Prediction vs. Forecast

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Definitions

- ***Prediction*** *is a deterministic* statement that a future earthquake will or will not occur in a particular geographic region, time window, and magnitude range

- ***Forecast*** *gives a probability that* such an event will occur

Jordan, et al., 2011

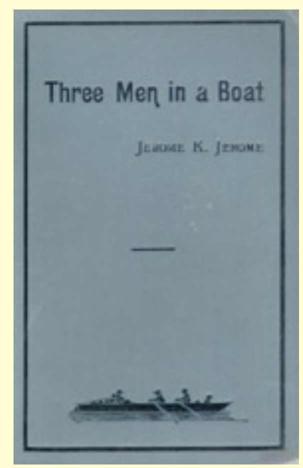
Weather forecasts in the past

"I do think that, of all the silly, irritating tomfoolishness by which we are plagued, this "weather-forecast" fraud is about the most aggravating. It "forecasts" precisely what happened yesterday or the day before, and precisely the opposite of what is going to happen to-day."

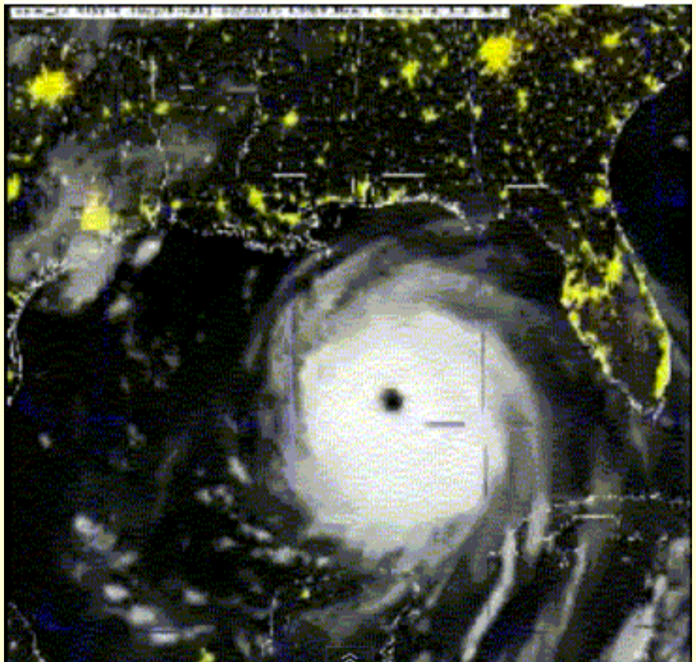
…………………………………….

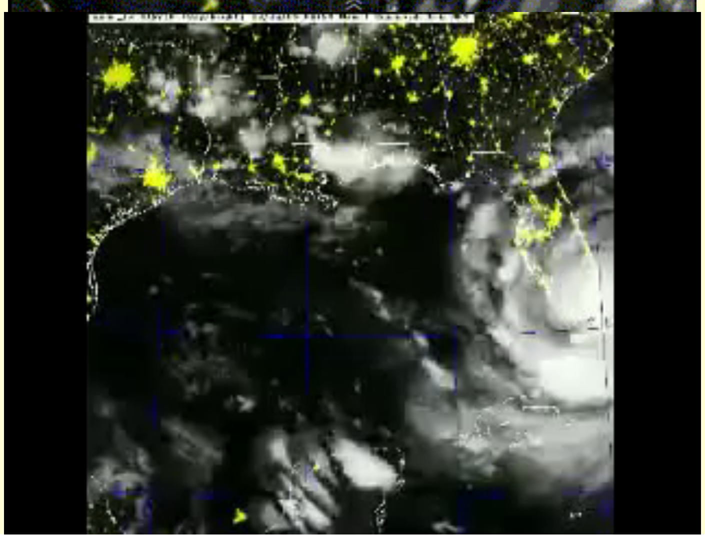
"The weather is a thing that is beyond me altogether. I never can understand it. The barometer is useless: it is as misleading as the newspaper forecast."

Jerome K. Jerome, 1889.



Hurricane forecasts lose uncertainty because of investments in new technologies





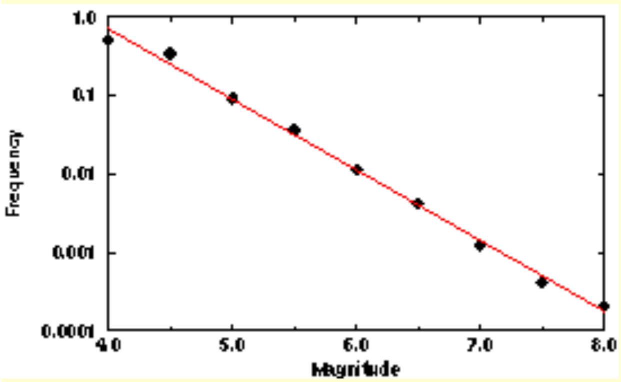
Evacuations are ordered using no “probability” language

Property is damaged but human losses are minimal

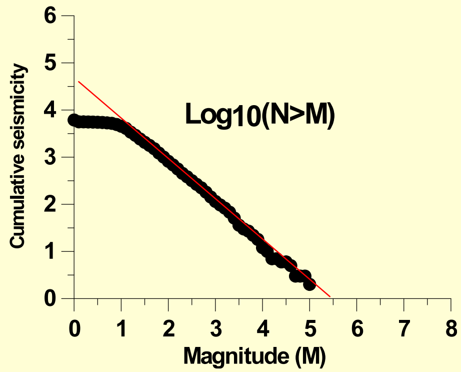
Gutenberg-Richter Law

$$Log_{10}P(> M) = a - bM$$

Worldwide seismicity in 1985



Parkfield seismicity 1970-2004



Acoustic emission during rock crushing

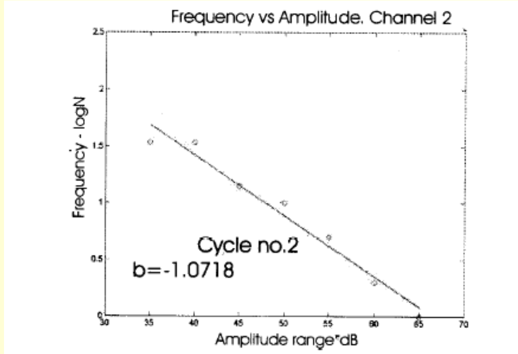


Fig. 4. Example of calculation of *b*-values for Channel 2 during loading cycle Number 2. *b*-value is calculated for groups of events during whole cycle. Graph represents log-frequency-magnitude chart and its relative curve fitting and *b*-value calculation for group of 100 events.

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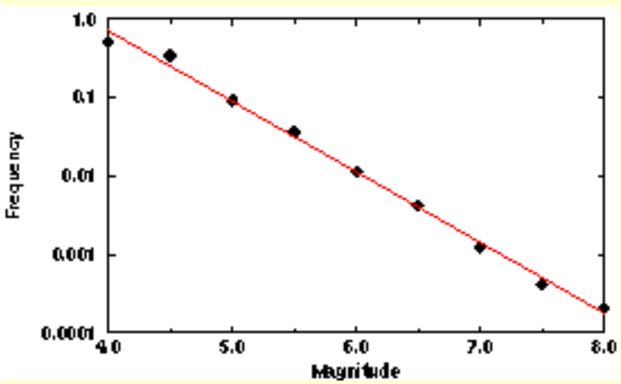

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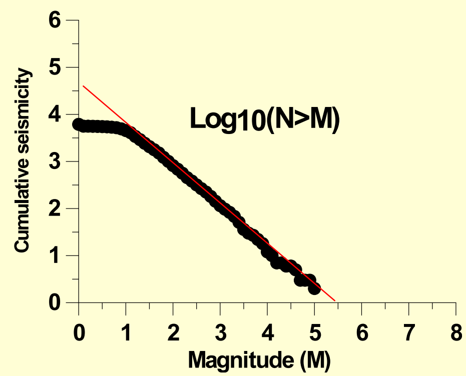

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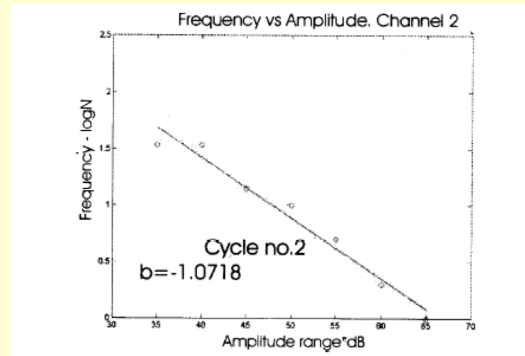

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Probability describes a statistical limit when number of trials is infinite.

What does mean "a probability of a rare event" that occurs once in 100-200 years?

Gutenberg-Richter Law

$$Log_{10}P(>M) = a - bM$$

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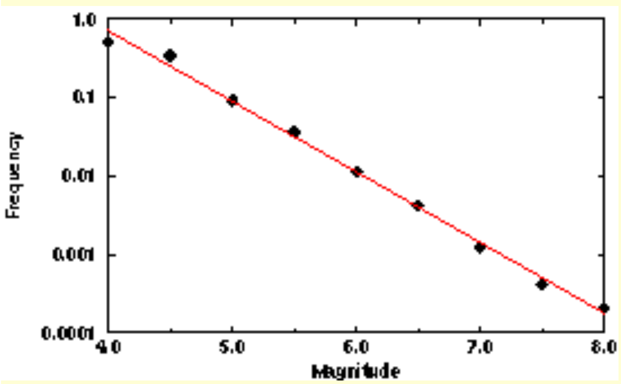

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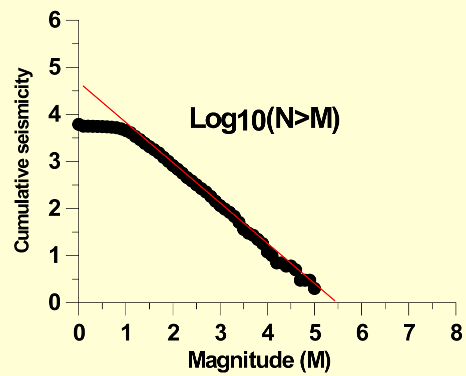

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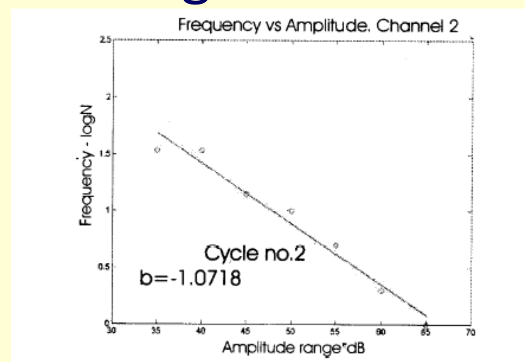

