Forecasting Earthquakes

- Difference between Predictions and Forecasts
- Earlier Efforts in Earthquake Prediction
- Long-term Probability Estimates

Earthquake Predictions versus Forecasts

Predictions have specific times, locations, and magnitudes for future earthquakes.

Forecasts are more long-term estimates of earthquake occurrences. Often they include probability information.

What is needed in an earthquake prediction ?

1. Time window
2. Location window
3. Magnitude window
4. Indication of confidence
5. Chances earthquake occurs anyways as a random event
6. Prediction must be presented in accessible form for later evaluation

Allen, 1996

Optimism in the 1960's and 1970's

'Now, when will earthquake prediction be possible and an efficient Forewarning service available ? ...if we start the project presented here we should be able to answer the question with sufficient certainty within ten years.'

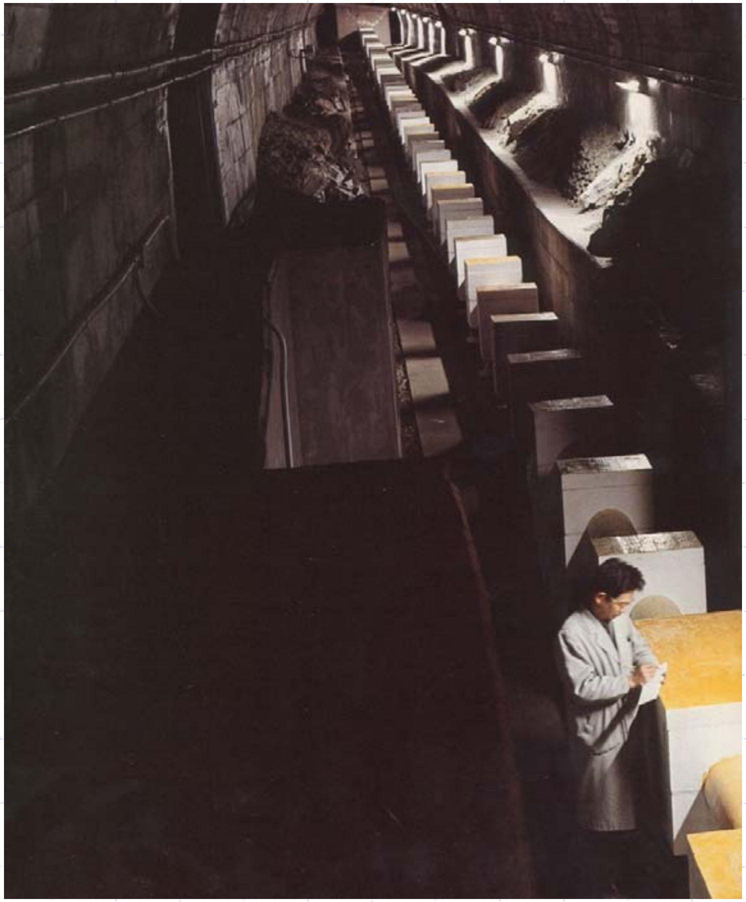
The Japanese Blueprint (Tsuboi et al, 1962)

'Based on an assessment of worldwide observations and findings over the past few years, it is the panel's unanimous opinion that the development of an effective earthquake prediction capability is an achievable goal. ...with appropriate commitment and level of effort, the routine announcement of reliable predictions may be possible within ten years...'

Panel of the US National Research Council (Allen et al., 1976)

Earthquake Prediction Research in the 1970's

Distance Measurements on the San Andreas fault



Matsushiro strainmeter

Reprinted from
31 August 1973, Volume 181, pp. 803-810

SCIENCE

Earthquake Prediction: A Physical Basis

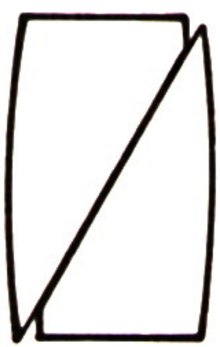
Rock dilatancy and water diffusion may explain a large class of phenomena precursory to earthquakes.

