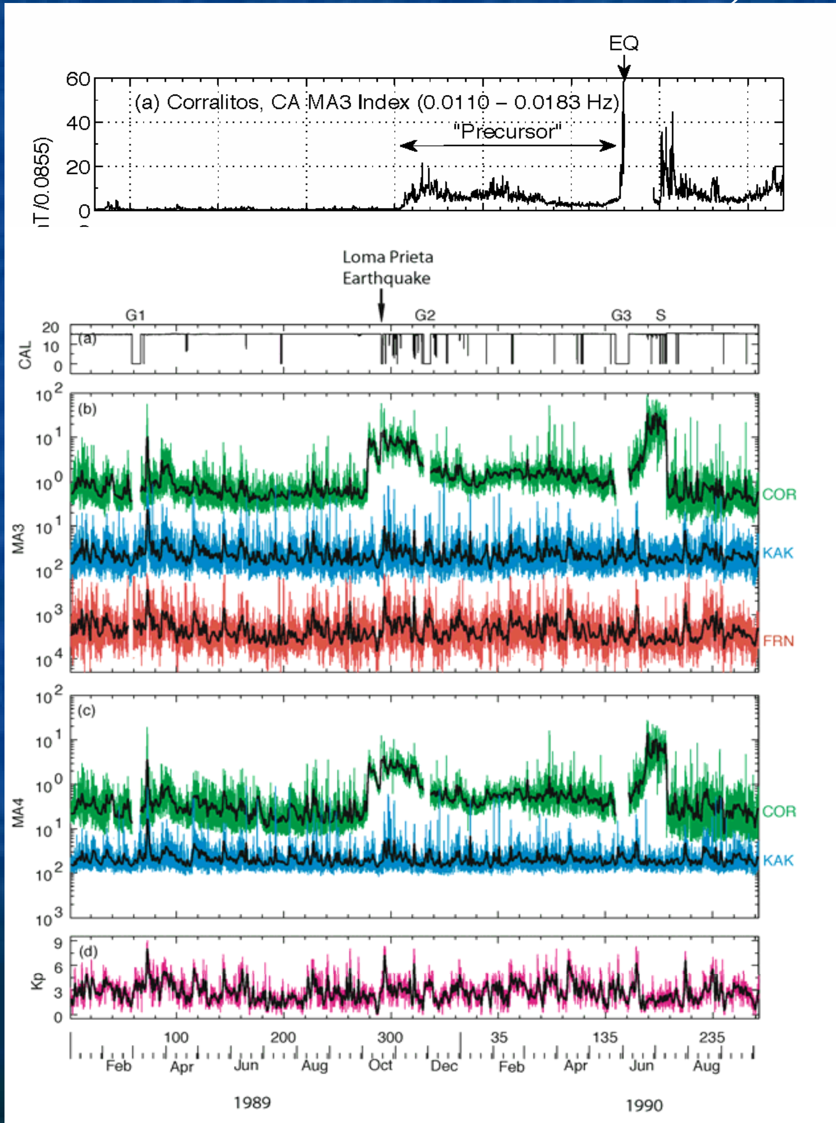
- Solutions: Use Earthquakes to relate EM to the fault failure process

- Conclusions

EM and Earthquake Prediction - The Red Flag Problems

After Fraser-Smith et al. 1990)

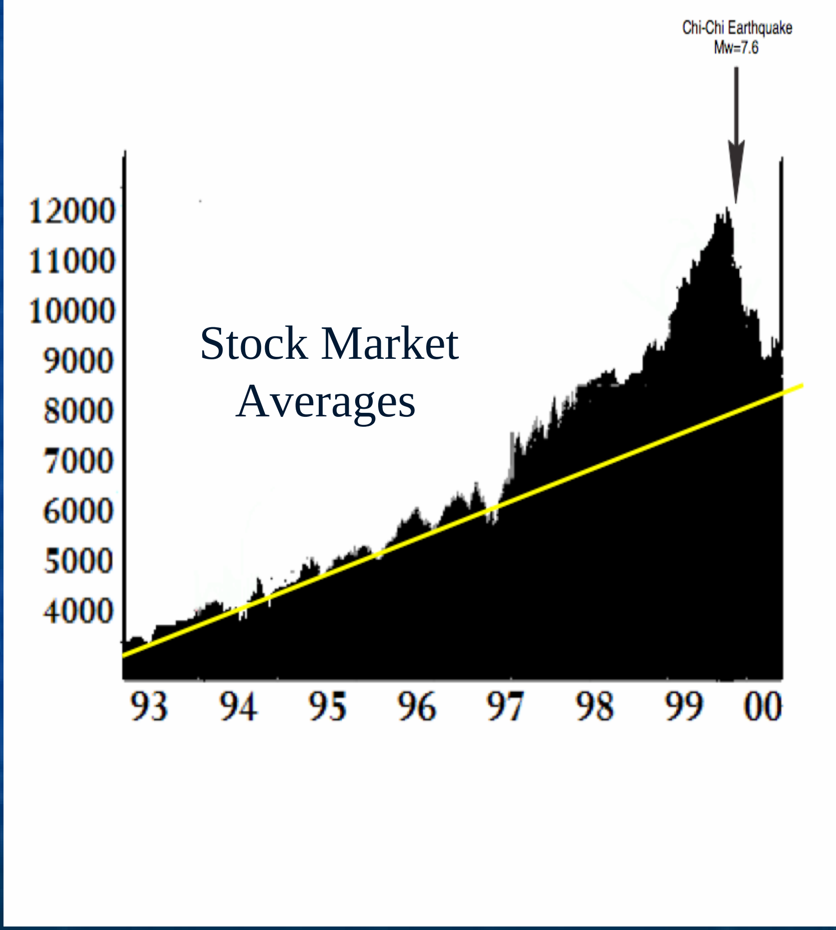
- Predictions with data shown for just a short time before a single event. As is obvious, it is always possible to find some change in any parameter before any point in time. Believability comes from demonstration of relation to mechanics and repeatability.