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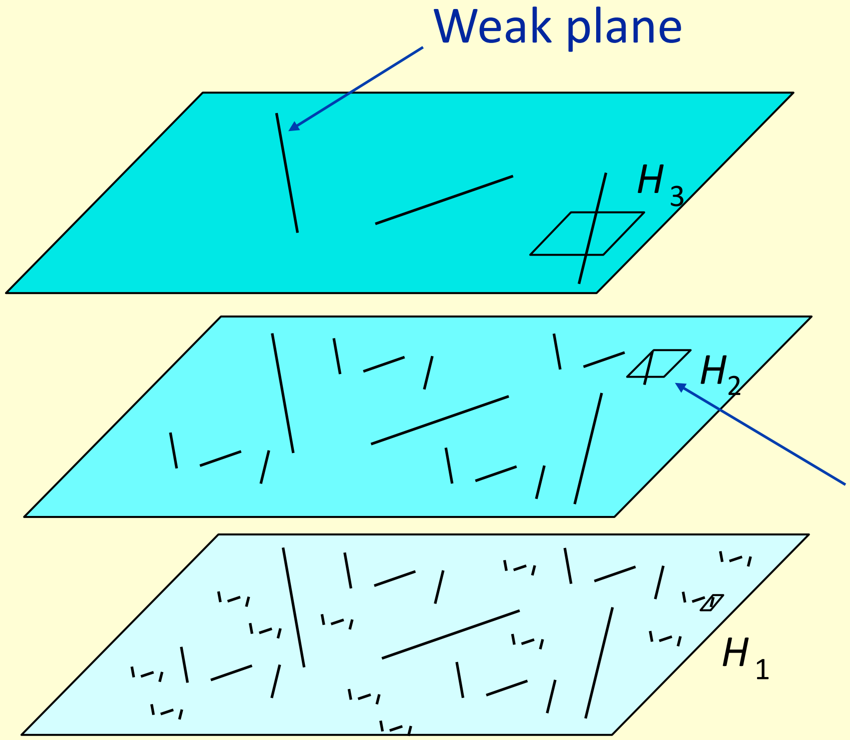
Probability describes a statistical limit when number of trials is infinite.

What does mean "a probability of a rare event" that occurs once in 100-200 years?

Information is an ability to cause changes (actions) that defines a true value of a predictive (forecasting) statement.

Special case of self-similarity, $\sigma_c^H = 0$



- Fracturing is related to sliding over pre-determined weak planes resisted by cohesionless friction
- Number per unit volume of weak planes of sizes greater than H:

$$M_H = cH^{-m},\ m>1$$

- Number per unit volume of volume elements of sizes $(H, H+dH)$, in which the fracture criterion is satisfied:

$$\mu H^{-D} dH$$

Number per unit volume of fractures of sizes *greater* than H

$$N^H = \frac{\mu c}{D+m-4} H^{D+m-4}$$

Gutenberg-Richter law

Dyskin, 2004, PAGEO

Can we use b-value for earthquake forecasting?

The Gambler's fallacy is the belief that if deviations from expected behavior are observed in repeated independent trials of some random process, future deviations in the opposite direction are then more likely.

H	H	T	T
T	T	T	T
T	T	T	T
T	H	T	H
T	T	H	T
H	H	T	T
H	T	T	T

Number of flip:
28
Number of heads
8
Number of tails 20

The probability so far to get heads is 0.2857142857142857

The probability so far to get tails is 0.7142857142857143

http://www.basic-mathematics.com/coin-toss-probability.html

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Randomness and a coin toss

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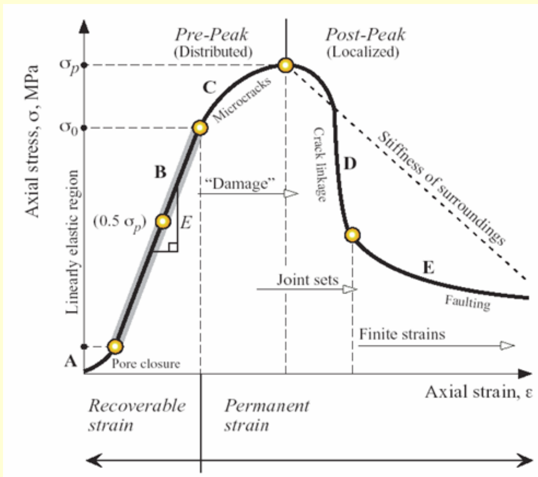
Randomness and a coin toss

We can predict a result of coin landing
after an investment in information acquisition

Rock failure phenomenon

Stress-strain curves



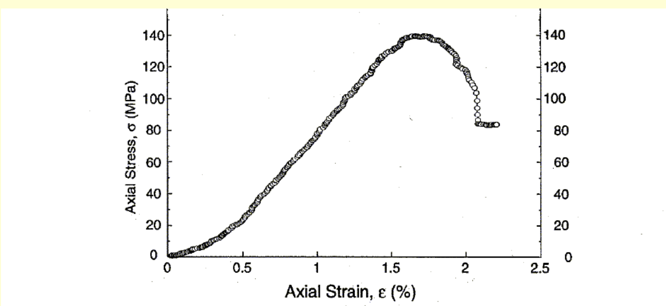
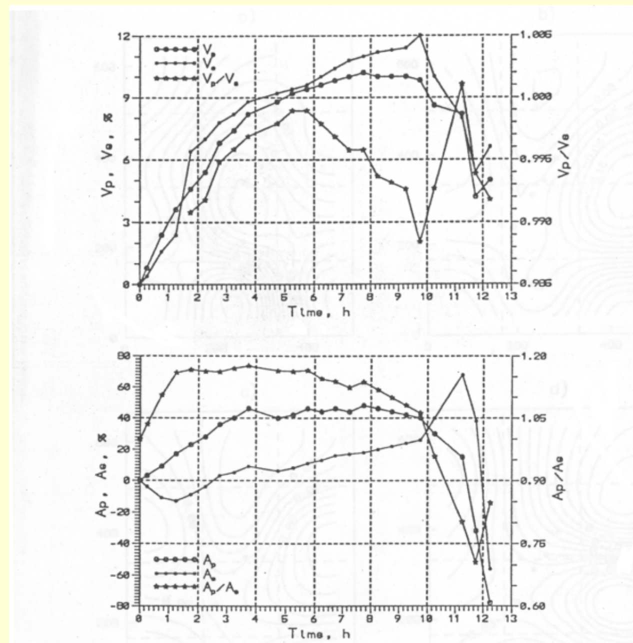


Figure 3. The variation of complex resistivity at 1 kHz during triaxial deformation until failure of a sample of Darley Dale sandstone saturated with initially pure deionized water in undrained conditions, combined with the stress/strain curve. Strain rate: 0.01%min^{-1}, confining pressure: 50 MPa.

Glover et al., 1996, Surveys in Geophysics

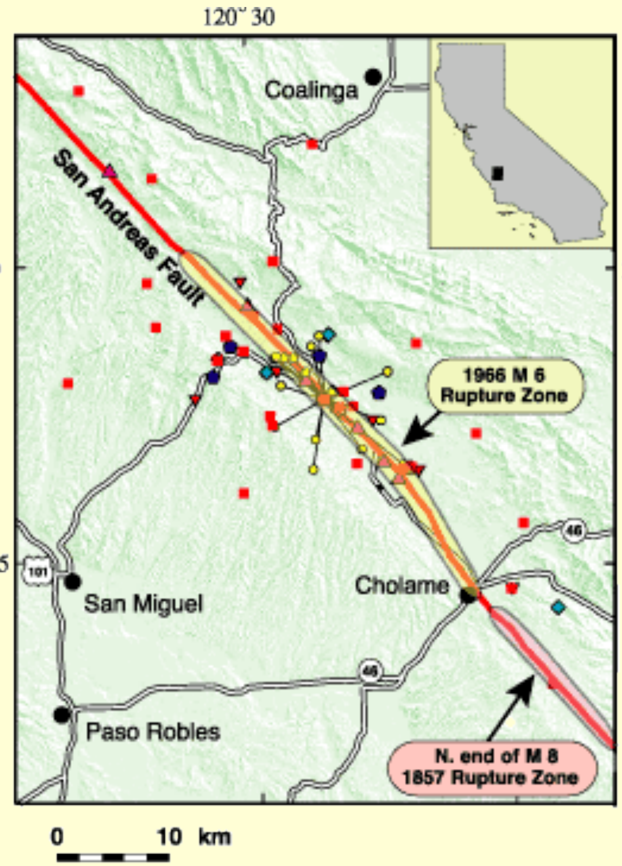
Amplitude and velocity changes vs. deformation

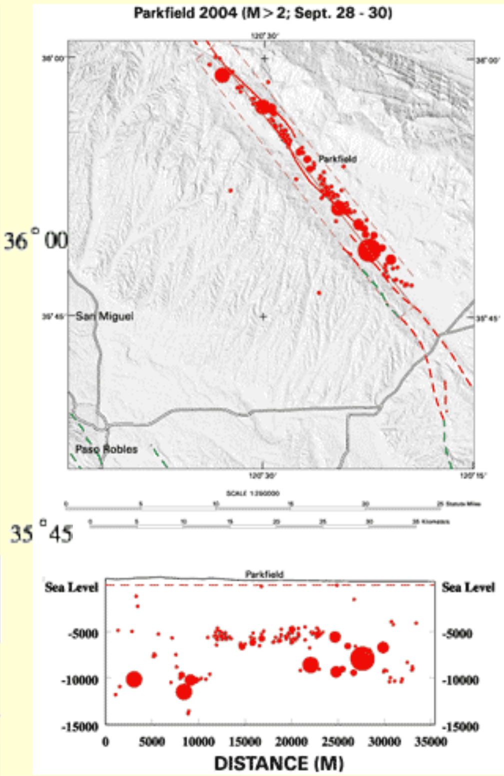


Variations in the propagation times (a) and amplitudes (b) of longitudinal and transverse elastic waves and in their ratios for the route 5–5 crossing the central region of macrocrack preparation in the marble block.