Christopher H. Scholz, Lynn R. Sykes, Yash P. Aggarwal

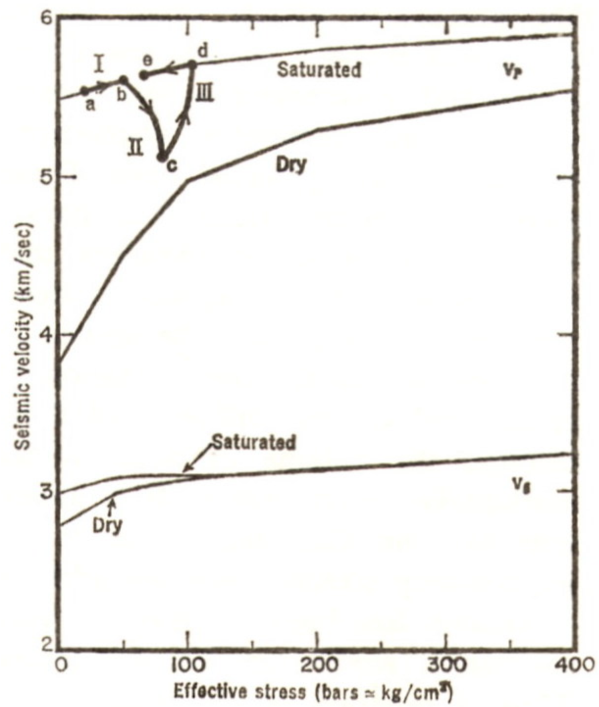
The Dilatancy Model

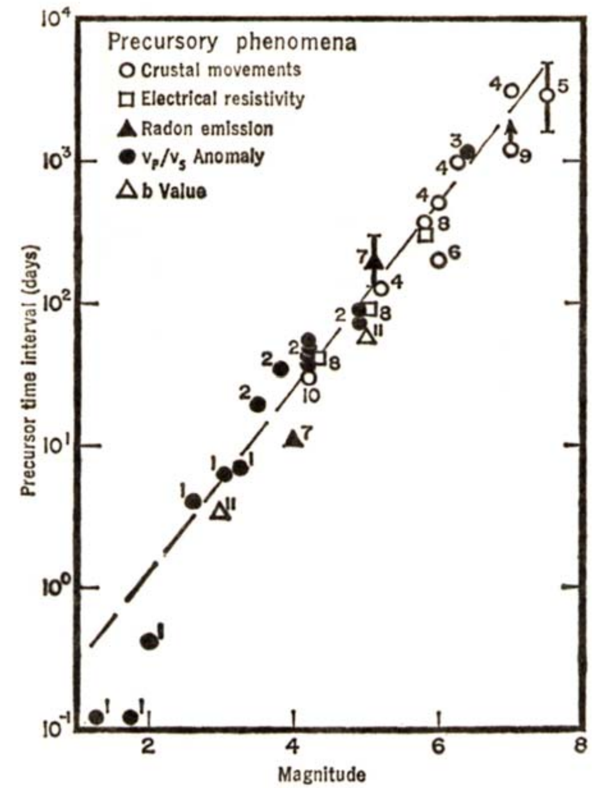
Observations for a number of earthquakes made at Garm, U.S.S.R., and in the New York Adirondacks and observations of the San Fernando earthquake show that, prior to each of these earthquakes, the ratio of seismic velocities v_P/v_S decreased to anomalously low values. In each of these cases, earthquakes occurred shortly after the return of v_P/v_S to its normal value.

Nur (*4*) and Aggarwal *et al.* (*2*) independently put forward a model that would explain this phenomenon. The model is based on laboratory fracture studies which show that rock



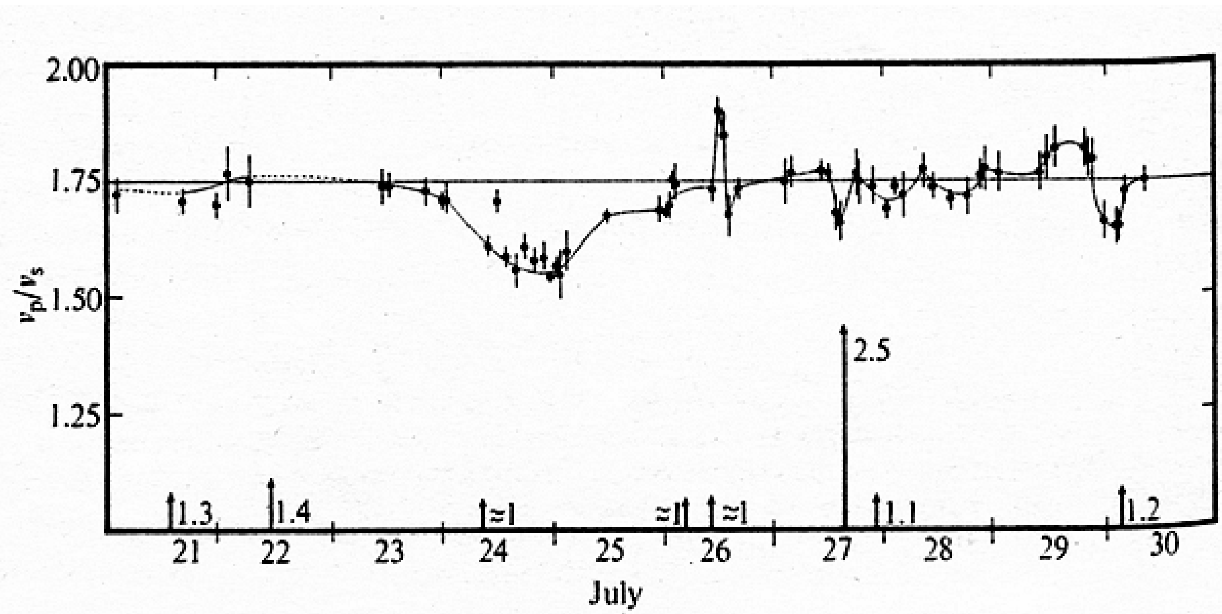
‘Dilatancy’