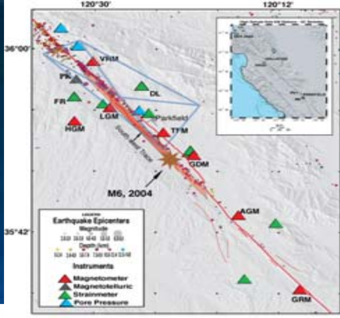
EM and Earthquake Prediction - The Red Flag Problems

- Predictions using data from a single station not necessarily close to an eq. with big change before the eq. but no changes observed during the eq. when major deformation, stress change, seismicity, etc occur.

Sept, 20, 1999



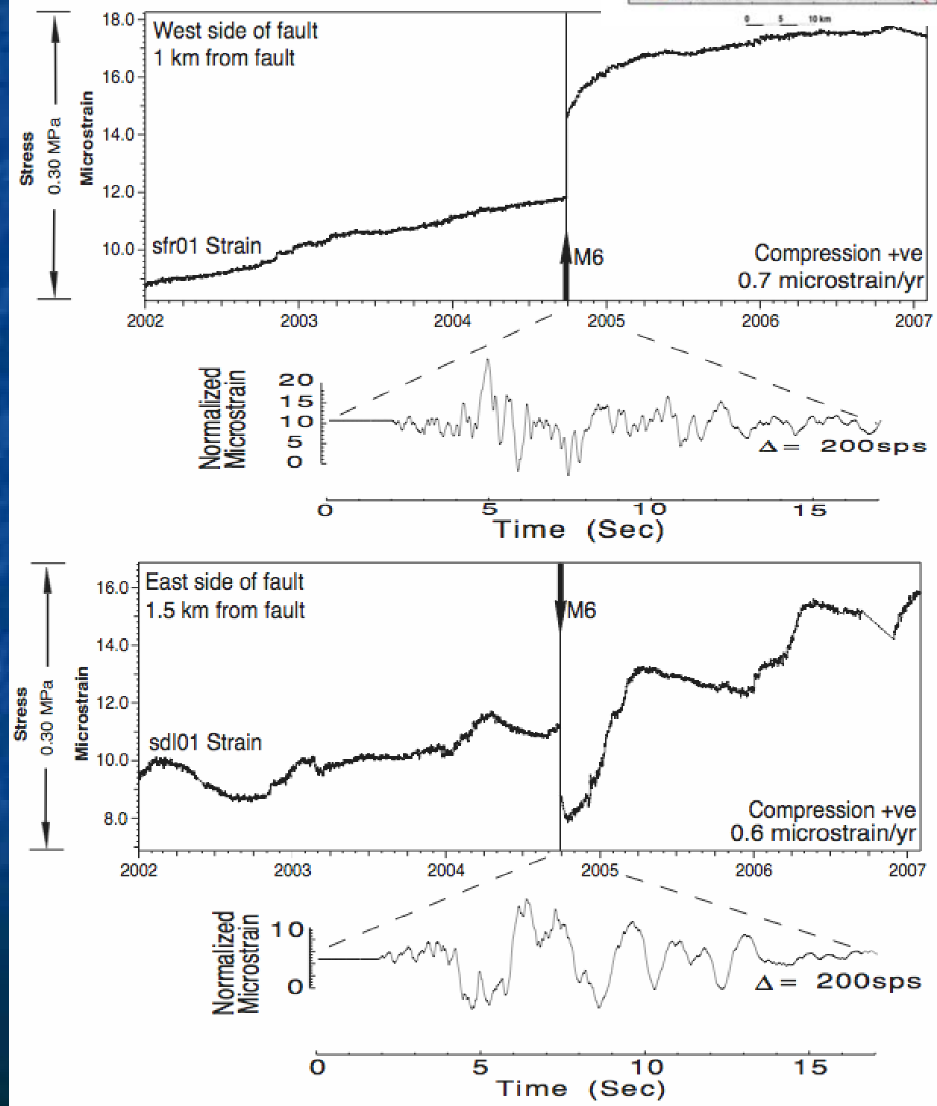
EM and Earthquake Prediction - The Red Flag Problems



- Predictions with no tie to earthquake mechanics or available copious information on crustal deformation, seismicity and conductivity data

  -extremely important

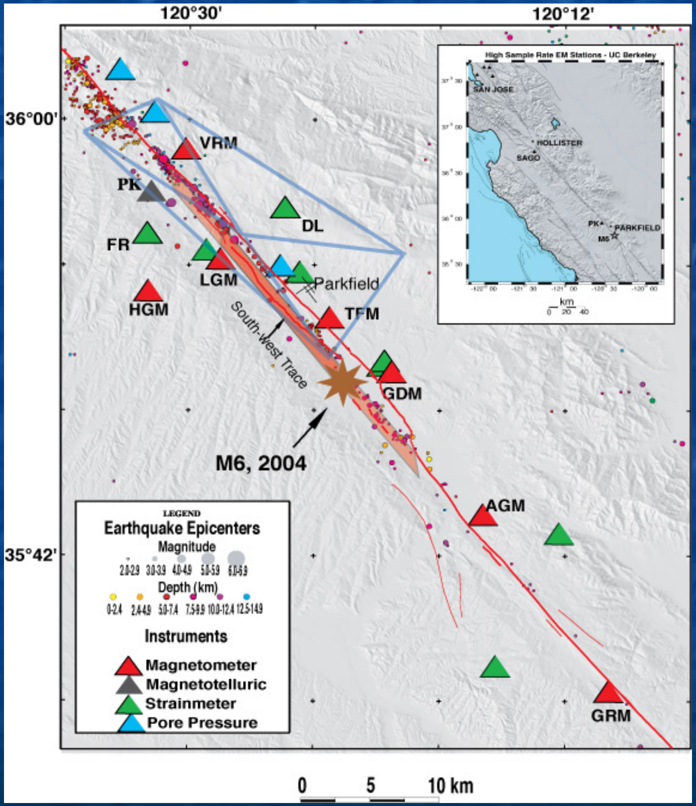
- Predictions without statistics showing significance