Sobolev, et al.,1996. Journal of Earthquake Prediction Research

M6.0 September 28, 2004, Parkfield

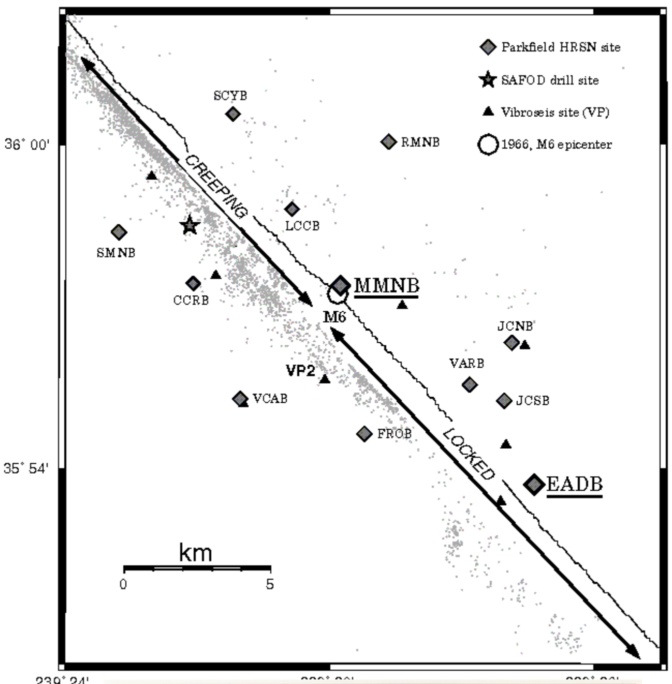


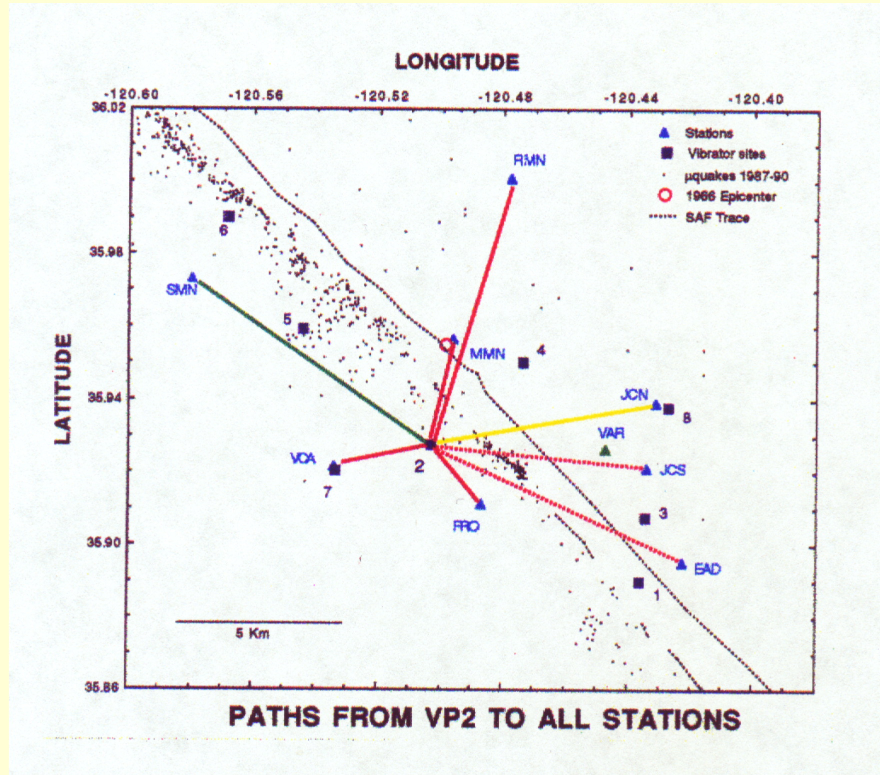


All measurements are made outside of seismogenic zones

Vibroseis Monitoring at Parkfield (1987-1996)

HRSN Network and Vibroseis Locations





Stable (green)

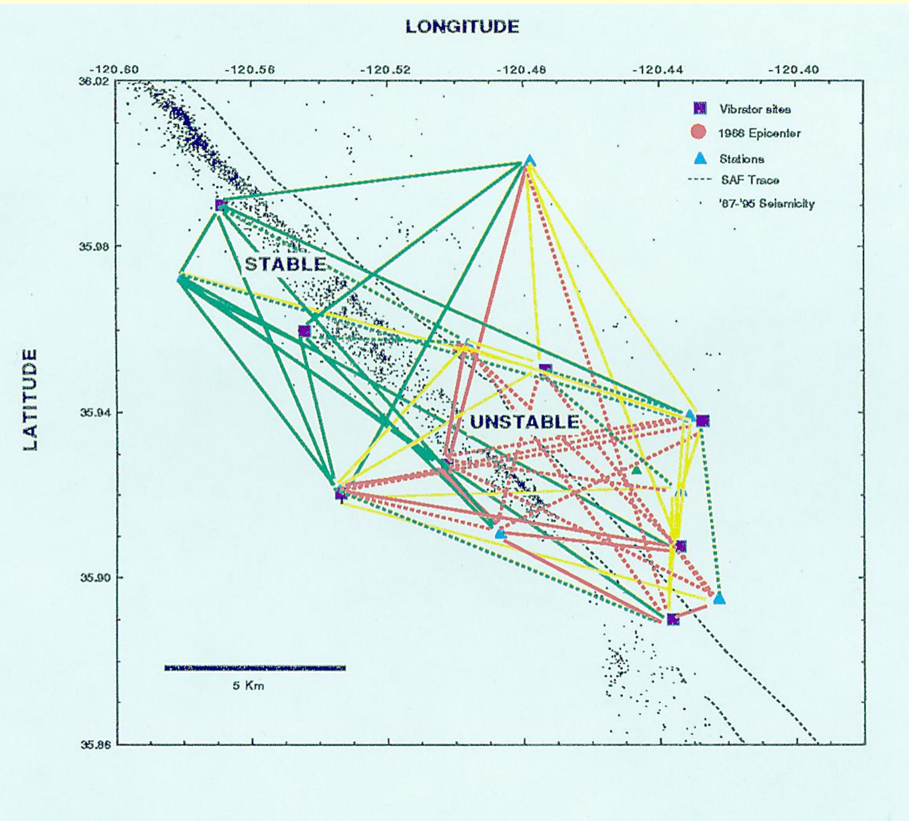
Moderately unstable (yellow)

Unstable (red)

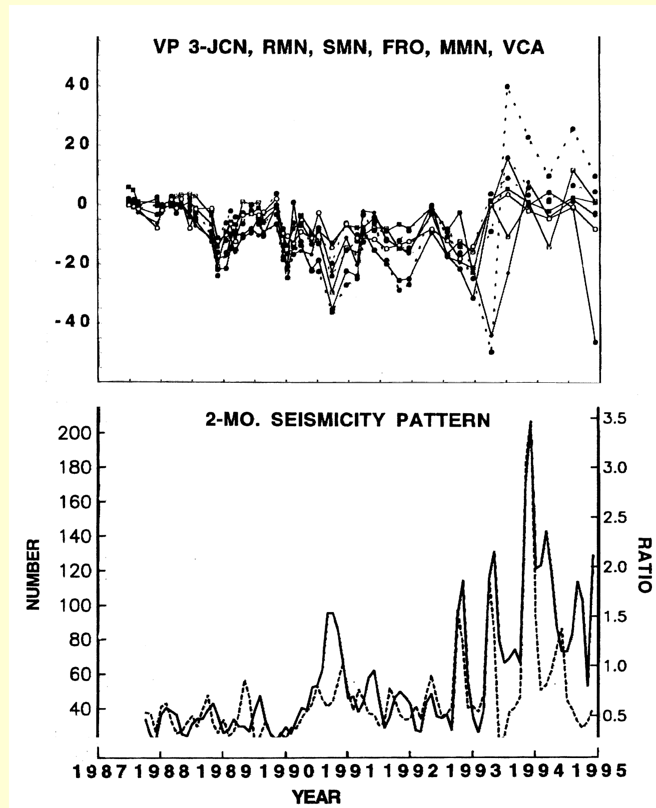
Karageorgy et al., 1997, BSSA; Karageorgy et al., 1992, BSSA