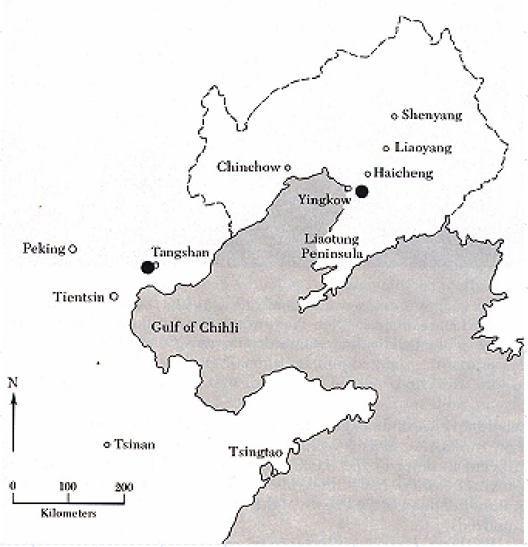


Premonitory Changes in Seismic Velocities and Prediction of Earthquakes

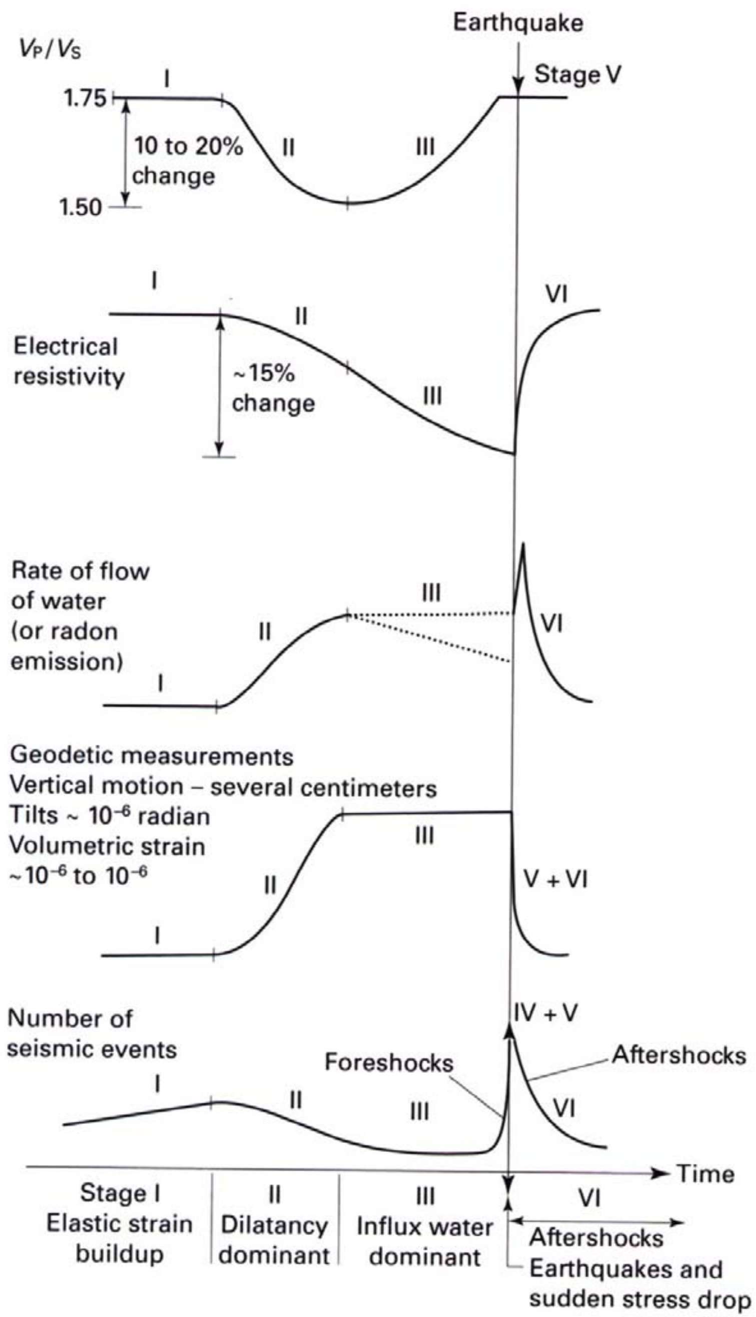
YASH P. AGGARWAL, LYNN R. SYKES, JOHN ARMBRUSTER & MARC L. SBAR
Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964



Prediction of the 1975 Haicheng, China Earthquake (M7.3)



