

S41D-03

## Re-affirming the Magnetic Precursor to the 1989 Loma Prieta, CA, Earthquake Using Magnetic Field Data Collected in the US in 1989 and 1990

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### Outline

1. Loma Prieta (Corralitos) ULF-EM precursor:
  - multiple phenomena requiring explanation
  - a unique data set deserving the closest scrutiny
2. Campbell (2005) contends that instrumental problems created the appearance of a precursor.
  - “Campbell contention” seems implausible if we examine a longer time series.
3. Thomas-Love-Johnston (2007) contend that processing errors created the appearance of a precursor.
  - “TLJ contention” fails to model all the multiple phenomena observed or to offer a reasonably plausible explanation of aspects it does model
4. Conclusion: the Loma Prieta ULF-EM signals are a *plausible earthquake precursor*

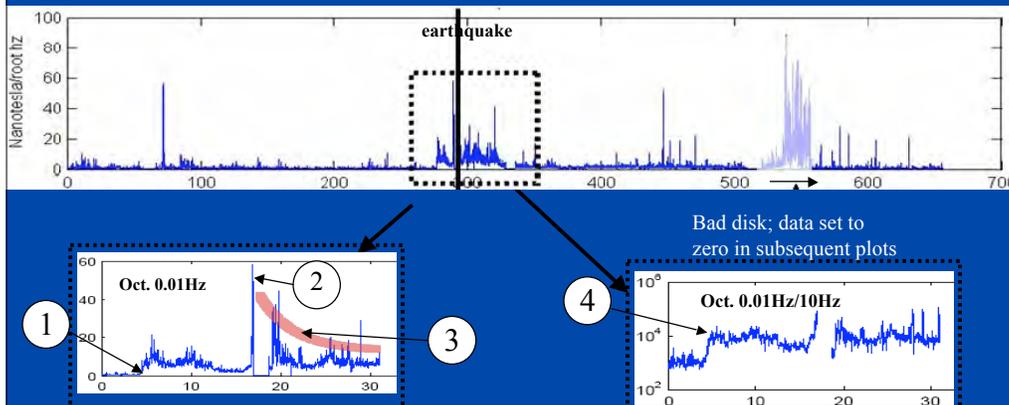
## The Loma Prieta ULF-EM signals recorded at Corralitos

Fraser-Smith et al. (1990); Bernardi et al. (1991); Fenoglio et al. (1993)

1. Broadband signal (x10) for two weeks prior to the earthquake
2. Extreme amplification (x100) for three hours prior to the earthquake (multiple high-amplitude samples were recorded before the power failure at the time of the earthquake clearly preceding and unrelated to ground motion or shaking of the magnetometer)
3. Long-term amplitude decay after earthquake
4. Dominant low frequency consistent with source at hypocentral depth

\* Multiple phenomena to be explained as a precursor ... or explained away as an artifact

Two years of data, Corralitos magnetometer



## Loma Prieta ULF-EM signals: precursor or artifact?

- the multiple phenomena have been modeled using sub-surface fluid effects. (Draganov et al., 1991; Fenoglio et al., 1995; Merzer & Klemperer, 1997; Simpson & Taflove, 2005)
- new claims have been made that some of the “precursory” phenomena are artifacts. (Campbell, 2005; Thomas et al., 2007)
- we can never prove with absolute certainty what created *any* geophysical recording.
- arguments for or against the earthquake origin of the Loma Prieta signals (precursor or artifact) ultimately rely on the plausibility of the explanation.
- we are in this predicament because only a single station, with only a single magnetic component, recorded the Loma Prieta signals:

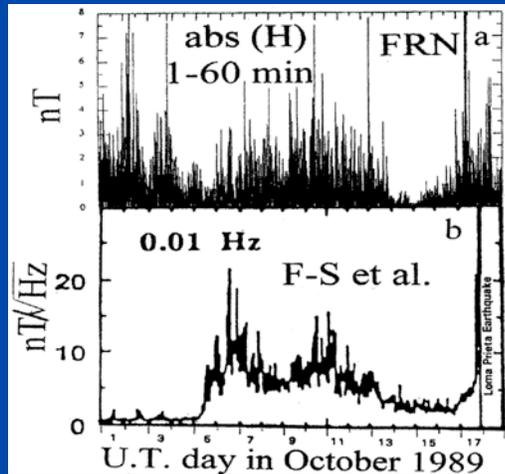
*stable funding for long-term arrays of multi-component EM sensors is essential to push forward this area of science.*