The observed changes

Changes Relate to Locked Zone

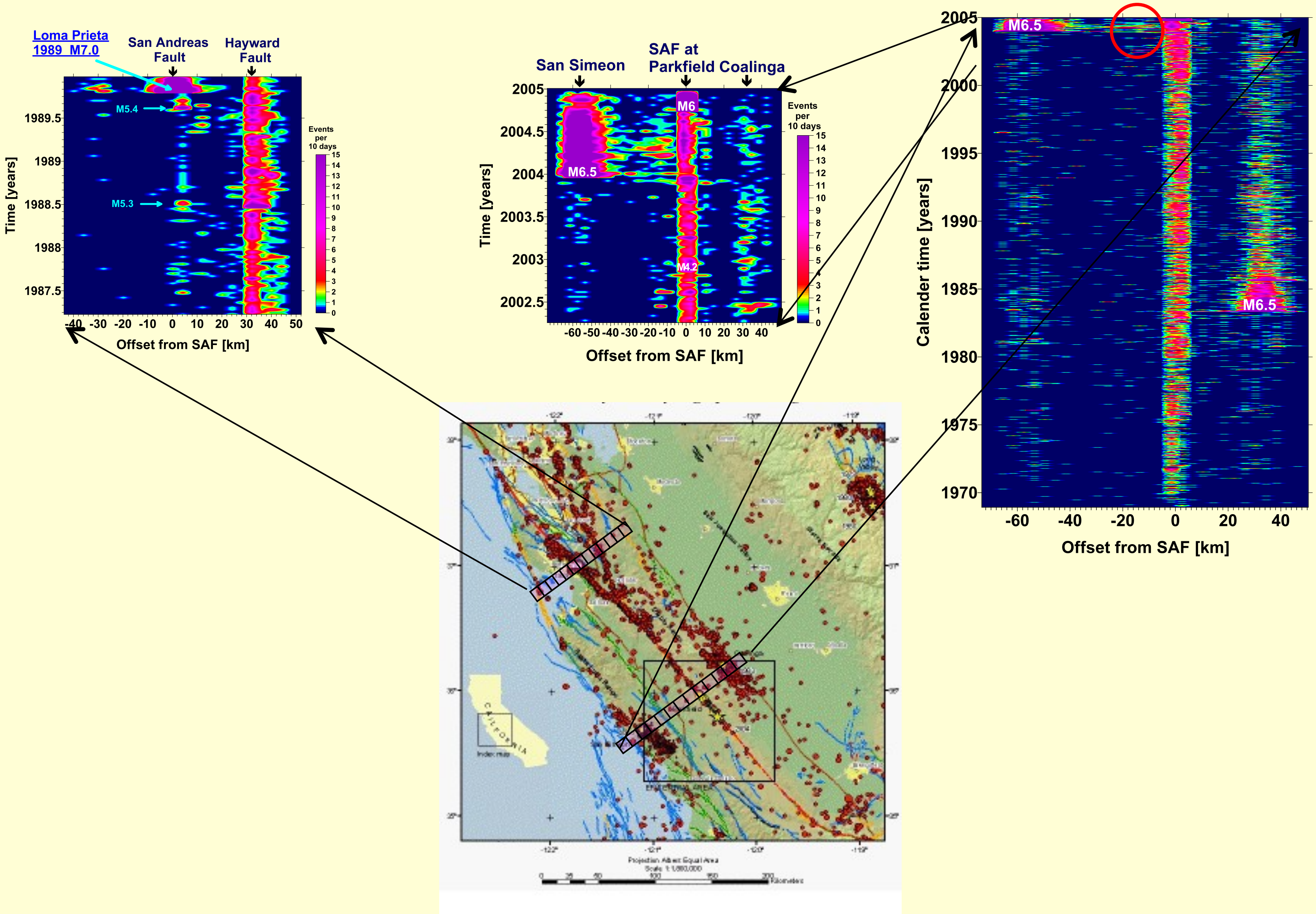


Traveltime changes correlate with seismicity



Karageorgy et al., 1997, BSSA; Karageorgy et al., 1992, BSSA

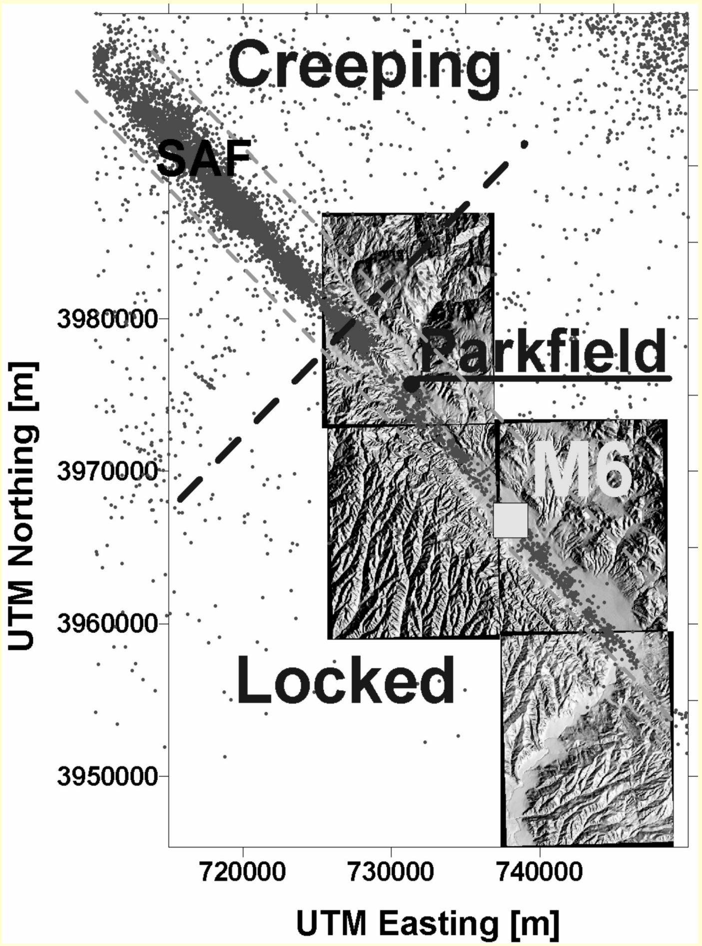
Seismicity scans



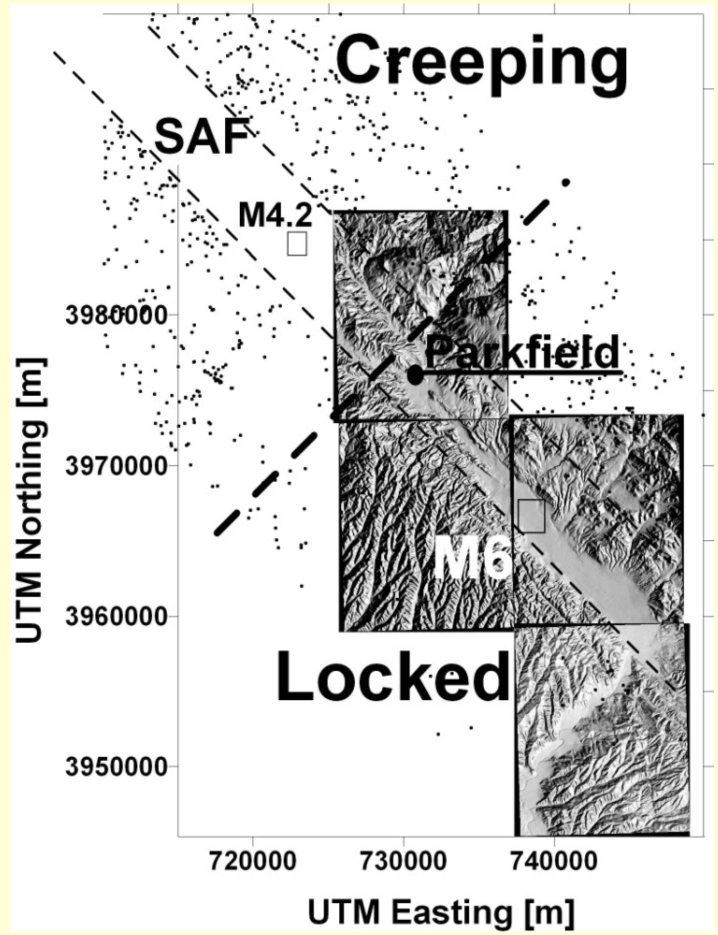
Korneev 2005,2010

Parkfield area seismicity 1968-M6 2004

All events

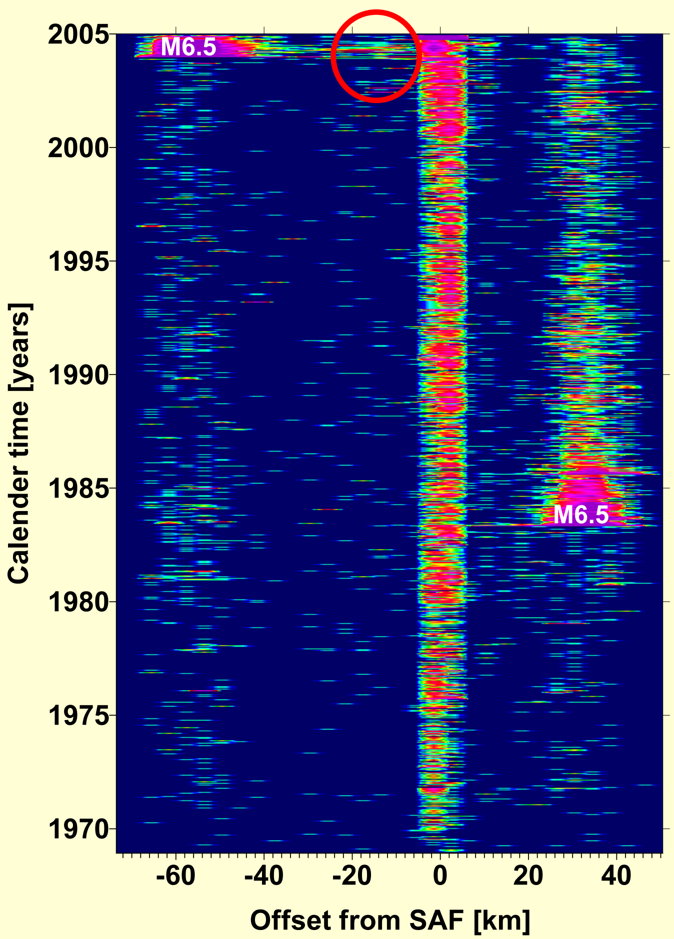


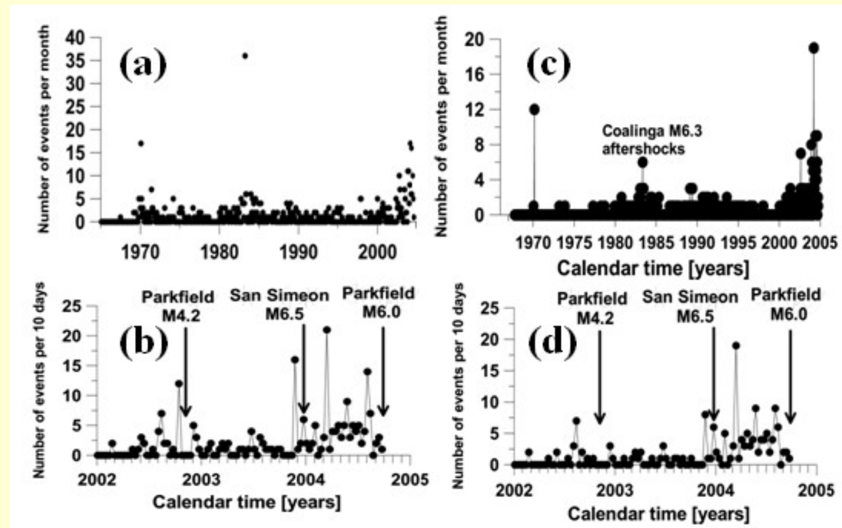
Selected events

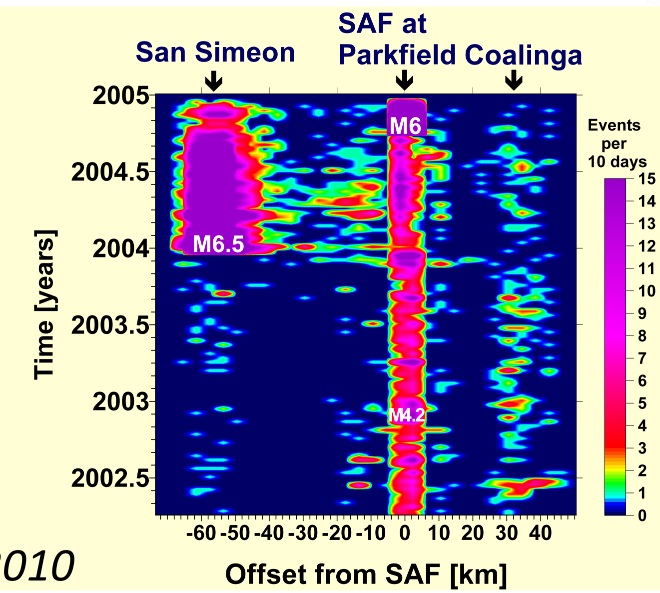


Korneev 2005,2010

Pre- M6 2004 Parkfield seismicity

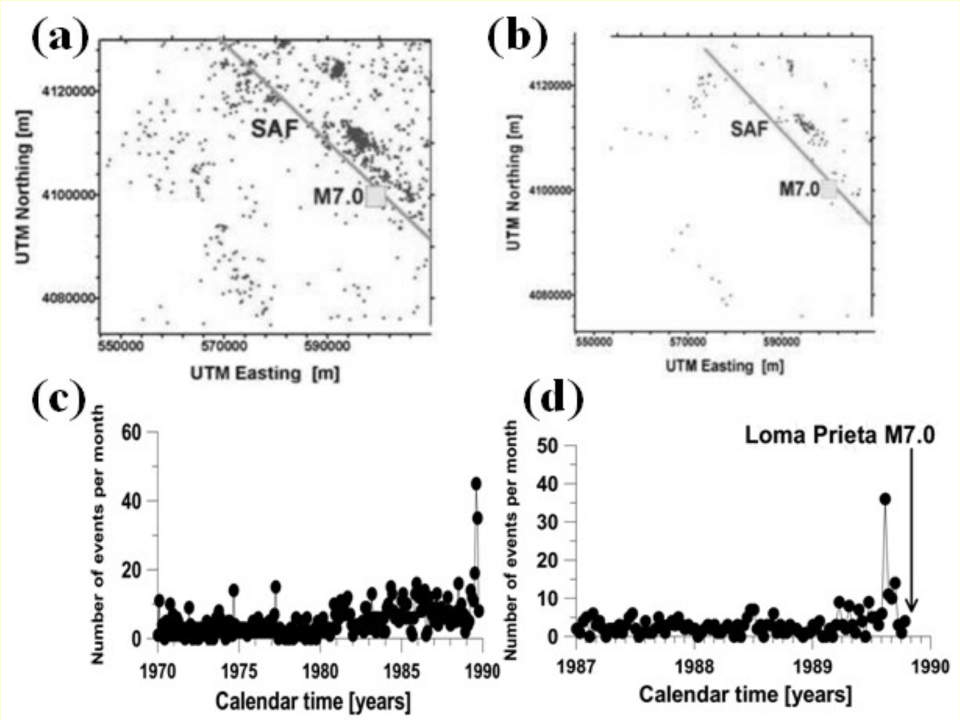