Prediction based on foreshocks and animal behavior saved many lives



Scholz et al., 1973

Short-Term Crustal Deformation Precursor

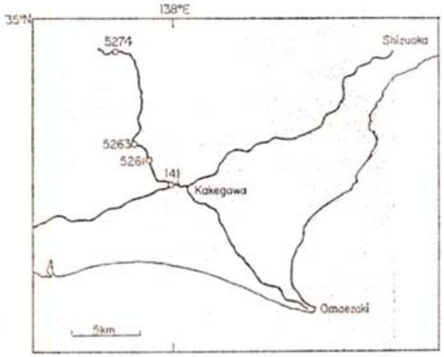
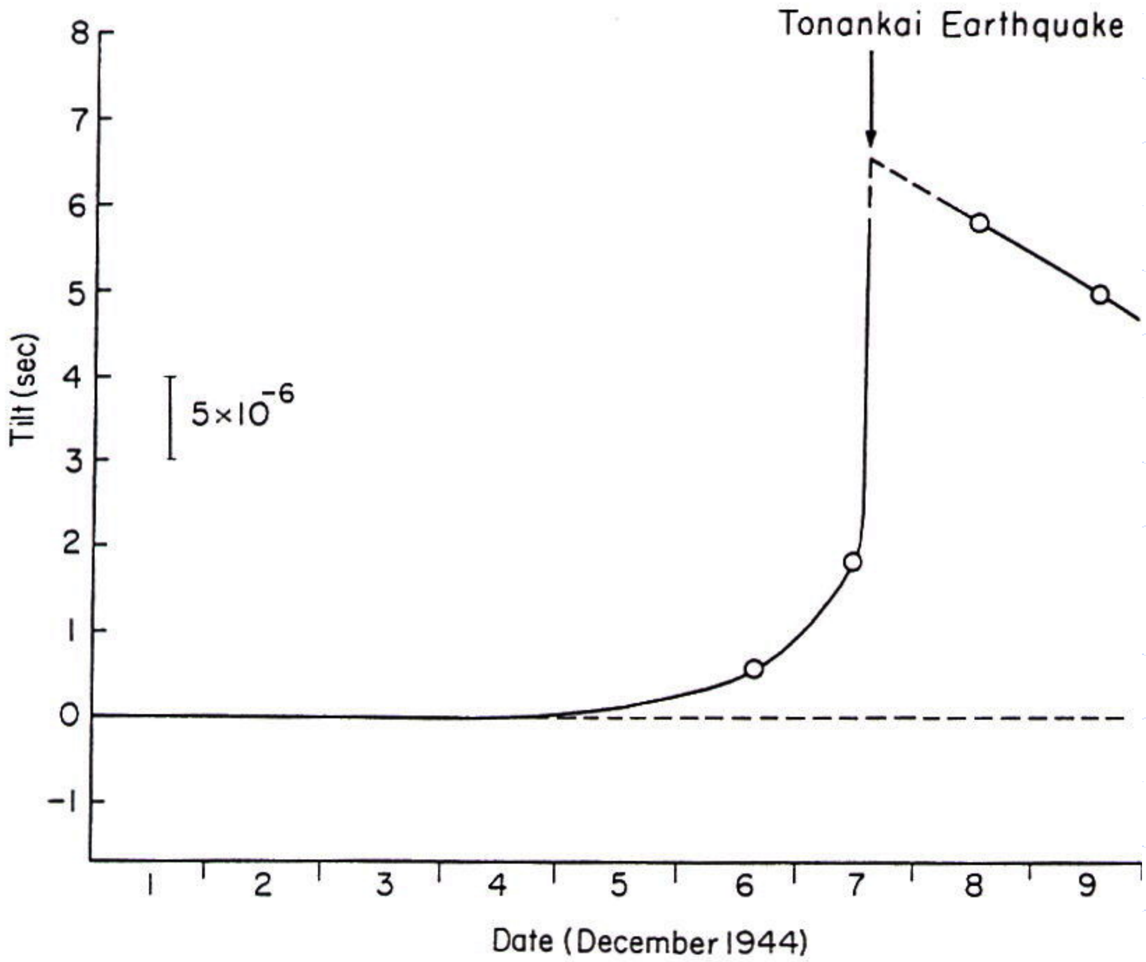
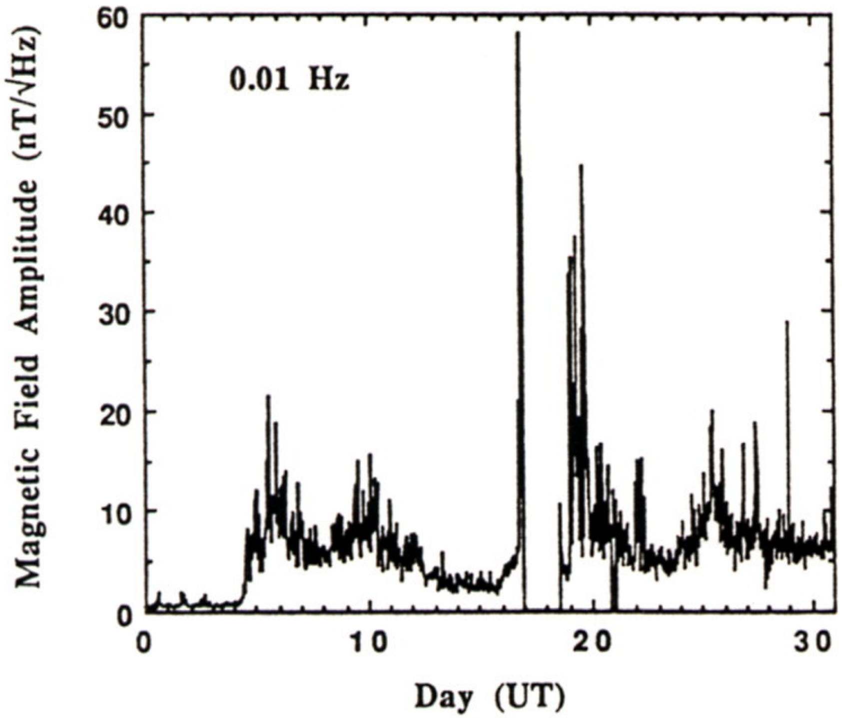


Fig. 1. Leveling routes in the Tokai region surveyed before and after the 1944 Tonankai earthquake.