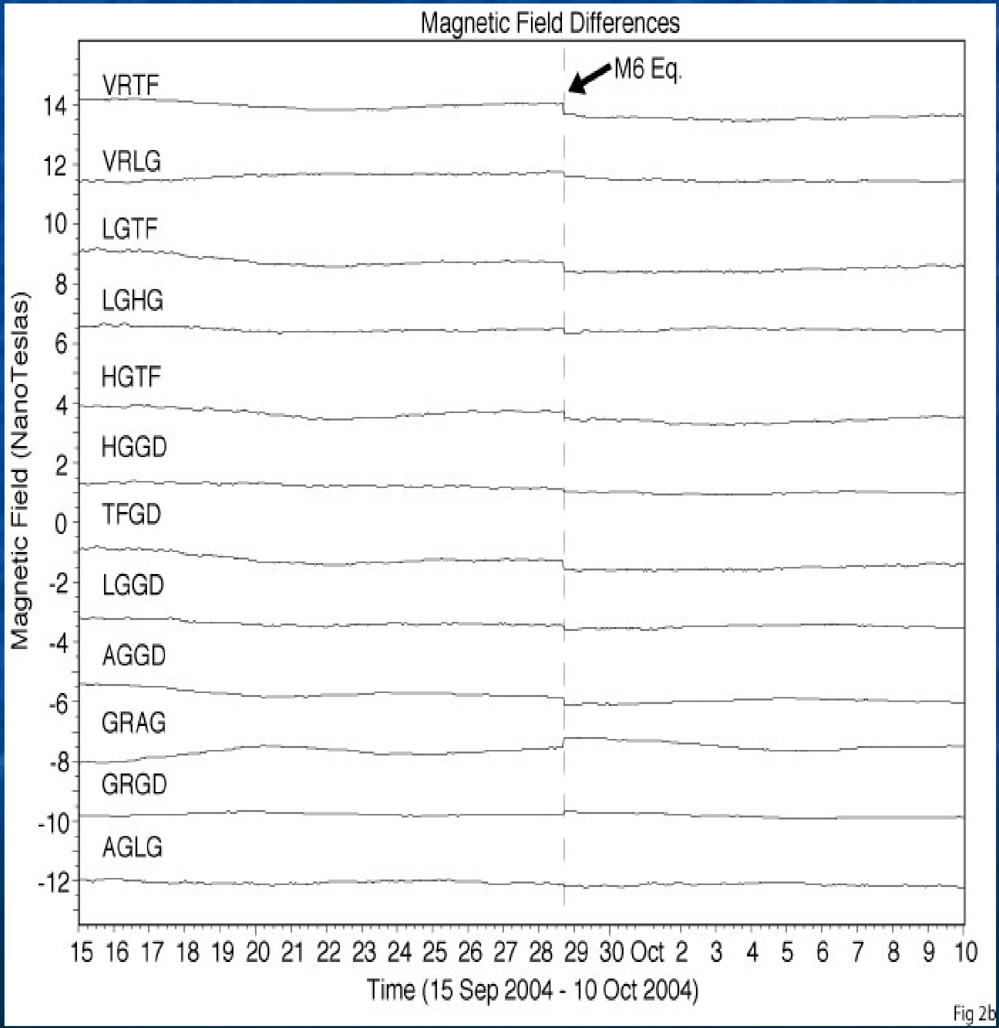


Solution: Use Earthquakes to relate EM to Fault Failure

- Coseismic Stress/Strain offsets
- Dynamic Stress Waves (seismograms)
- Traveling Ionospheric Disturbances (TIDS)