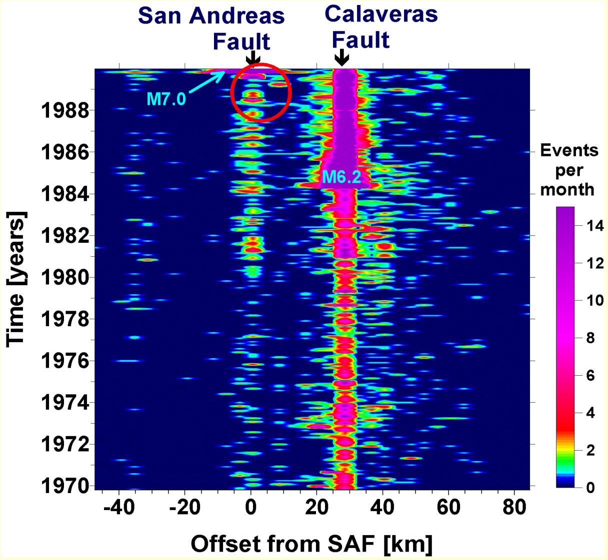


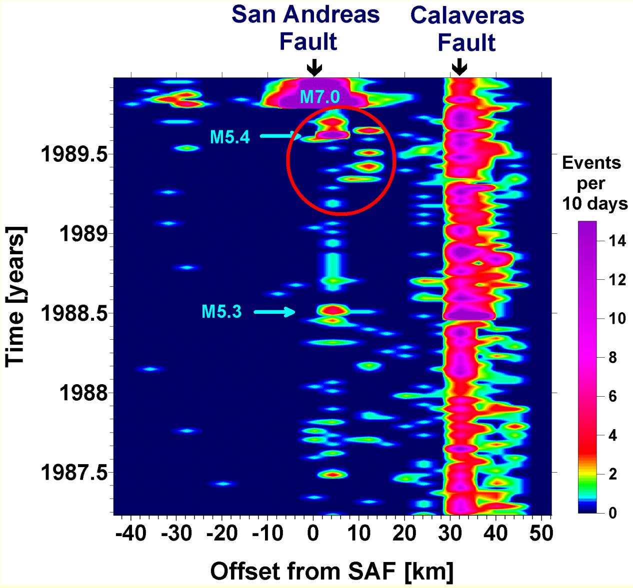


Korneev 2005,2010

Pre- M7 1989 Loma Prieta seismicity

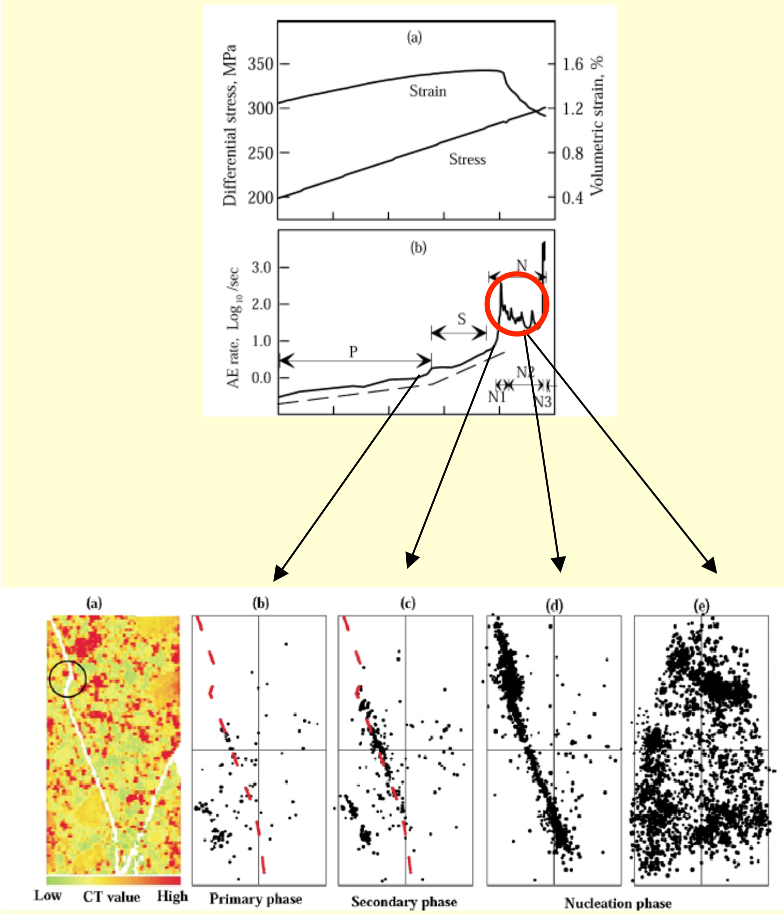


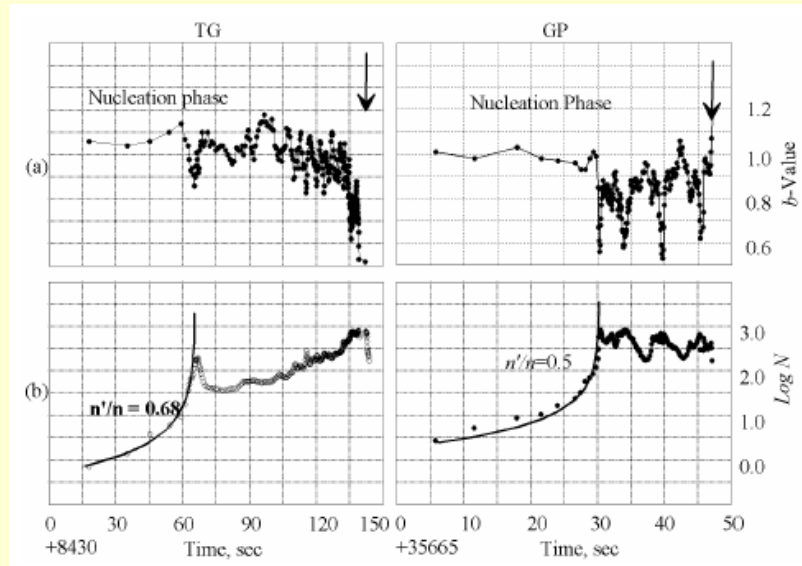


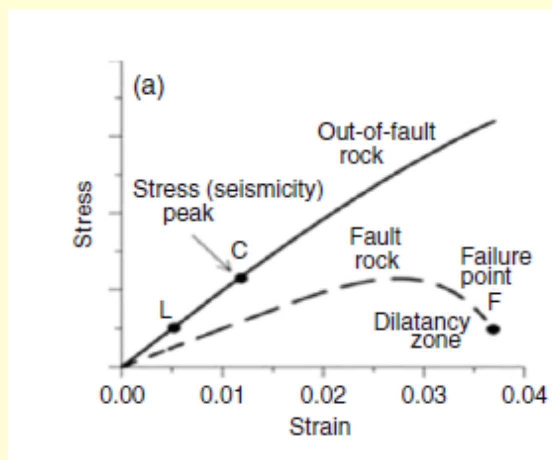


Korneev 2005,2010

Acoustic emission during rock crushing





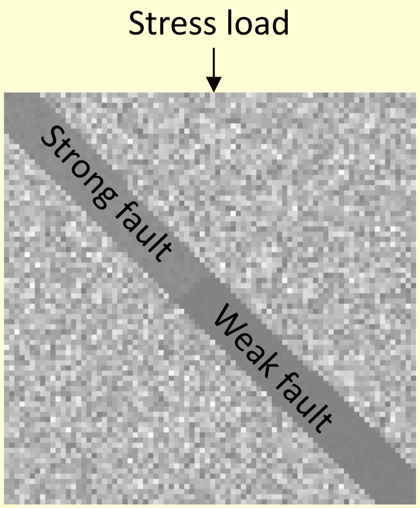


Stress peak causes seismicity peak

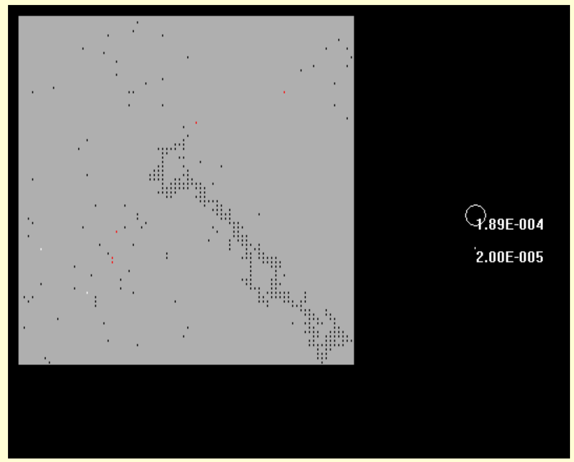
Lei et al., (2004)

FD Modeling of Rock Failure Under Stress Load

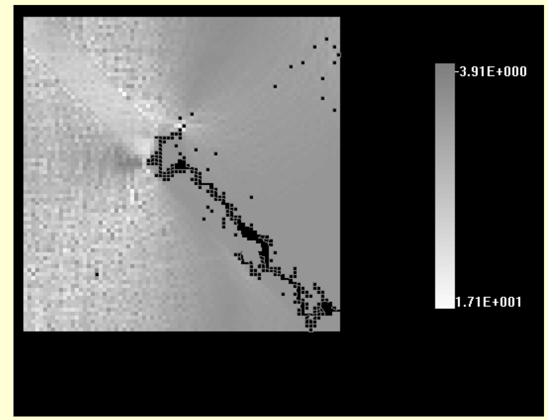
Model (shear modulus distribution)