Mogi, 1984

Short-Term Electromagnetic Precursor

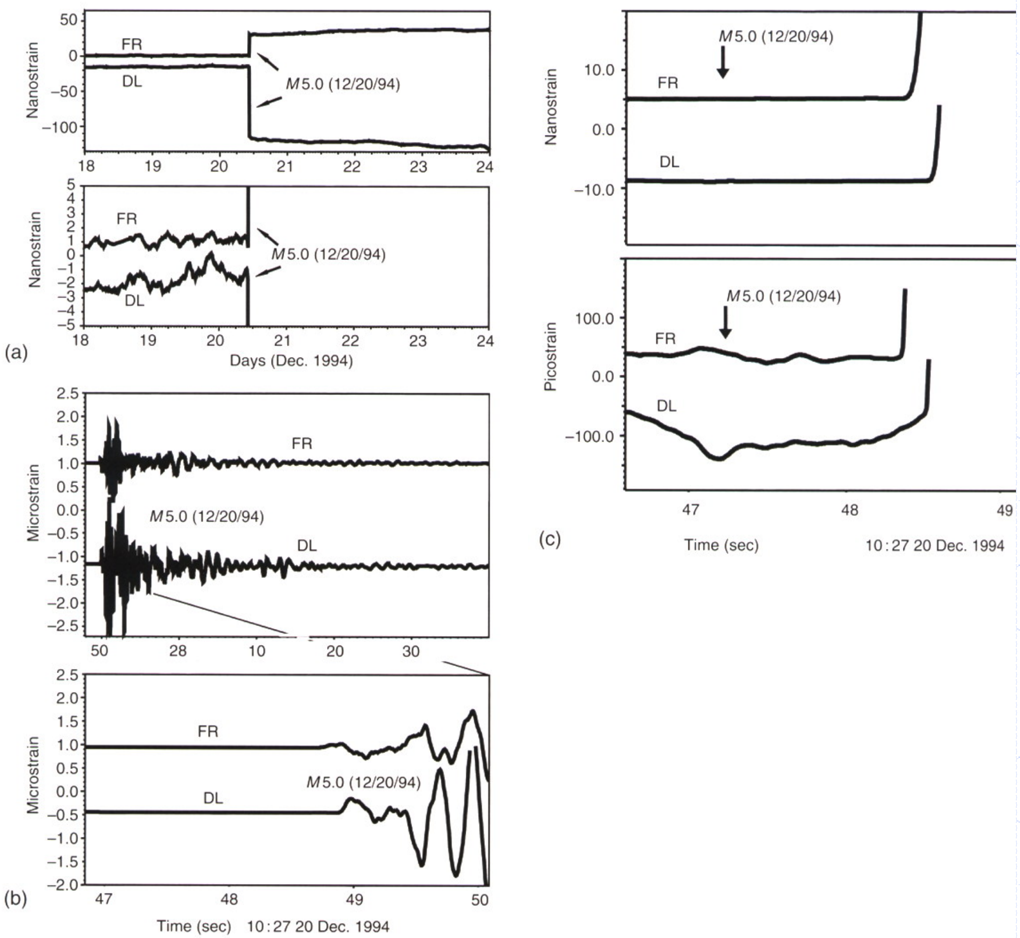


Loma Prieta 1989

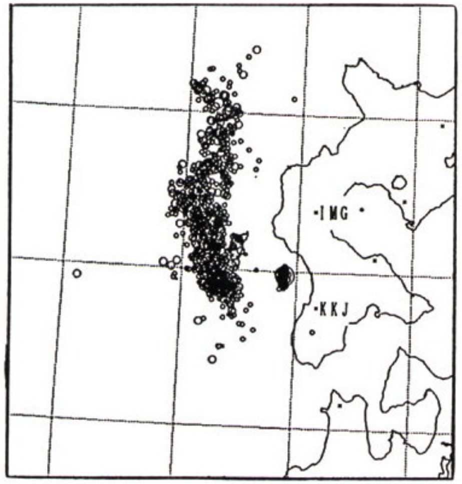
Fig. 3. Variation of the Corralitos 0.01 Hz magnetic field measurements during October 1989. The Loma Prieta earthquake started just after 0004 UT on October 18 and a power failure occurred almost immediately, whereupon the magnetic field measurements went to zero. The large peaks following the earthquake include many aftershocks as well as a magnetic storm that peaked October 20–21. The amplitudes can be converted to nT units (where 1 nT = 1000 pT) by multiplying by $\sqrt{0.00732}$, or 0.0855.

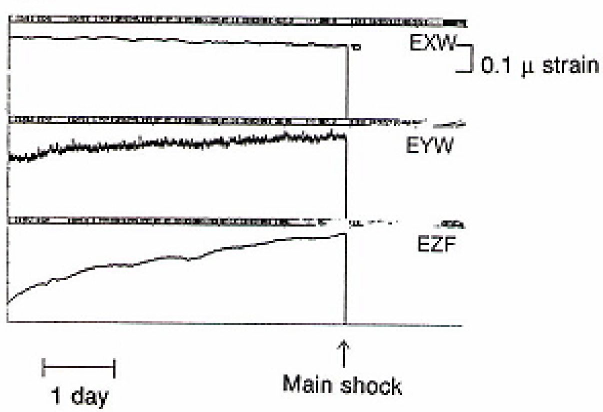
Fraser-Smith, et al., 1990

For short-term precursors, there are currently more ‘negative’ results than ‘positive’ results.



Johnston and Linde, 2002





Kanamori et al., 1996

Notable Successes and Failures

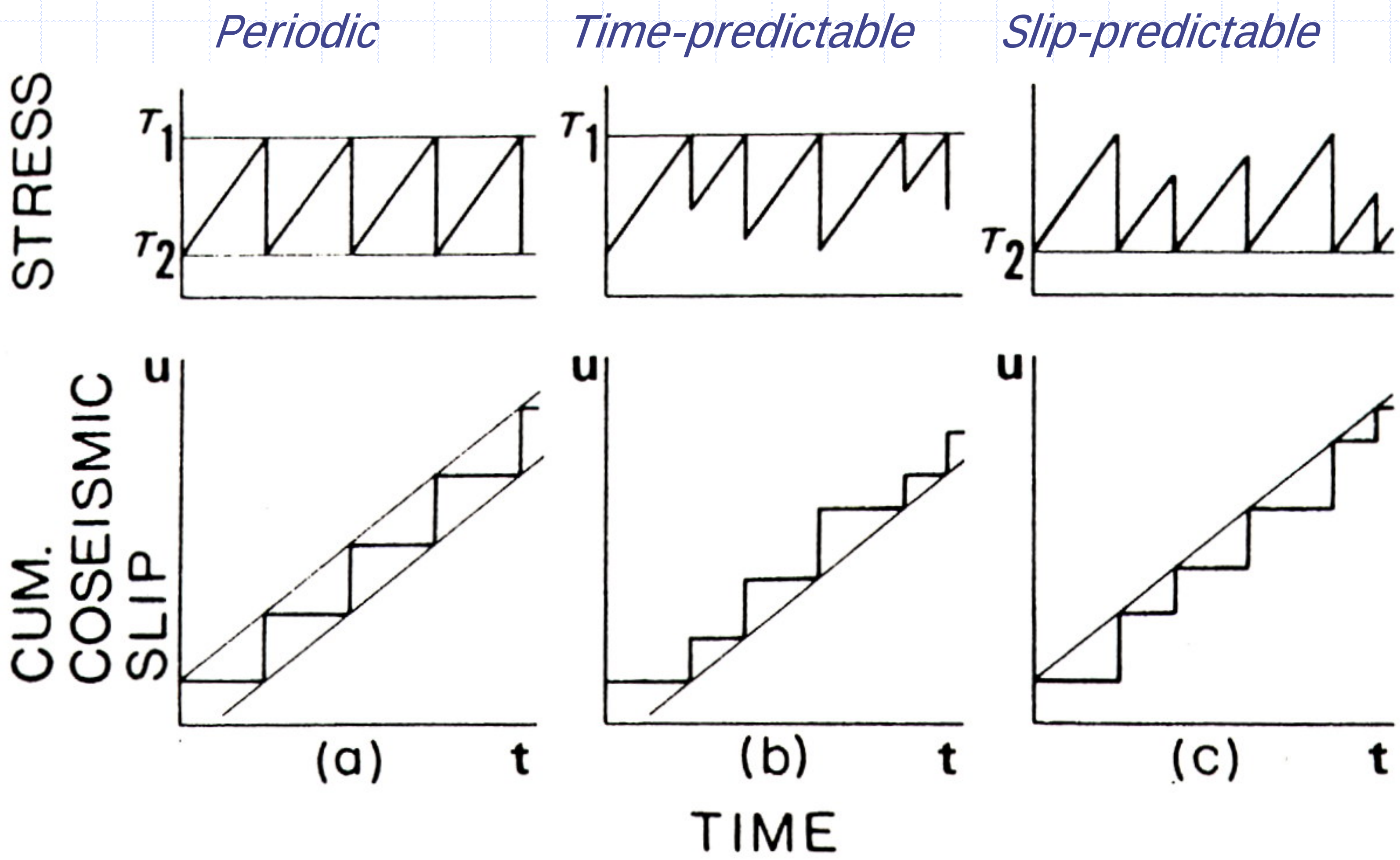
'Precursors'