## The “Campbell contention”

Campbell (2005 and unpublished preprint) claimed that:

- the existence of a precursor “is very likely false”
- the reported precursor was recorded throughout the western US and was therefore a solar-terrestrial disturbance
- the extreme amplitudes recorded were due to a gain change of the Corralitos magnetometer “by a factor of 5 to 10, on 4 to 5 October”, *i.e. instrumental malfunction*

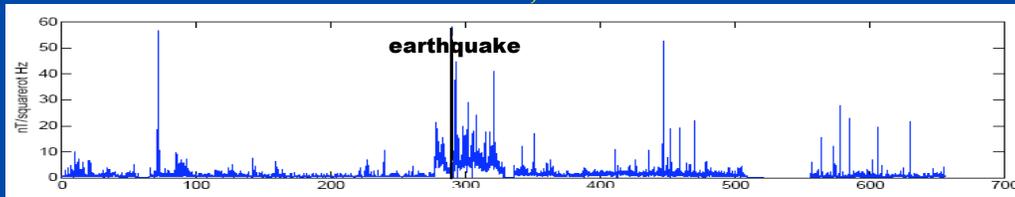
- only qualitative comparison
- only 3 weeks data considered
- only one aspect of multiple phenomena considered



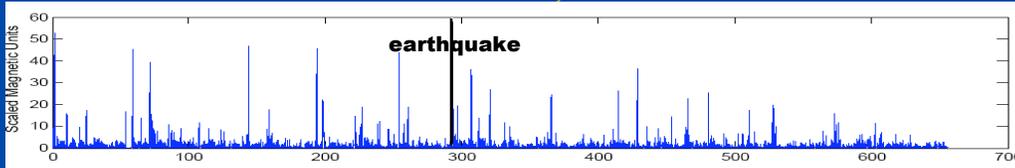
Campbell, unpublished ms.

## The “Campbell contention” tested, quantitatively with 2 years data

Corralitos 0.01 Hz, 1989-1990



Fresno .001-.0083 Hz, 1989-1990

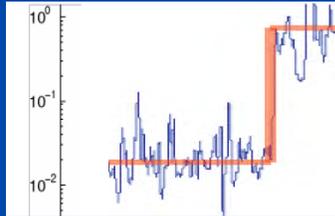


Fresno is the closest USGS geomagnetic reference station, 201 km distant  
 Expectation: Fresno will show global effects (magnetic storms)  
 but not local earthquake signals

## Corralitos/Fresno “inter-station transfer function” (log ratio)

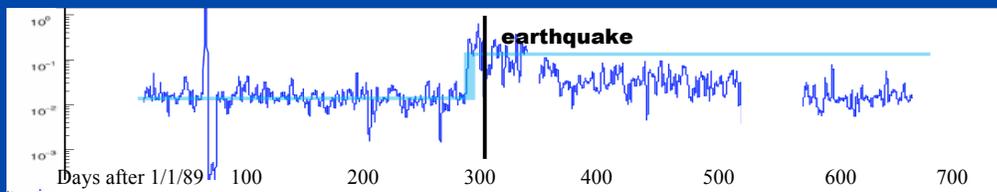
1) Campbell prediction: single gain change x10 prior to earthquake

Sep-Oct 89

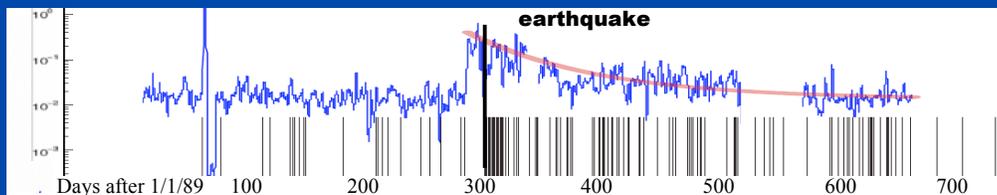


## Corralitos/Fresno “inter-station transfer function” (log ratio)

1) Campbell prediction: single gain change x10 *does not fit data*



2) observation: complex long-term behavior, consistent with extended period of aftershocks and possible fault-healing: not a simple gain change