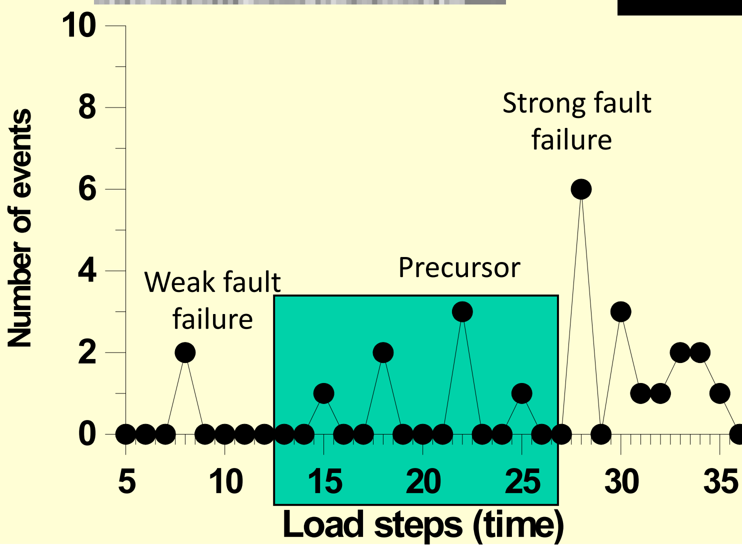


Cumulative AE before failure

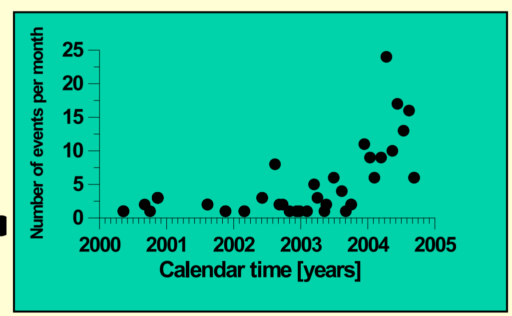


Shear stress before failure

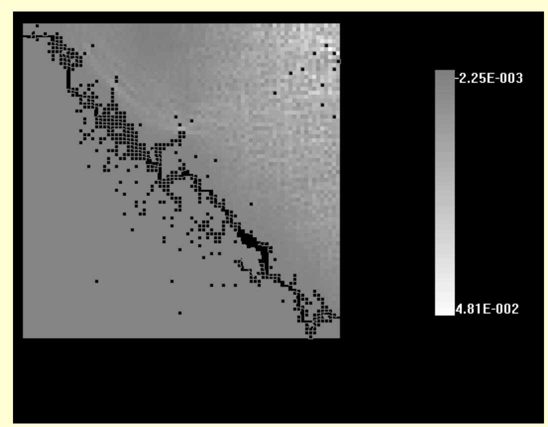




Parkfield seismicity

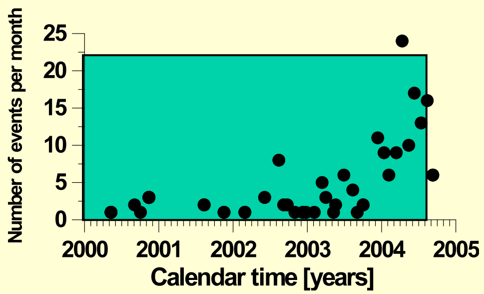


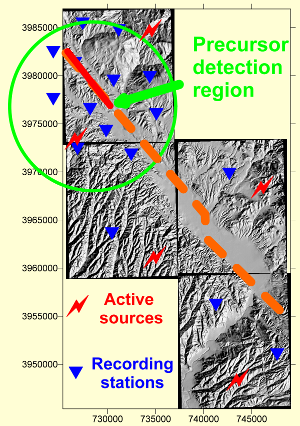
Shear stress after failure



Earthquake Prediction Strategy

Stage 1: Precursor detection



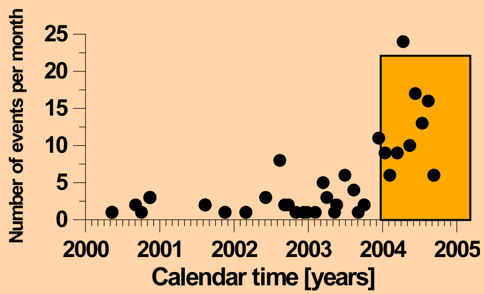


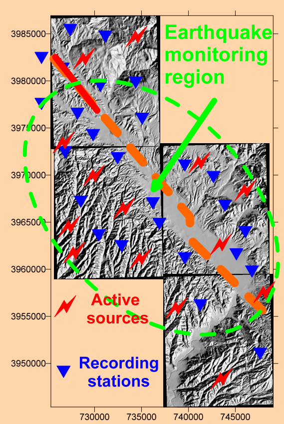
High-resolution passive monitoring

Moderate active monitoring

Alert triggering

Stage 2: Detail monitoring



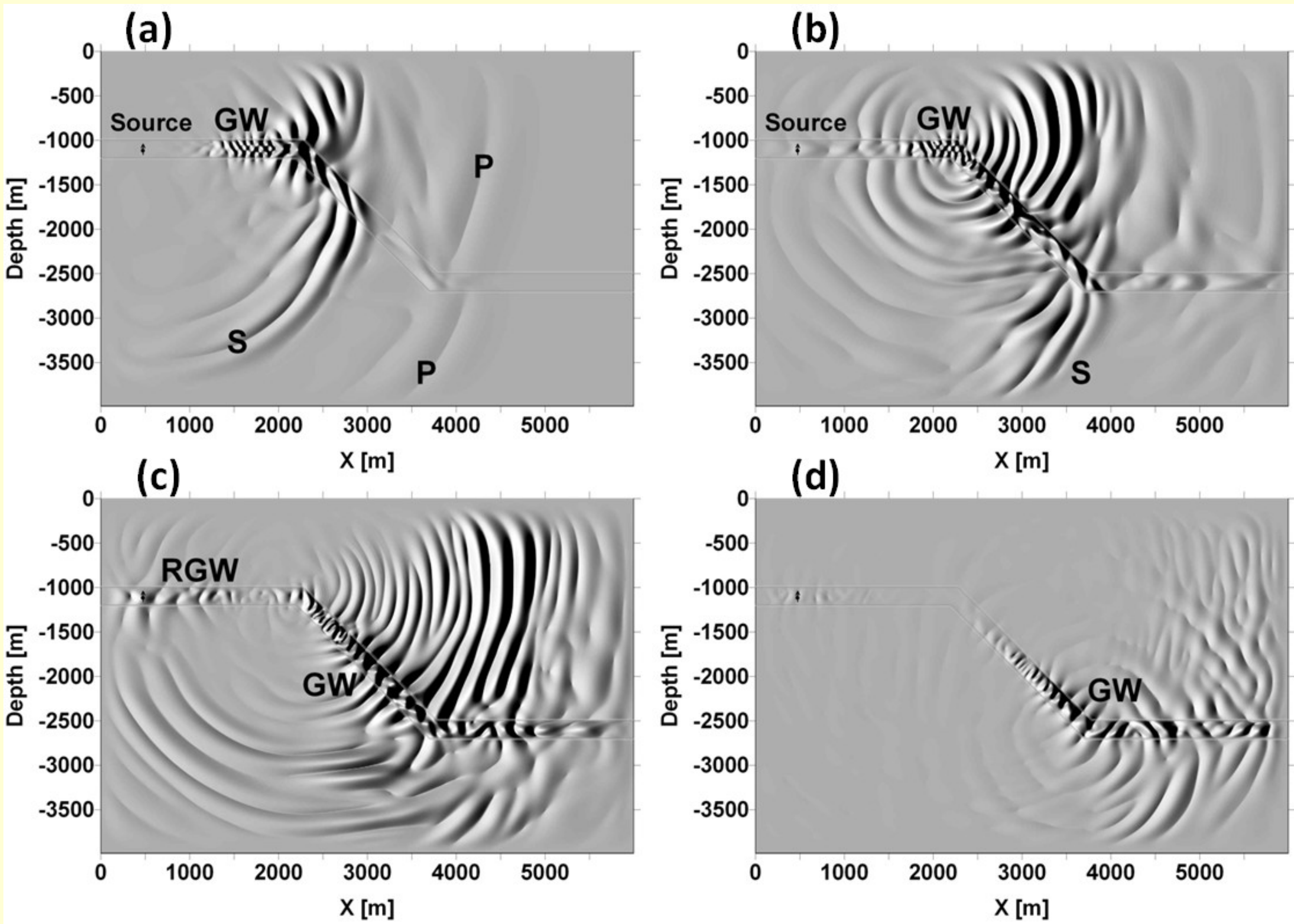


Mobilization of geophysical resources