Coseismic Stress/Strain offsets – Parkfield M6, Sept 28, 2004



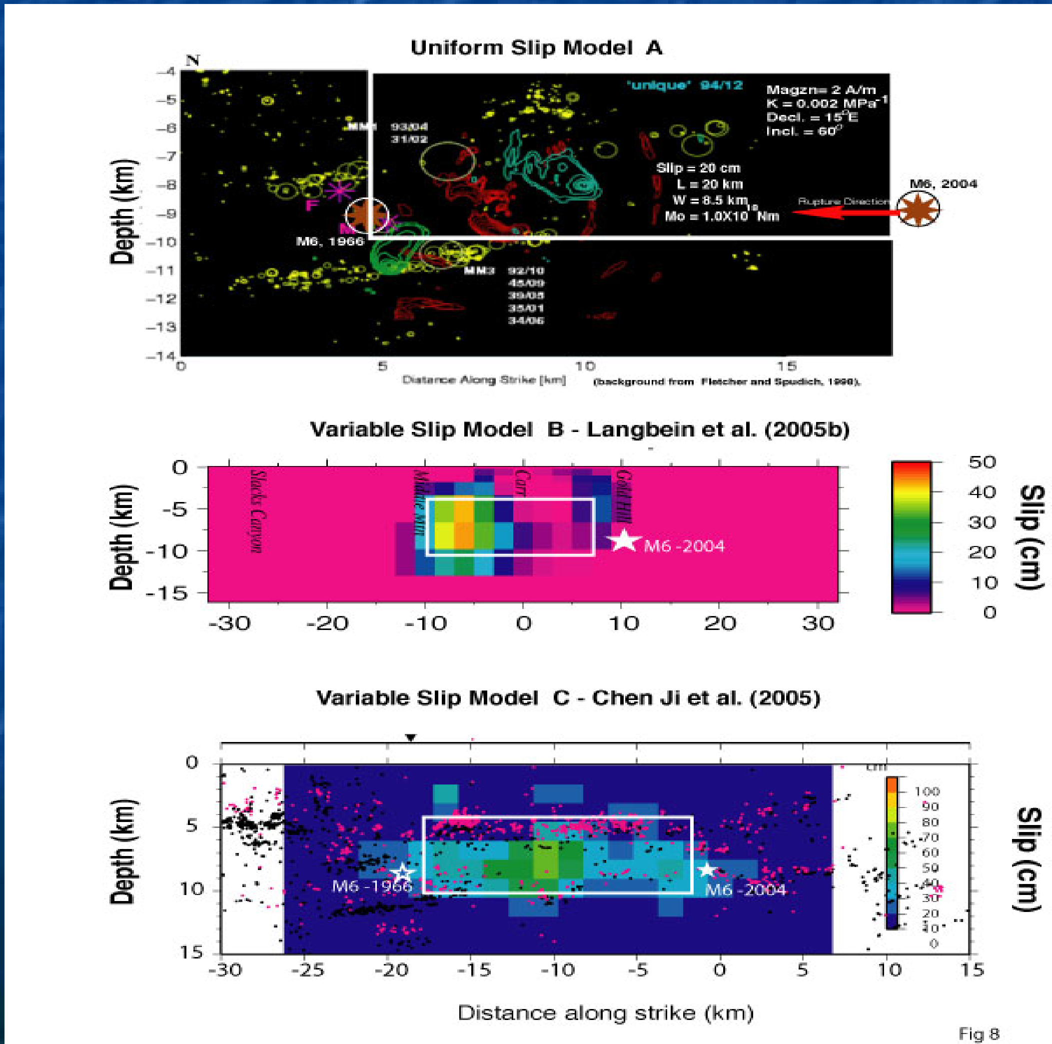


Comparison with Seismic and Geodetic Models

-General Agreement

-Overall, models quite tightly constrained

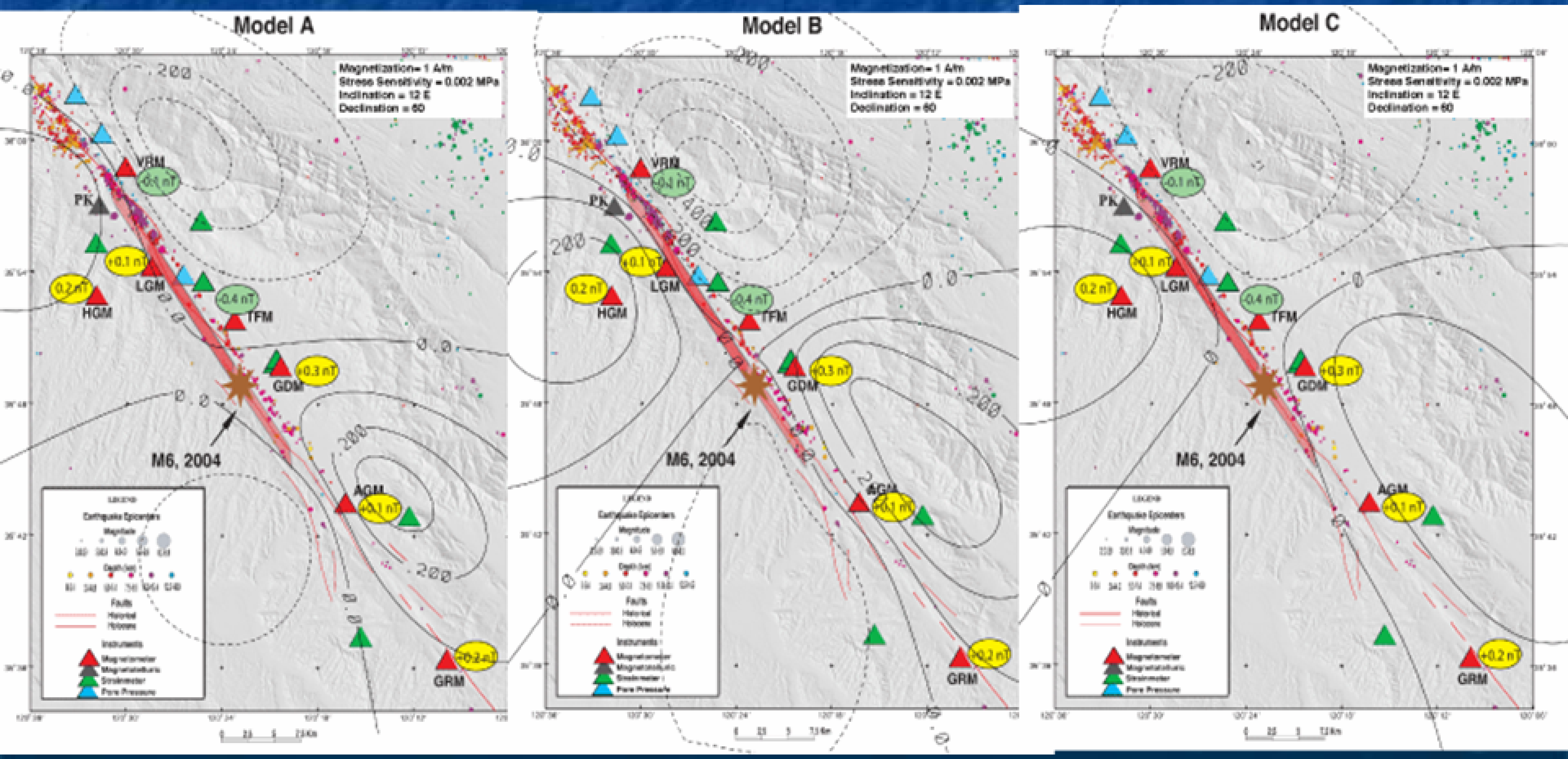
-Fault Failure process thus generally well understood



See BSSA, V96, S206-220, 2006

Piezomagnetic Models

Simple uniform slip | Inversion of geodetic data | Inversion of geod./seismic data

