A USGS Perspective on Earthquake Prediction Research

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USGS Statutory Role

- USGS Director has the delegated responsibility to issue warnings for an earthquake, volcanic eruption, landslide, or other geologic catastrophe (1974 Disaster Relief Act 41 U.S.C. 5201 et seq).

- USGS Director has the authority "to issue an earthquake prediction or other earthquake advisory" (Sec. 101(e)(2) of P.L.96-472, 1980).

- Statute: The USGS shall conduct research and other activities necessary to characterize and identify earthquake hazards, assess earthquake risks, monitor seismic activity, and improve earthquake predictions.

Times of increased concern

- USGS and government partners have the need to make official statements at times of increased concern.

  - Scientific concern.

  - Public and media attention.

- USGS communicates to gov't partners, media, public, research community.

- Statements must be founded on established and reviewed methods.

- NEPEC reviews calculation methods, provides statements for USGS release.

USGS Research

- Internal and external components, incl. SCEC.

- Research on tectonic processes driving earthquakes; materials and conditions relevant to earthquakes and fault slip; nature of earthquake nucleation process; earthquake statistics.

- Observation, lab experiments, theory, modeling.

- New focus on operational earthquake forecasting.
  - Identifying what we can say now, and in what ways.
  - Research-to-implementation pathway.
  - Integration with network monitoring and reporting operations.

- Opportunities for increased coordination between sponsored (USGS, NSF, NASA, DHS, others).

National Earthquake Prediction Evaluation Council (NEPEC)

- Established by NEHRP legislation in 1980 to advise USGS Director, reviewing claimed earthquake forecasts and predictions.

- Advises on prediction-related lines of research.

- Endorsed Parkfield experiment in 1986.

- Endorsed intermediate-term earthquake forecasts for California in 1988, 1990, 1995.

- Operated until 1995 then re-chartered in 2005.

- Recent topics include Uniform California Earthquake Rupture Forecast, implications of ETS, Central US, and CSEP.

- Well-coordinated with CEPEC.

National Earthquake Prediction Evaluation Council (NEPEC)

- The NEPEC provides advice on whether a prediction has implications for public policy.

  - Would the predicted earthquake cause damage?

  - Has the method been validated?

  - Is the prediction sufficiently specific?

  - Is there new action that should be taken?

  - Is the method promising and worth pursuing?

Episodic Tremor and Slip (ETS)

NEPEC comments on ETS:

- Each of these ETS events represents an added increment of load to the locked part of the megathrust. Understanding their role in promoting, if not triggering, future large earthquakes is an important and intriguing challenge.

- ETS events, being frequent, are of limited value in predicting an imminent large earthquake.

- However, a change in the seeming regular pattern of the ETS events, or the occurrence of a moderate or larger earthquake in association with one, should lead to a significant reconsideration of this view.

Two huge hurdles…

- **First hurdle:** For an earthquake prediction method to gain acceptance within the earthquake science community.

  – Extraordinary claims require extraordinary proof.

  – Statistical analyses and prospective tests are key.

  – Good null hypotheses are hard to beat.

  – Research community is appropriately skeptical.

- **Second hurdle:** For a method to be deemed ready to guide public policy actions.

  – Risks are high, so the level of confidence in method must be commensurately high.

 – Must be demonstrated to work for important quakes.

"Can Earthquakes Be Predicted?"

- Depends on what you mean by "predicted"
- Location
    - Hypocenter
    - Fault
    - Rupture extent
   - Energy centroid
- Magnitude
- Time
- Impacts
- Earthquake rate

"Is it possible to predict the magnitude, location and time of an important earthquake a short time in advance, with confidence sufficient to warrant special actions?"

Earthquake Prediction Is Hard

- We have learned a lot since the 1970's.