- 1973 Blue Mountain Lake
- 1975 Haicheng, China
- 1978 Oaxaca, Mexico
- 1978 Izu, Japan

No precursors

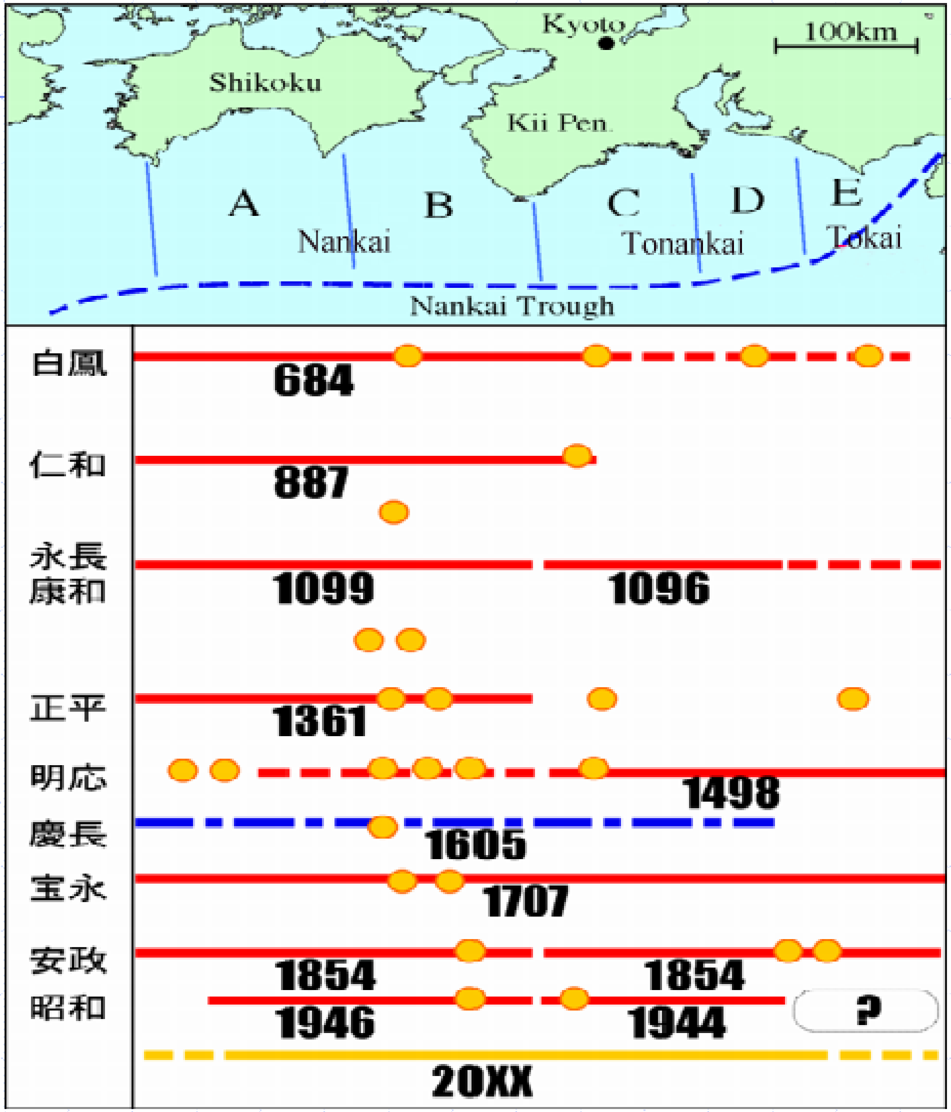
- 1976 Tangshan, China
  (M7.7 650,000 casualties)
- 2003 Tokachi-oki, Japan
- 2004 Parkfield, California