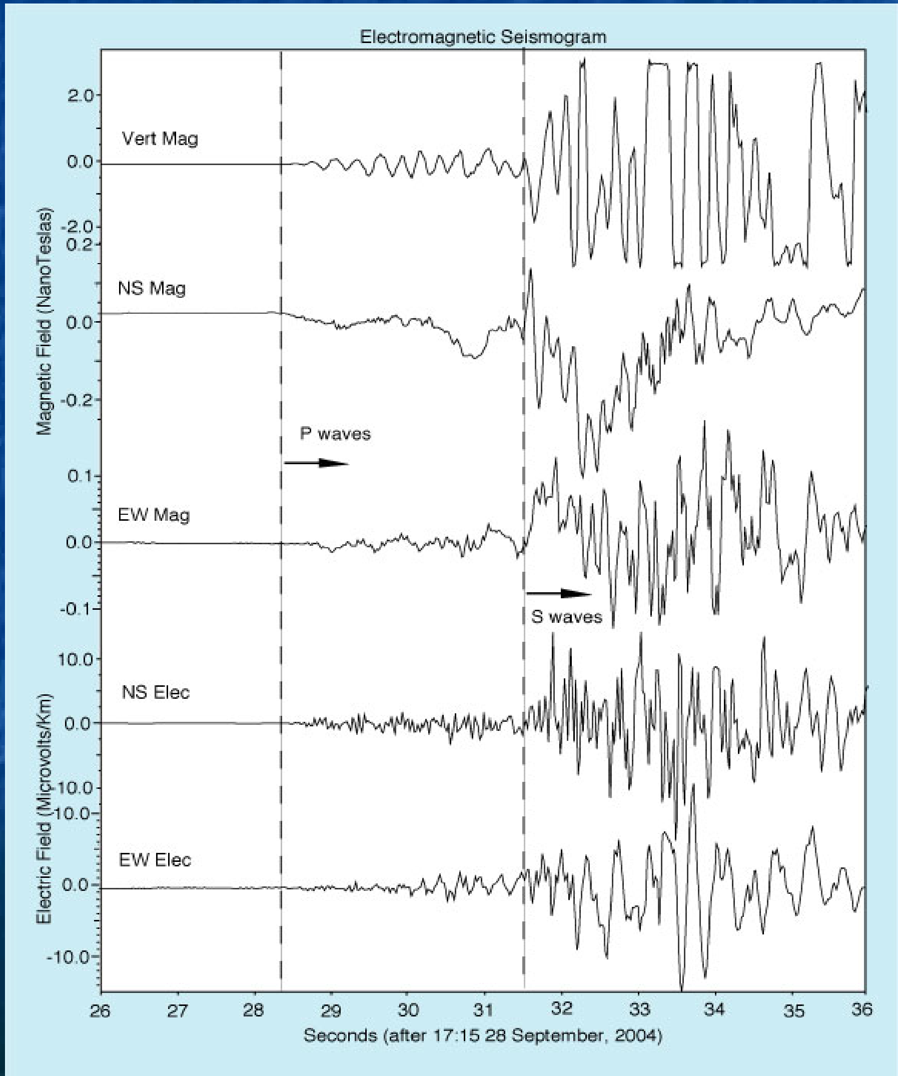


See BSSA, V96, S206-220, 2006

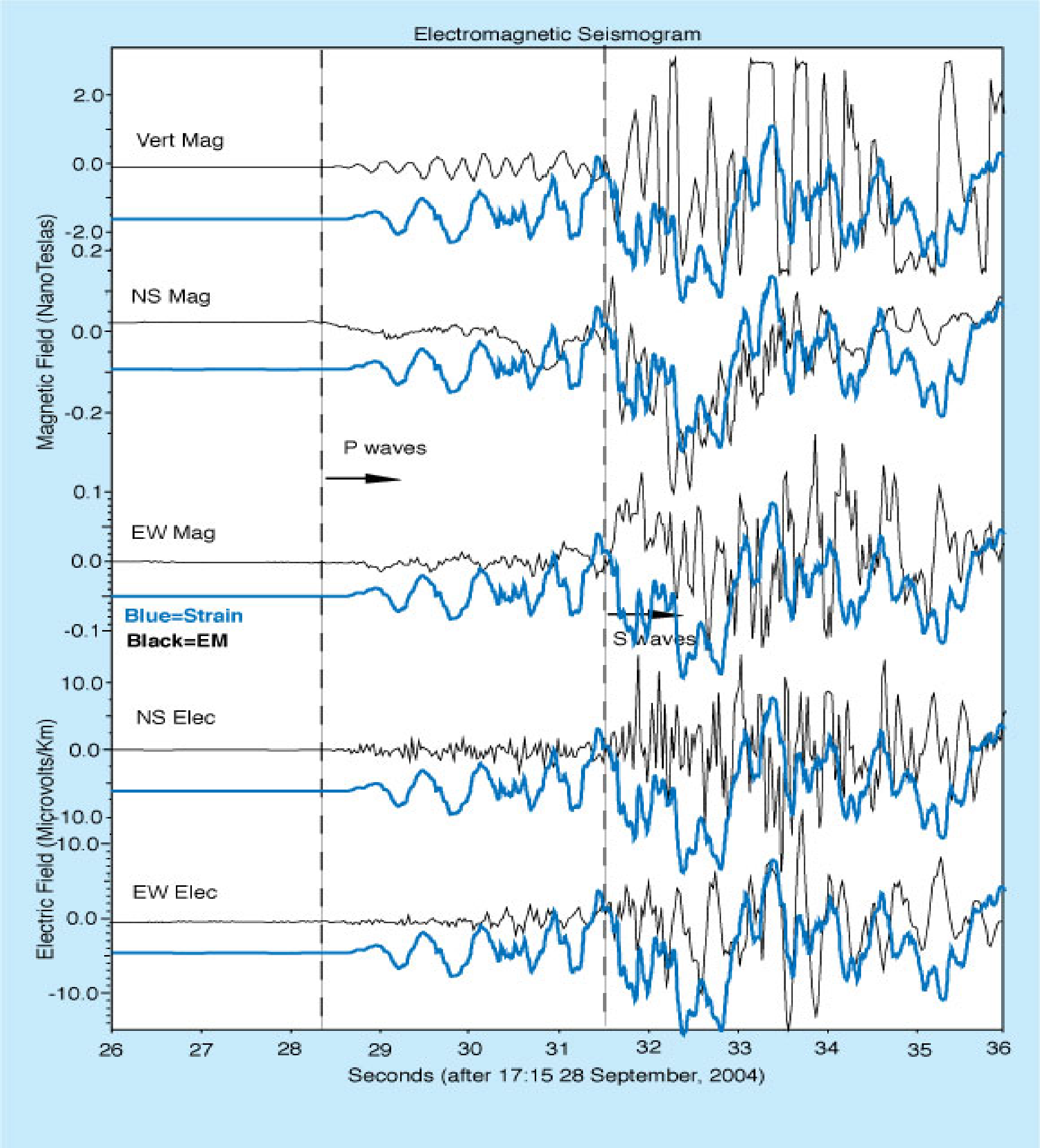
Dynamic Stress Waves

EM Seismogram for M6 2004 Parkfield earthquake

- Expect EM effects from
  - Stress wave
  - Ground shaking/rotation of EM instrument in Earths' magnetic field - should be minimal but depends on installation.
- Signals observed starting with first P arrival with larger signals during S wave arrivals