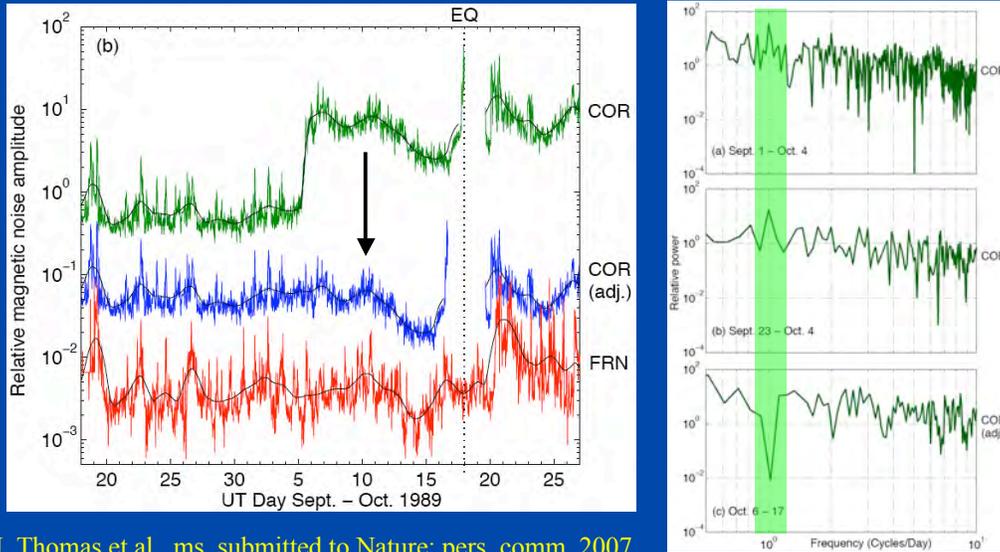


NCEDC catalog: all  $m > 3$  earthquakes in a 100-km area, plotted by day through 1989-1990, showing enhanced aftershock activity following Loma Prieta event

## The “Thomas-Love-Johnston (TLJ) contention”

TLJ (Nature preprint; IUGG 2007; AGU 2007) contend that:

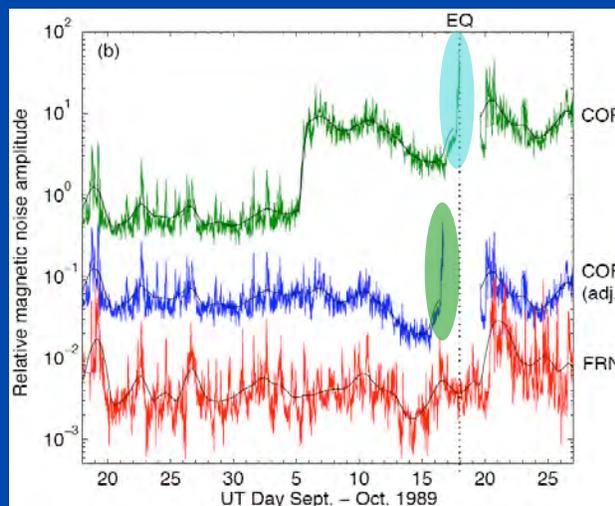
- the magnetic variations are not related to the Loma Prieta earthquake;
- they can be explained with a gain change plus a time adjustment;
- the lack of a diurnal signal implies data corruption.



J. Thomas et al., ms. submitted to Nature; pers. comm. 2007

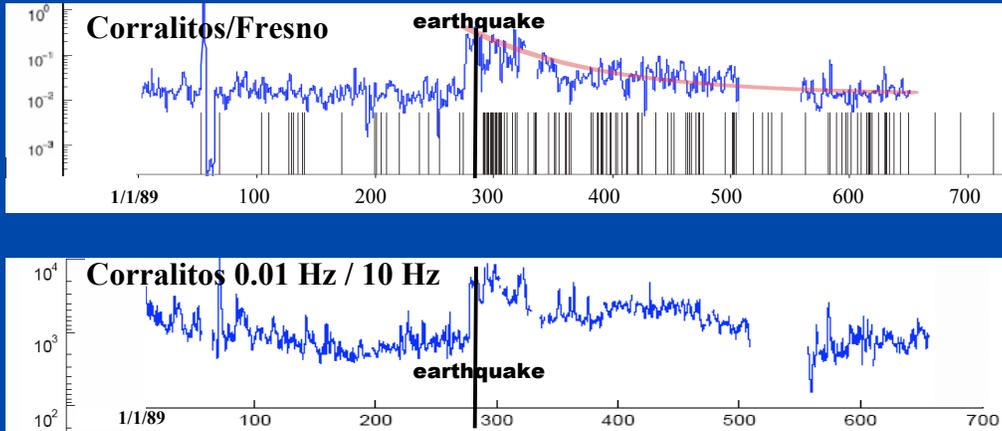
## The “TLJ contention”