Intensive active monitoring

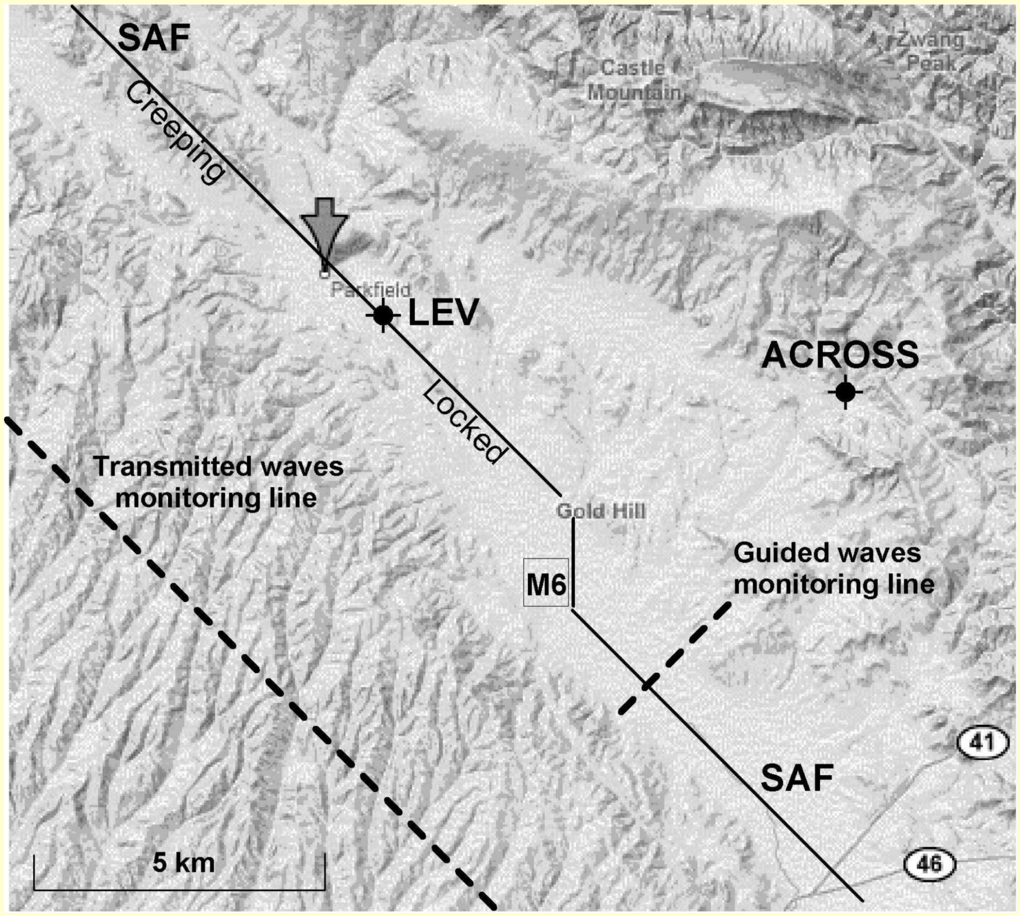
Public warning

Modeling of guided waves propagation in Cholame Valley



Korneev and Nadeau,2010

SAF active monitoring scheme in Cholame Valley



Korneev and Nadeau,2010

Magneto–Acoustic Sensor

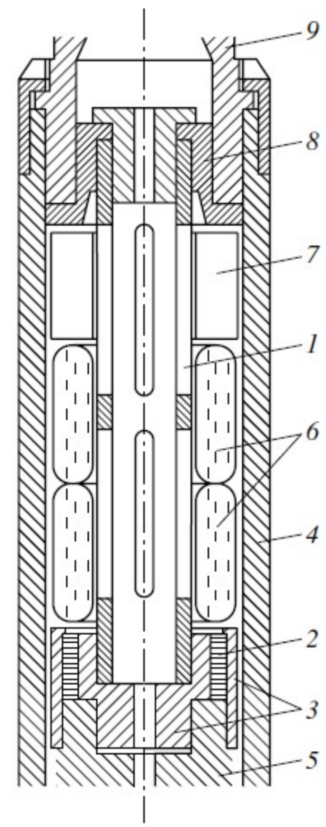
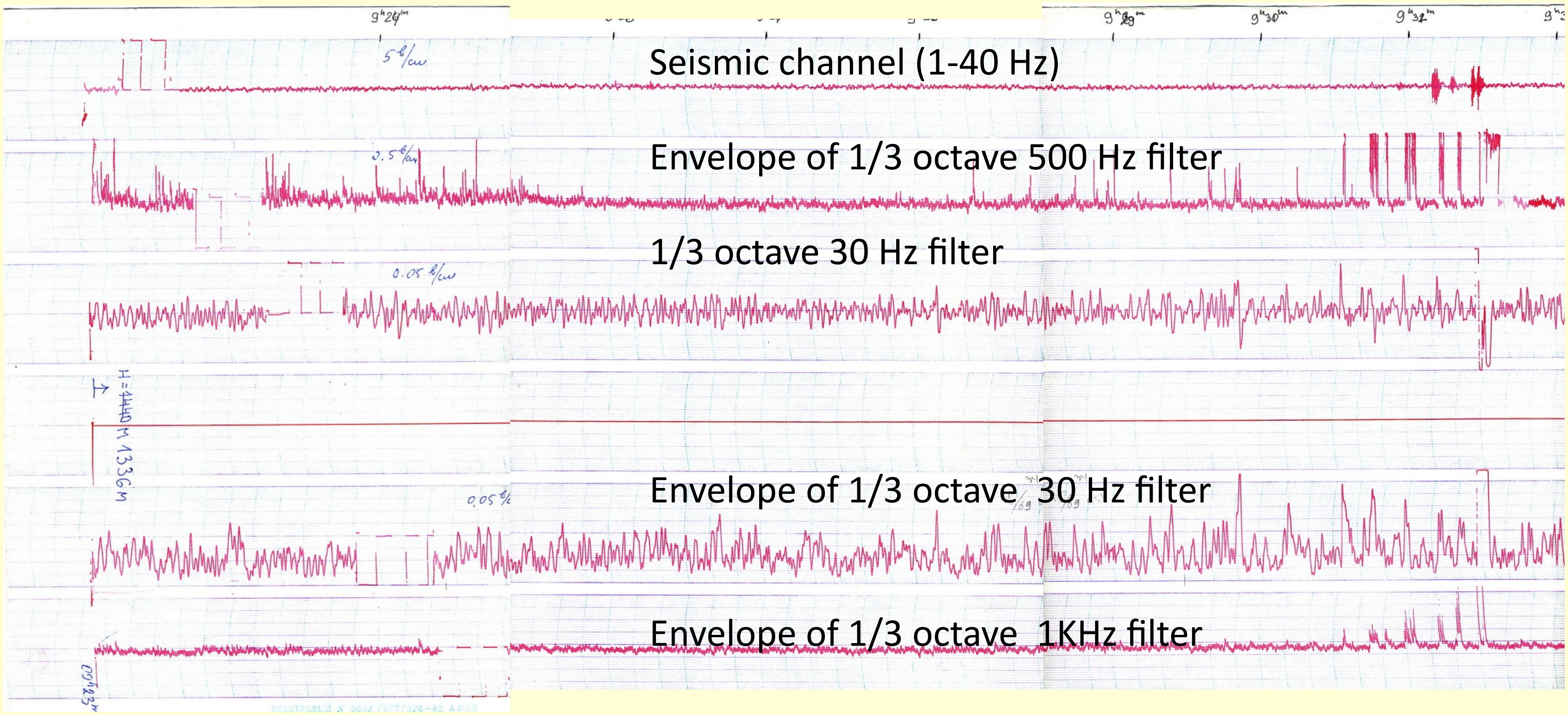


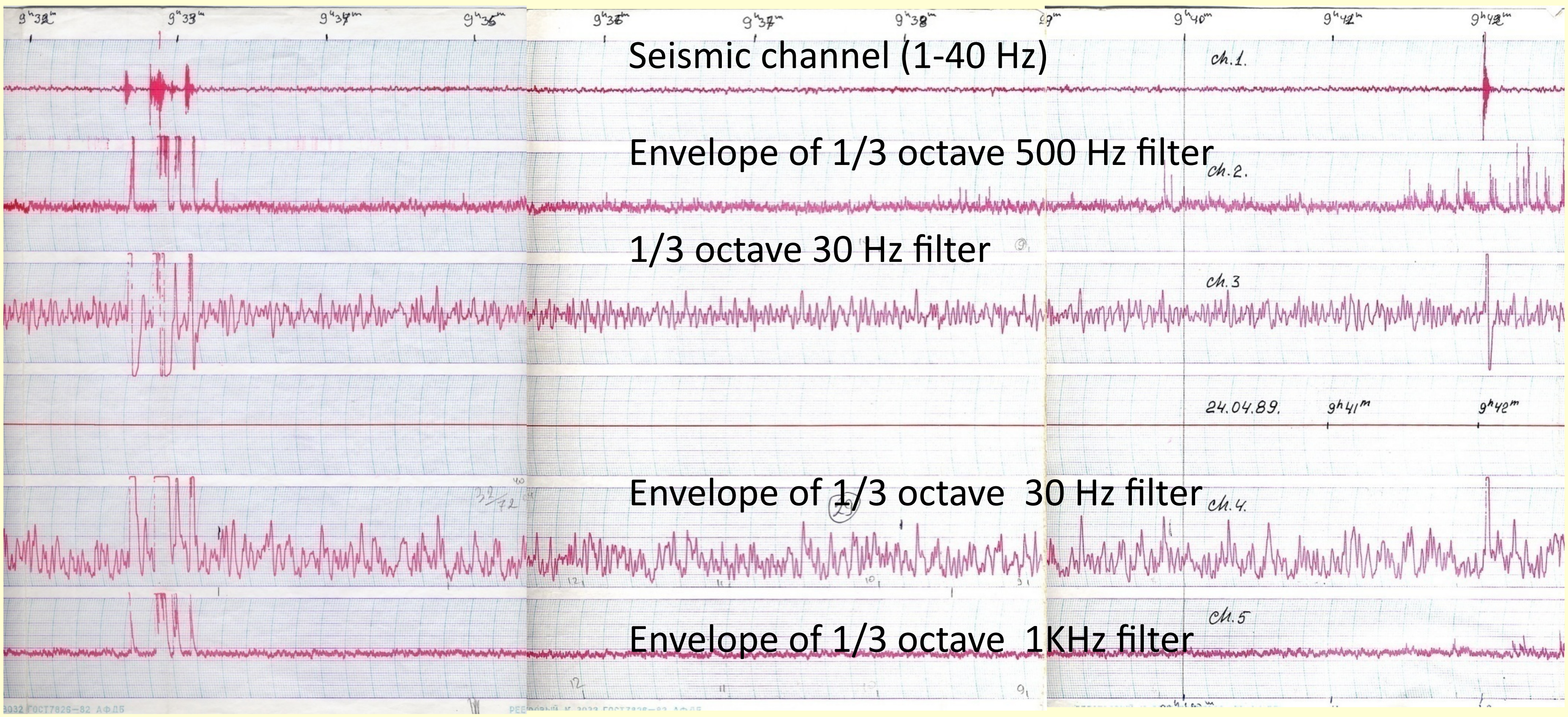
Fig. 9. Schematic diagram of an intrawell magnetoelastic geophone.

Belyakov, 2004, Proceedings RAS

Well 123, Pripyat' depression, Belorussia, 04/24/1989. Depth 1336 m. Z- component



Well 123, Pripyat’ depression, Belorussia, 04/24/1989. Depth 1336 m. Z- component (Cont-d)