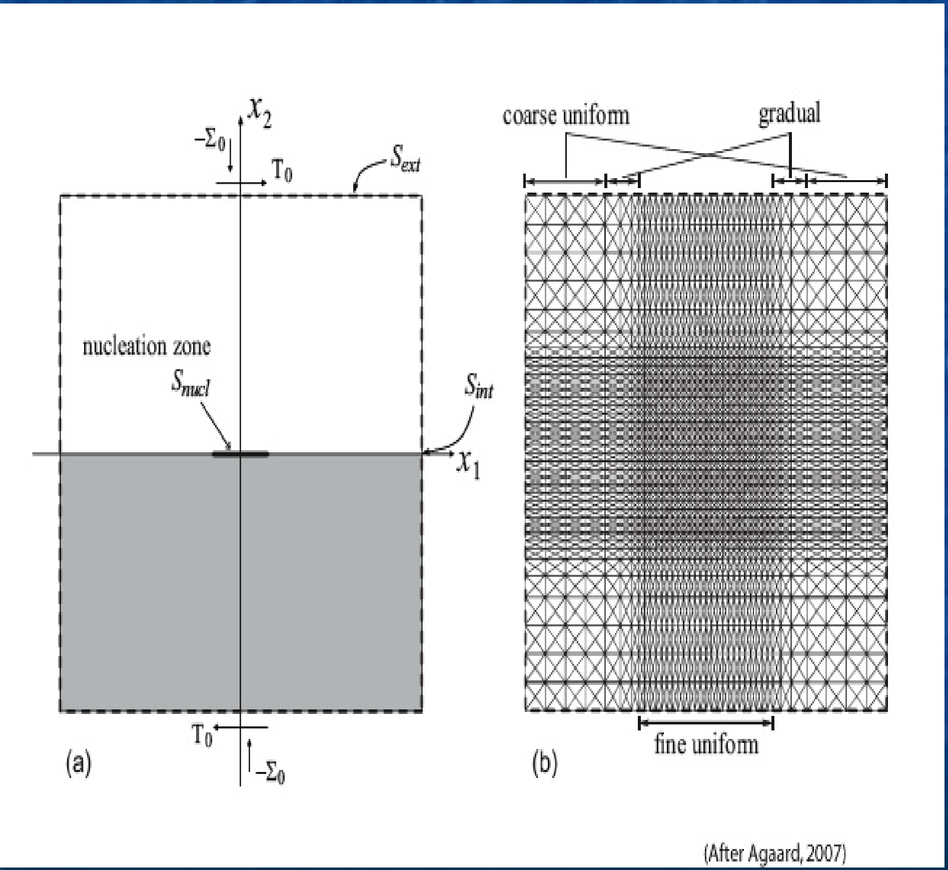


Comparison between EM and Strain



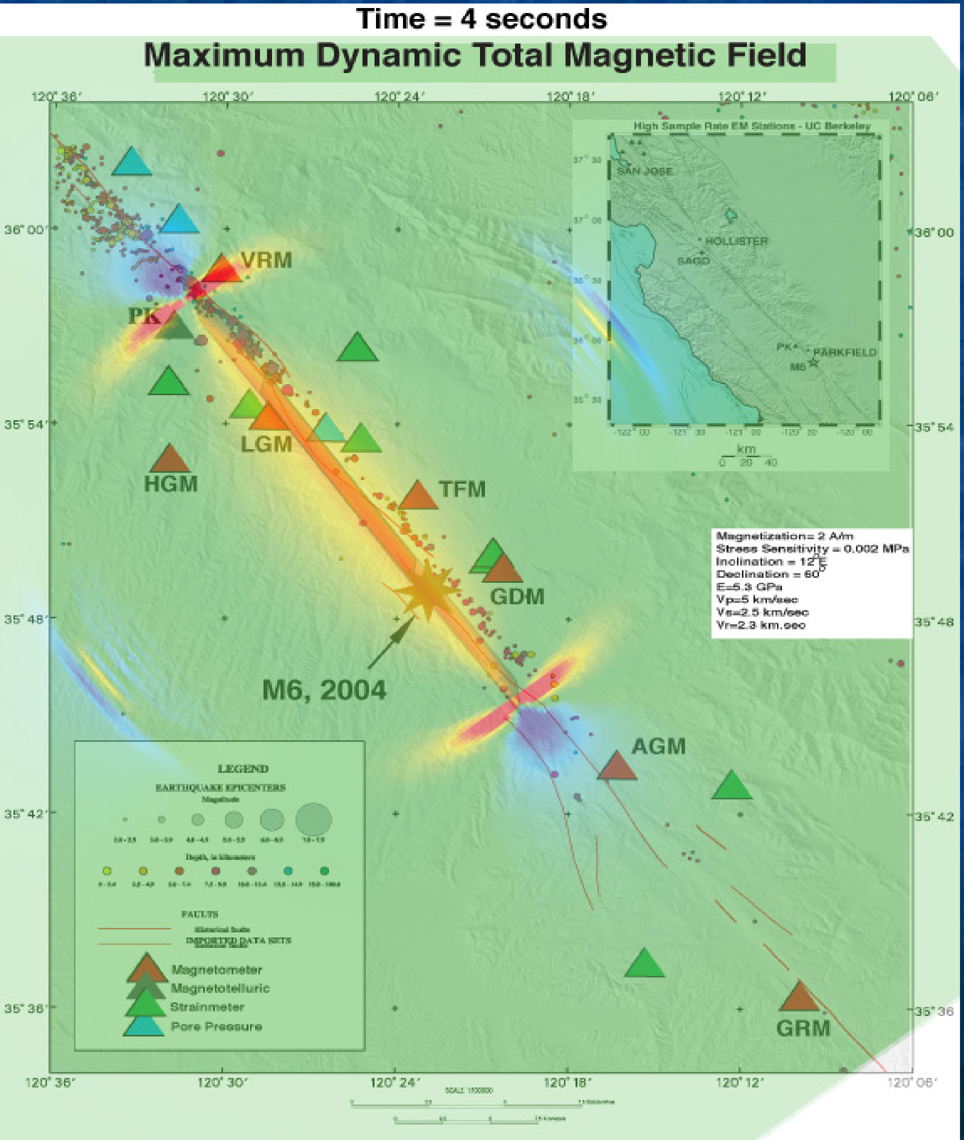
- Some correspondence for P waves (EW mag, NS elec) and some correspondence for S waves (vertical mag, NS mag, EW mag)
- Thus, stress related effects provide some contributions to EM data but not the entire story.