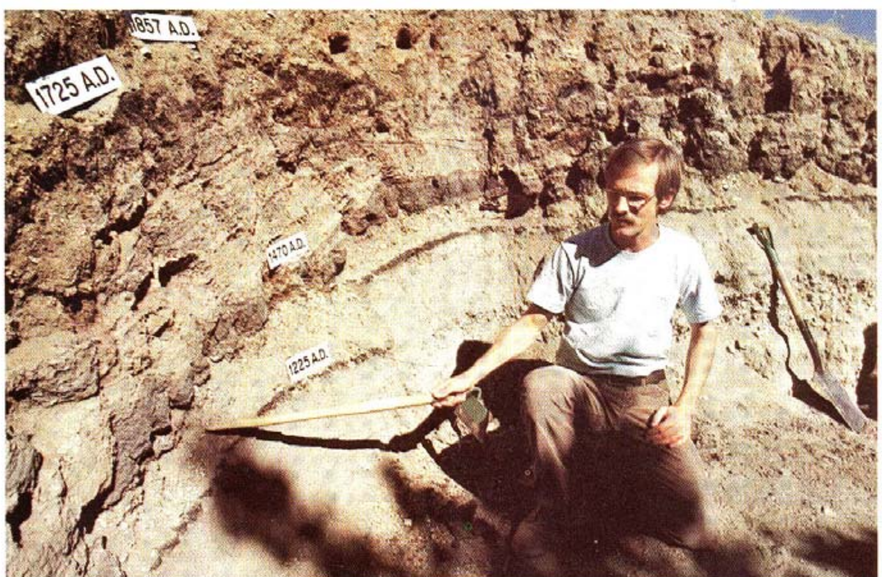
Earthquake Cycle



Shimazaki and Nakata, 1980

History of Nankai Earthquakes





Trenching faults to find geological evidence of past earthquakes

Pallet Creek site on the San Andreas fault

Probability

$$P(T \le t \le T + \Delta T) = \int_T^{T+\Delta T} f(t)\,dt$$

$$P(T \le t \le T + \Delta T | t > T) = \frac{P(T \le t \le T + \Delta T)}{P(t > T)}$$

Conditional Probability

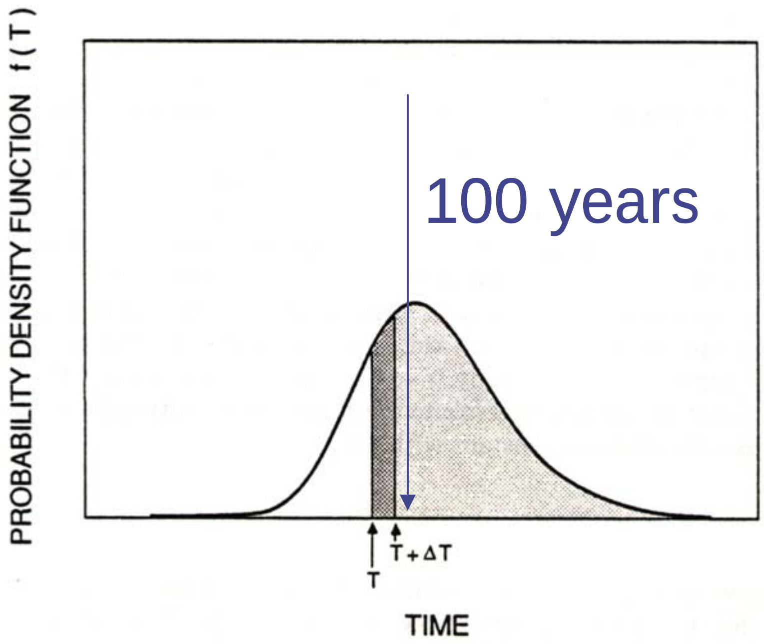
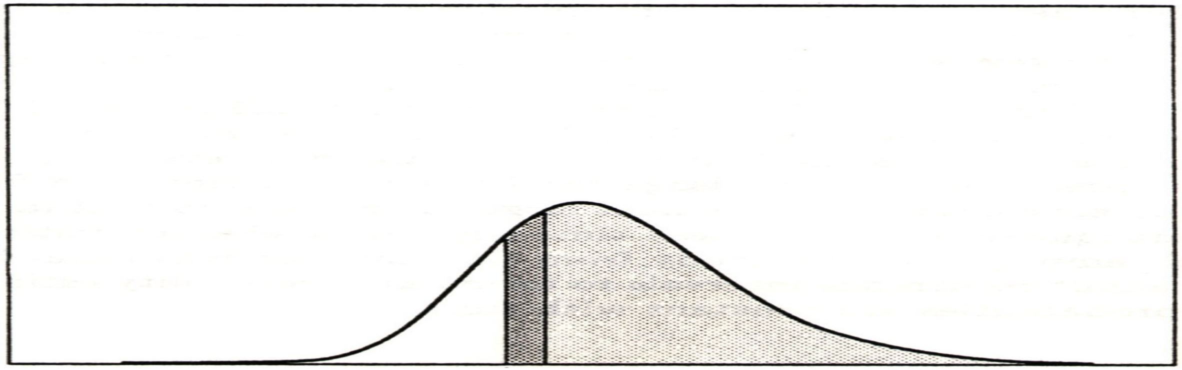


Figure 2. Probability density function for earthquake recurrence. The probability of an earthquake in the interval $(T, T + \Delta T)$ is given by the area of dark shading under the probability density curve. The probability, conditional on the earthquake not having occurred prior to T, is the ratio of the area of dark shading to the sum of the areas with dark and light shading.