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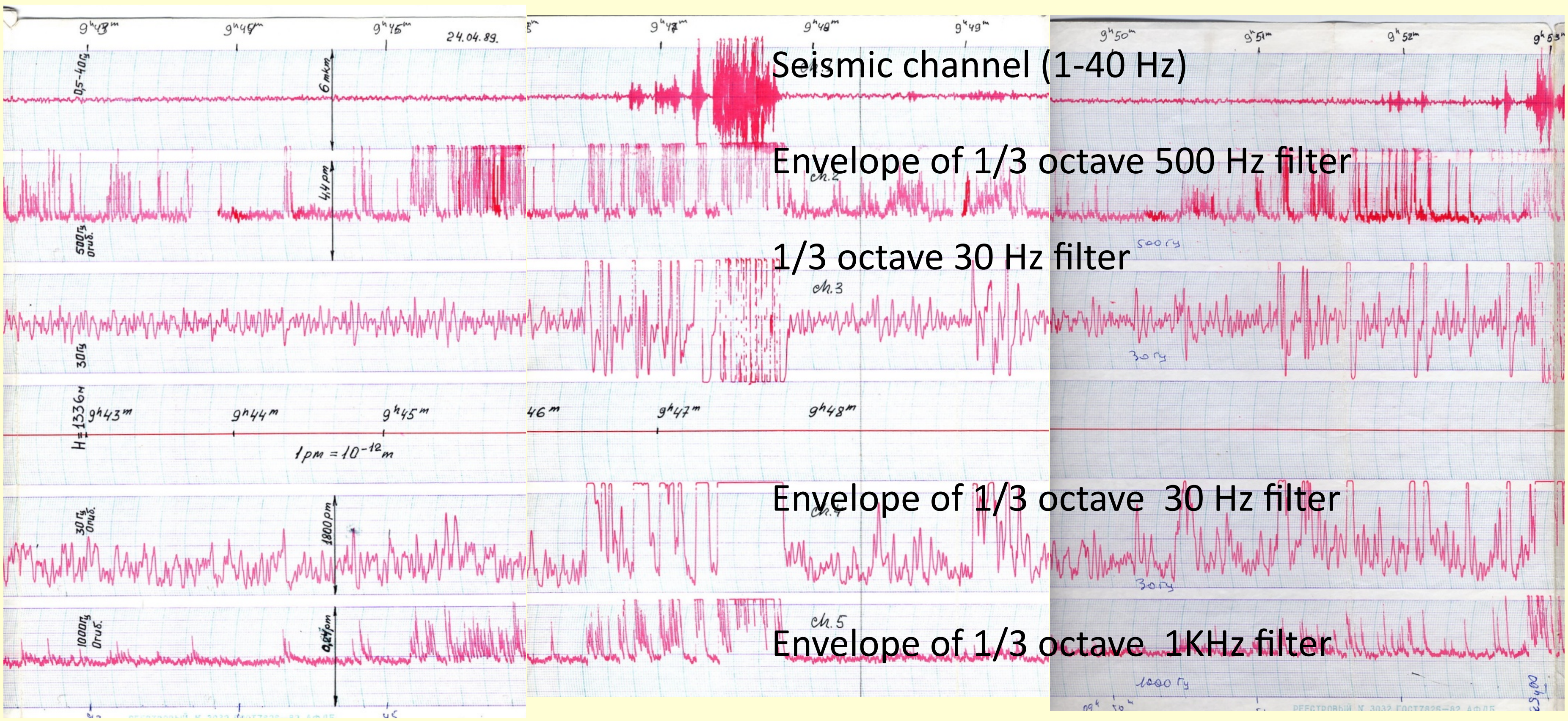
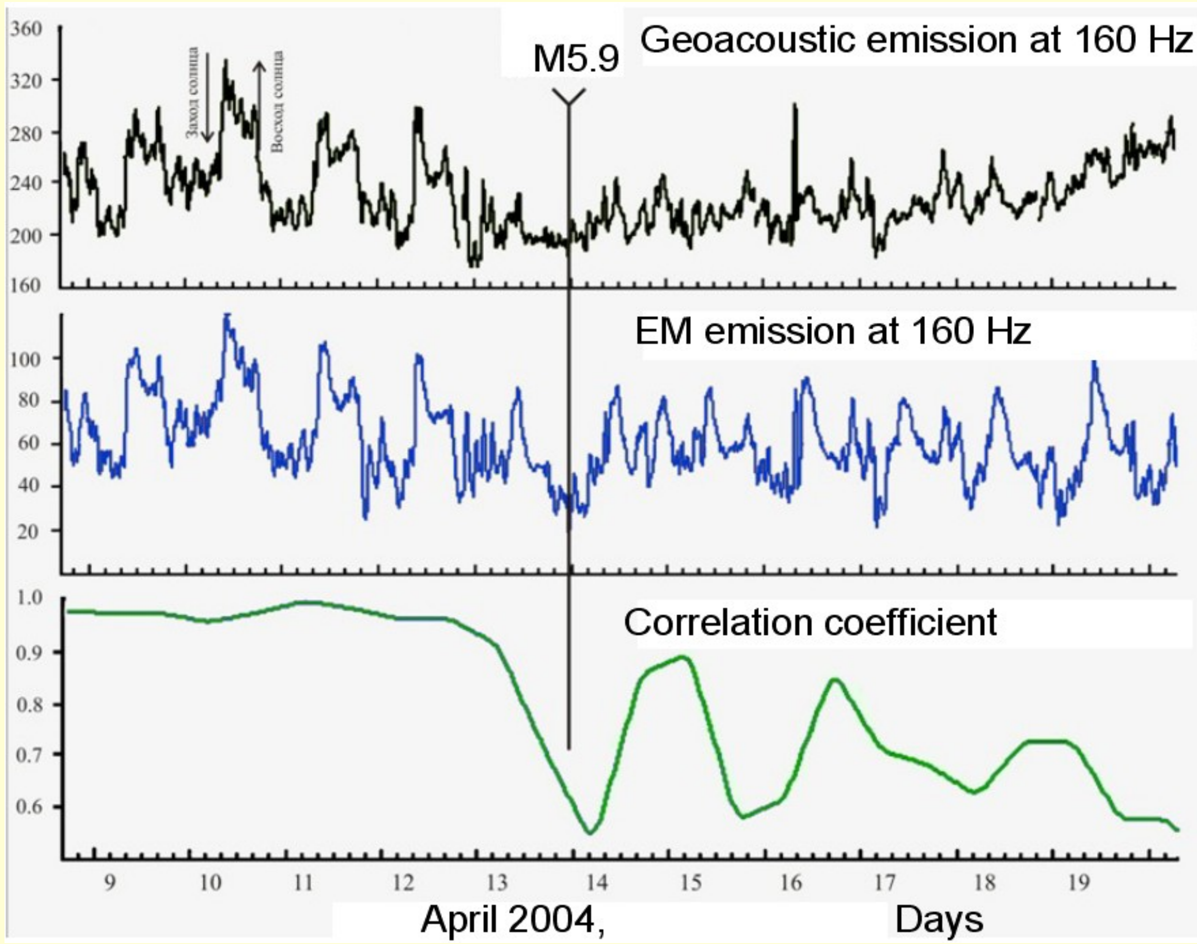


Changes in correlation between geo-acoustic and EM emissions before earthquakes

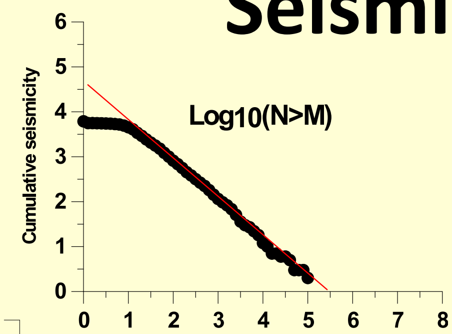


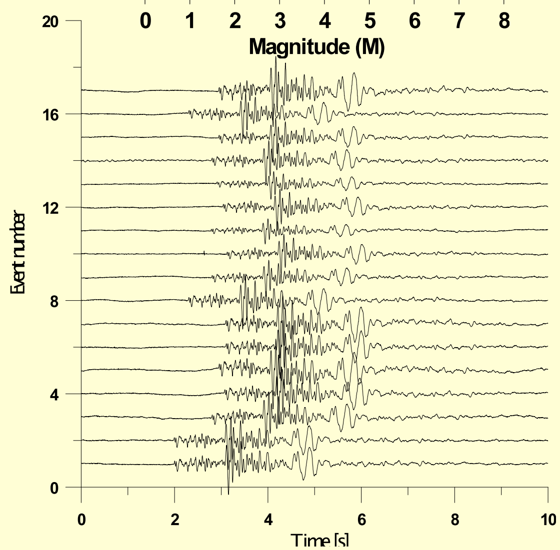
Gavrilov, 2007, Proceedings RAS

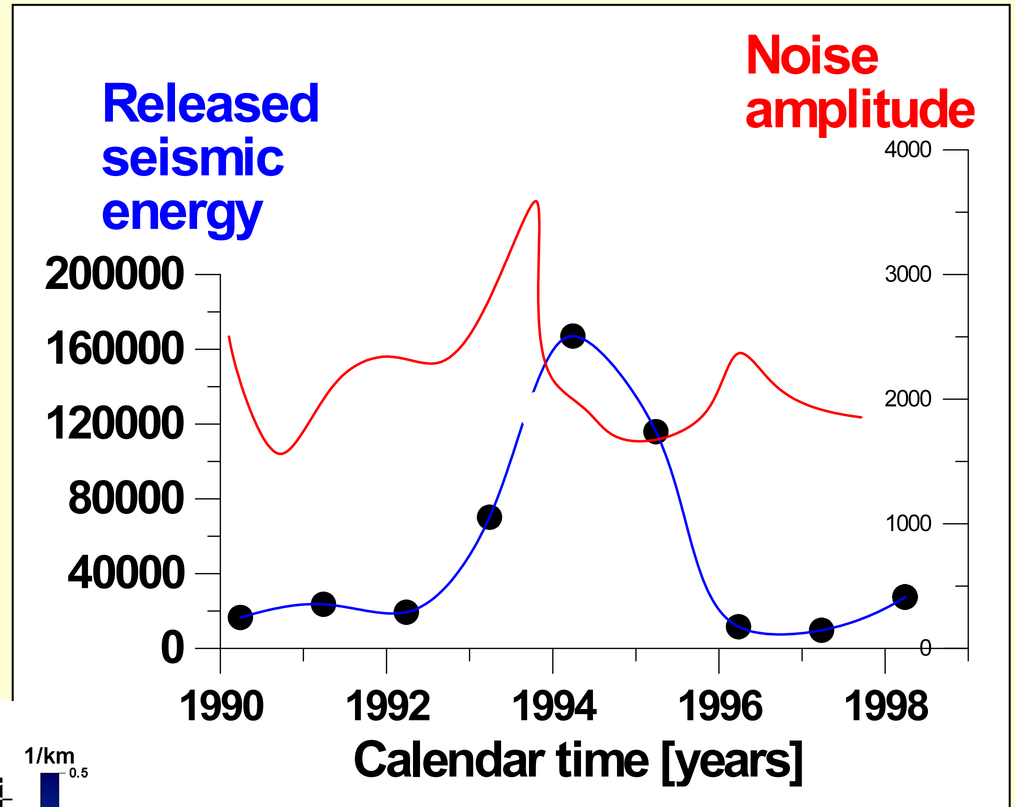
Conclusions

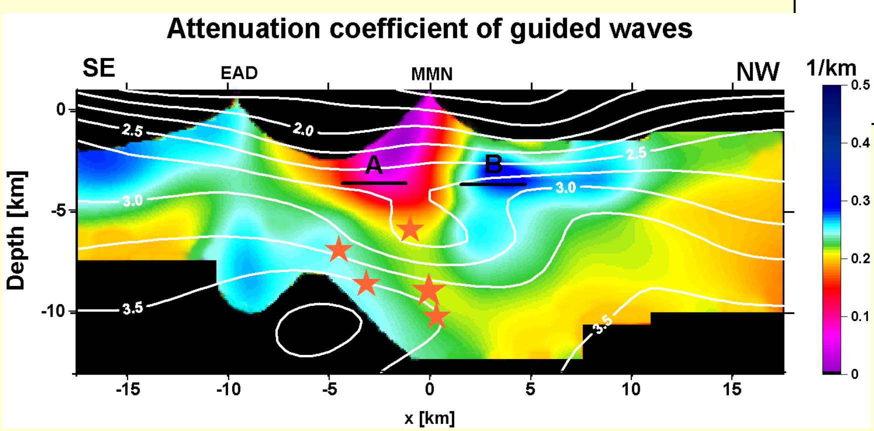
- Forecast *uncertainty* is a price that we pay for a luck of data
- Forecasts based on b-value changes need to be tested against the Gambler's fallacy
- Our goal is earthquake prediction, not forecasting
- Active monitoring is a way to earthquake prediction
- Precursors of different nature need to be combined if they represent the same origin phenomenon
- Earthquake triggering might be an option to solve the short term forecast uncertainty problem

Seismic Noise for 80-100 Hz at MMN









Gives the same precursory effect as the detected events