Quasi-static Piezomagnetic Dynamic Stress Model



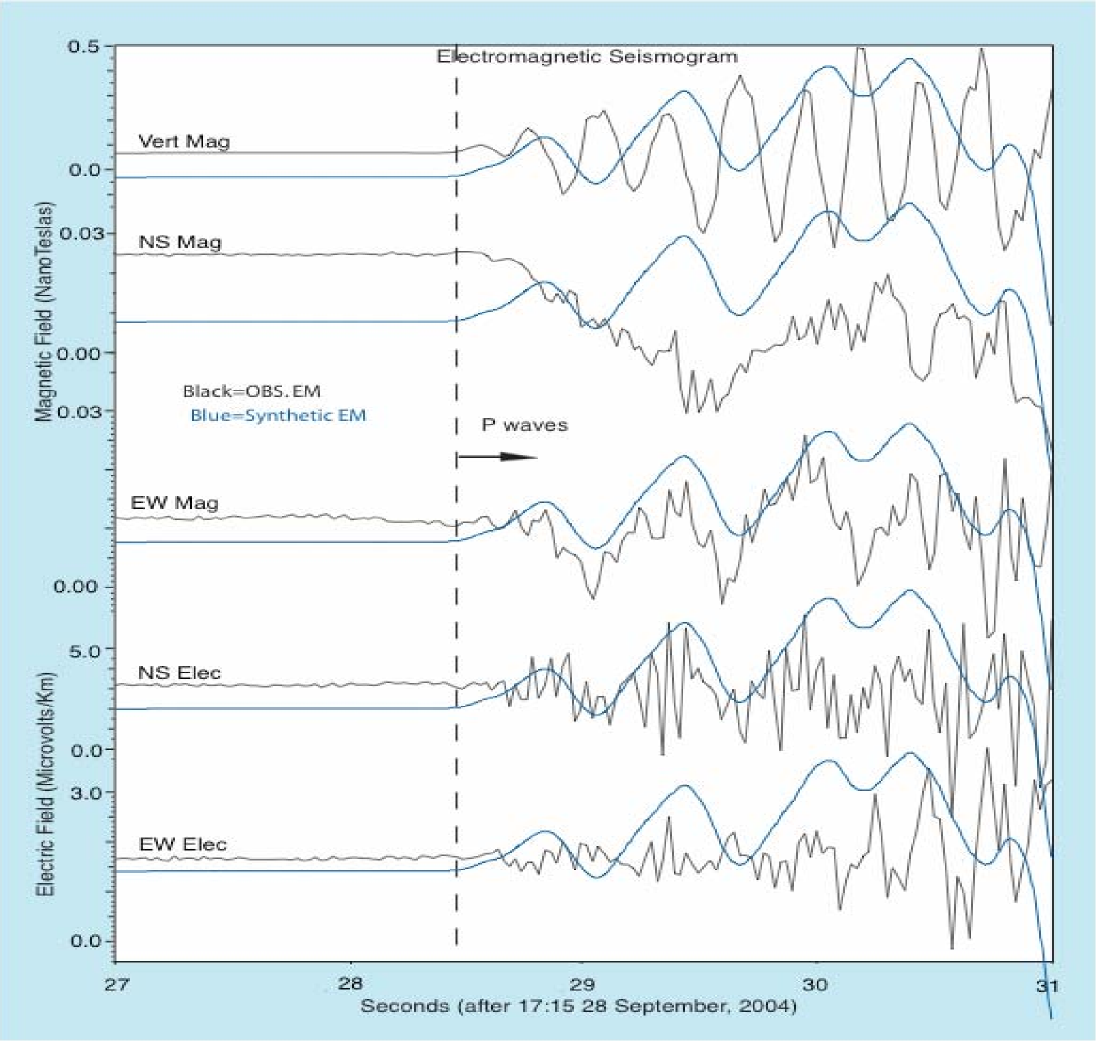
- Assume uniform magnetization and stress sensitivity of 2 A/m and 3E-3/bar and 0.01 S/m and 3E-4/bar for conductivity.
- Assume E=5.3 GPa, Vp=5 km/sec, Vs=2.5 km/sec, Vr=2.3 km/sec in finite element grid
- Assume uniform half space and uniform slip.
- Problems
- Computationally intensive.
- Spatial smoothing needed to get finite solutions for magnetic fields.