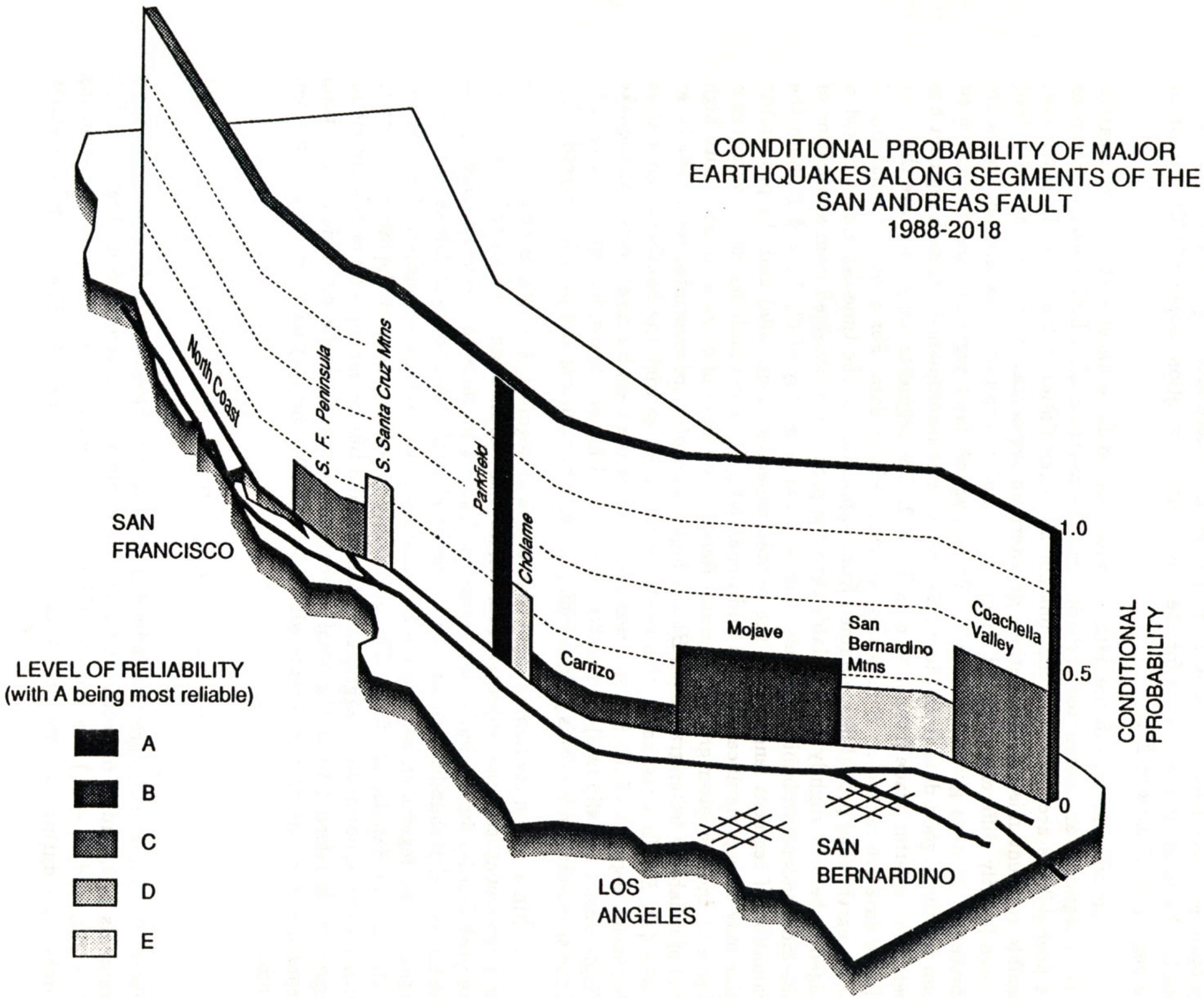
Variability in Repeating Earthquakes

Well defined recurrence interval
(Small variability)



Wide range of recurrence intervals
(Large variability)

Probabilistic Earthquake Forecasting for California



"… the Earthquake Research Committee announced on May 24, 2003, there was 10-20 percent chance of occurrence of a M8-class Off-shore Tokachi Earthquake over the next 10 years starting from January 1, 2003, and a 60 percent chance over the next 30 years"

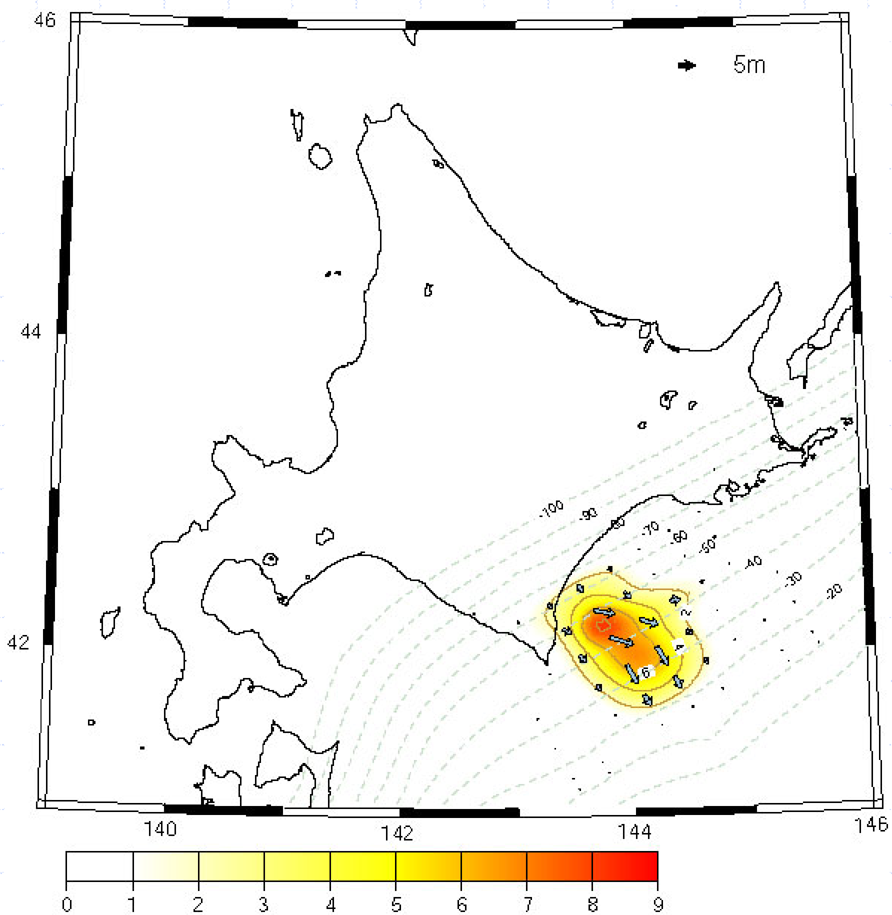


図１：（座標値２）－（座標地１）から得られる地震時変動から推定した地震時すべり分布
※座標値１＝9月2日から9月24日の平均値
※座標値２＝9月25日の本震と最大余震の間の1時間強のデータから推定した座標.

Tokachi-oki earthquake
September 26, 2004
M8.0

Future Outlook

Will we be able to predict earthquakes in the future ?

Long-term:	Probably
Intermediate term:	Maybe
Short-term:	Maybe