- 1) “TLJ contention” does not address the most dramatic part of the anomaly, the spike that lasted for several hours before the earthquake, and was not seen in Fresno



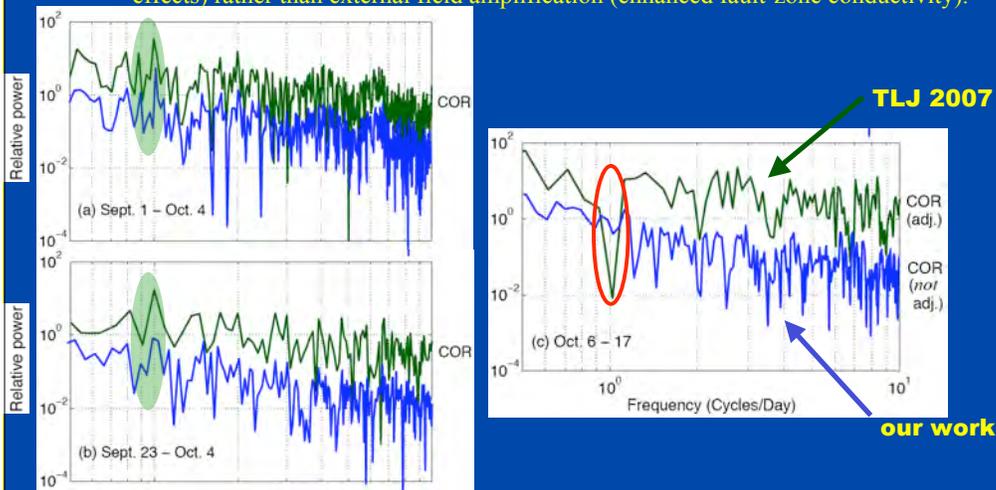
**The “TLJ contention”**

- 2) No single simple gain change explains the 2-year data record. Gain change would have had to have been applied to all 9 data channels (“MA indices”). Gain change would have to be different for each of 9 data channels to explain the strong relative low-frequency enhancement.



**The “TLJ contention”**

- 3) The diurnal signal (1 cycle/day) is weak immediately prior to the earthquake (Bernardi, 1991), but it is *not* absent. We wonder if the absence in Thomas’ figure (green line) is due to their “time-stamp adjustment” (11% change in sample rate) which must affect the frequencies they infer. The weak diurnal signal is evidence for signal generation at depth (electro-kinetic effects) rather than external field amplification (enhanced fault-zone conductivity).

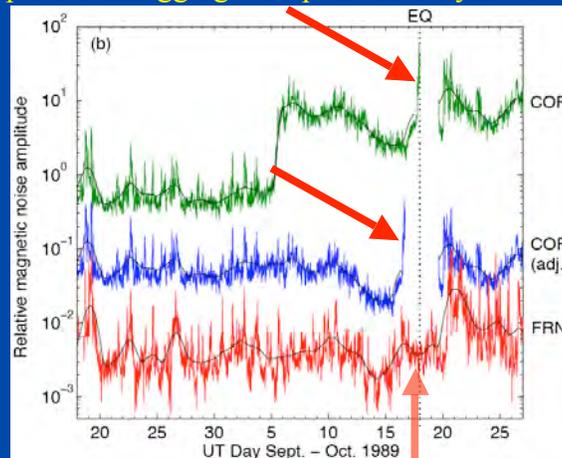


### The “TLJ contention”

4) The TLJ time-stamp adjustment (30 minute to 26.7 minute sample interval) may help match amplitudes, but it is *entirely implausible*: This time-stamp adjustment *shortens* the magnetometer record from October 5-18 by 11%, i.e. 1.5 days, so implies that the power-failure that interrupted data-logging took place 1.5 days before the earthquake!

The TLJ contention implies the power-failure anticipated the earthquake by 1.5 days.

We know *this is not true*: residents of the house where the equipment was located would have noted a power failure.



We know the power failure occurred at the earthquake, not 1.5 days earlier!

### Conclusions:

#### Loma Prieta ULF-EM signals: still best-explained as a precursor

- the claims that the “precursory” phenomena are artifacts require complex and implausible electronic failures, or complex and implausible failures of data curation.
- the observed phenomena can be modeled using sub-surface fluid effects, so the observed magnetic anomalies are most likely a precursor.
- stable funding for long-term arrays of multi-component ULF-EM sensors is essential to push forward this area of science.
- we thank NSF-Earthscope, NASA, and USGS for recognizing this need and recently funding such efforts.