Quasi-static Piezomagnetic Dynamic Stress Model

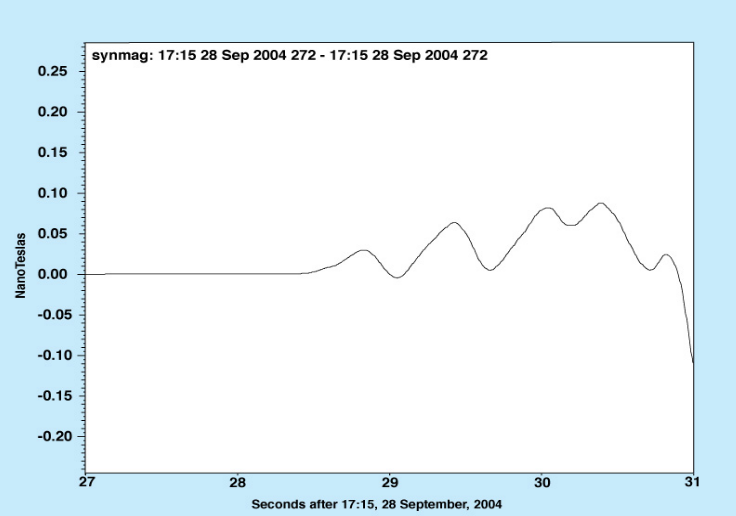


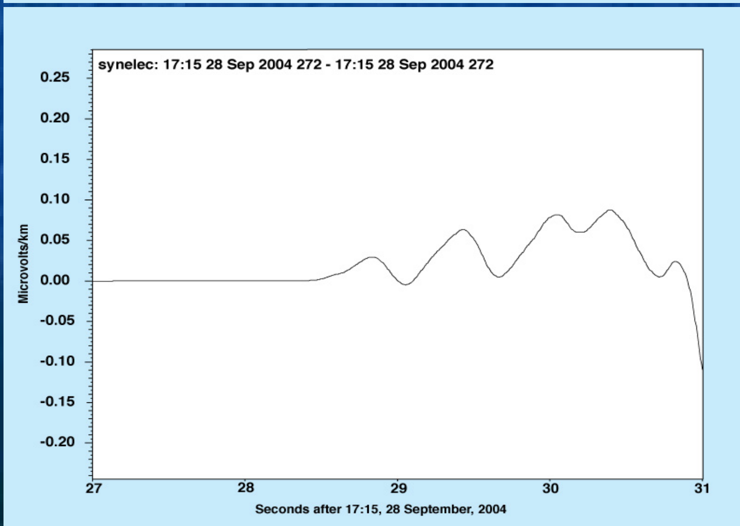
- More complex slip model needed from seismic inversion.
- Correction needed for local ground response. Need to determine surface Green's functions from co-located surface seismometer.
- Model fits only the low frequency components in the EM seismogram.

P Wave Data Comparison



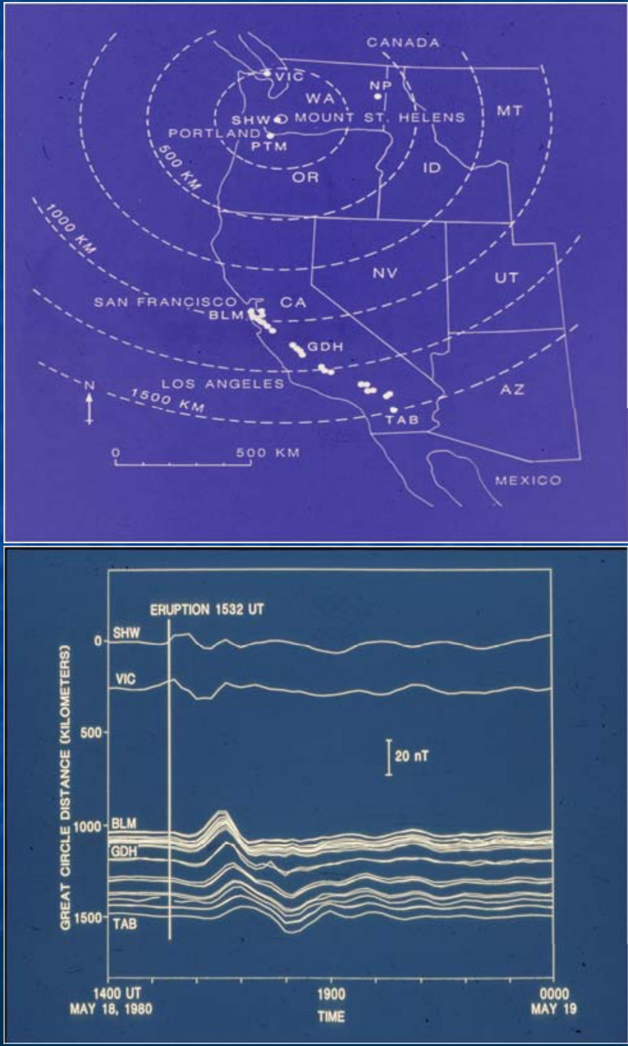
Synthetic Data



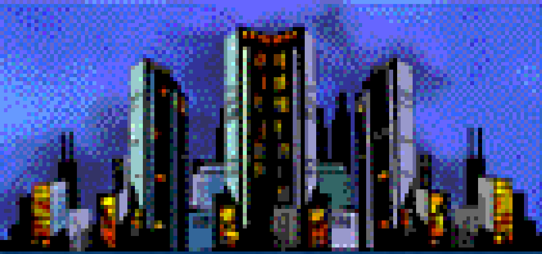


Traveling Ionospheric Disturbances (TIDS)

- Generated by acoustic (gravity) waves caused by static and dynamic ground displacement with earthquakes and explosive eruptions from volcanoes that are coupled into the atmosphere and trapped in the Ionosphere Earth wave guide.
- Various phases propagate at 200-300 m/s (Francis, 1976)



(see Mueller and Johnston, 1987



Conclusions

- Static stress field offsets, dynamic stress waves and acoustic waves from earthquakes are the largest earthquake related stress changes in the Earth’s crust.
- EM changes from these phenomena can be used to relate electromagnetic signals to real crustal behavior consistent with geodetic and seismic observations.
- Other EM signals related to other processes with earthquakes also occur and these provide important new information about the earthquake process and local ground response.
- It is apparent from our EM data together with data from multiple high-resolution strain, seismic and geodetic instruments in the near-field of earthquakes that precursory signals do NOT scale with earthquake size. These data argue for nucleation runaway models of earthquake failure and against concepts of large scale earthquake preparations zones.

Coseismic Stress/Strain offsets - North Palm Strings, Landers