- Abundant observations place severe constraints on the nature and size of a plausible pre-seismic process.
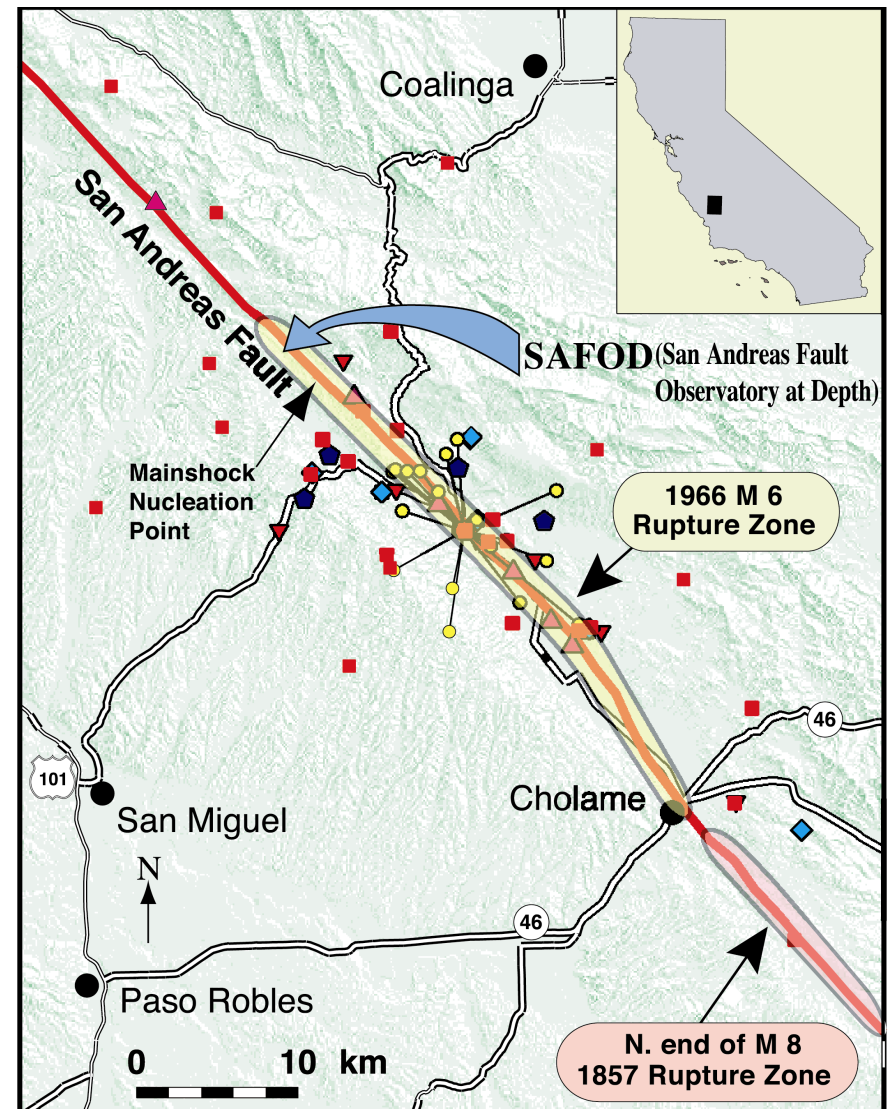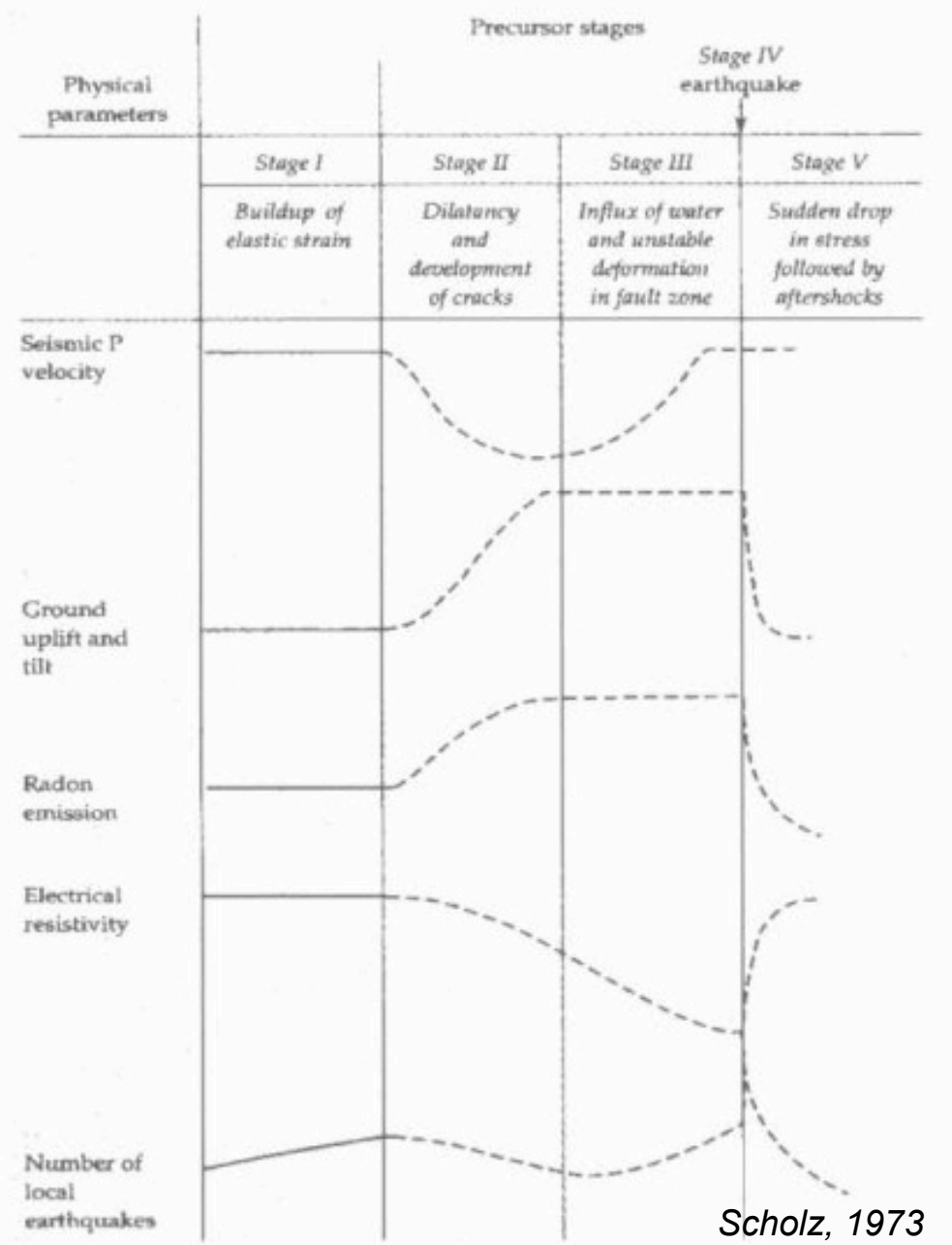
Earthquake Prediction Is Hard
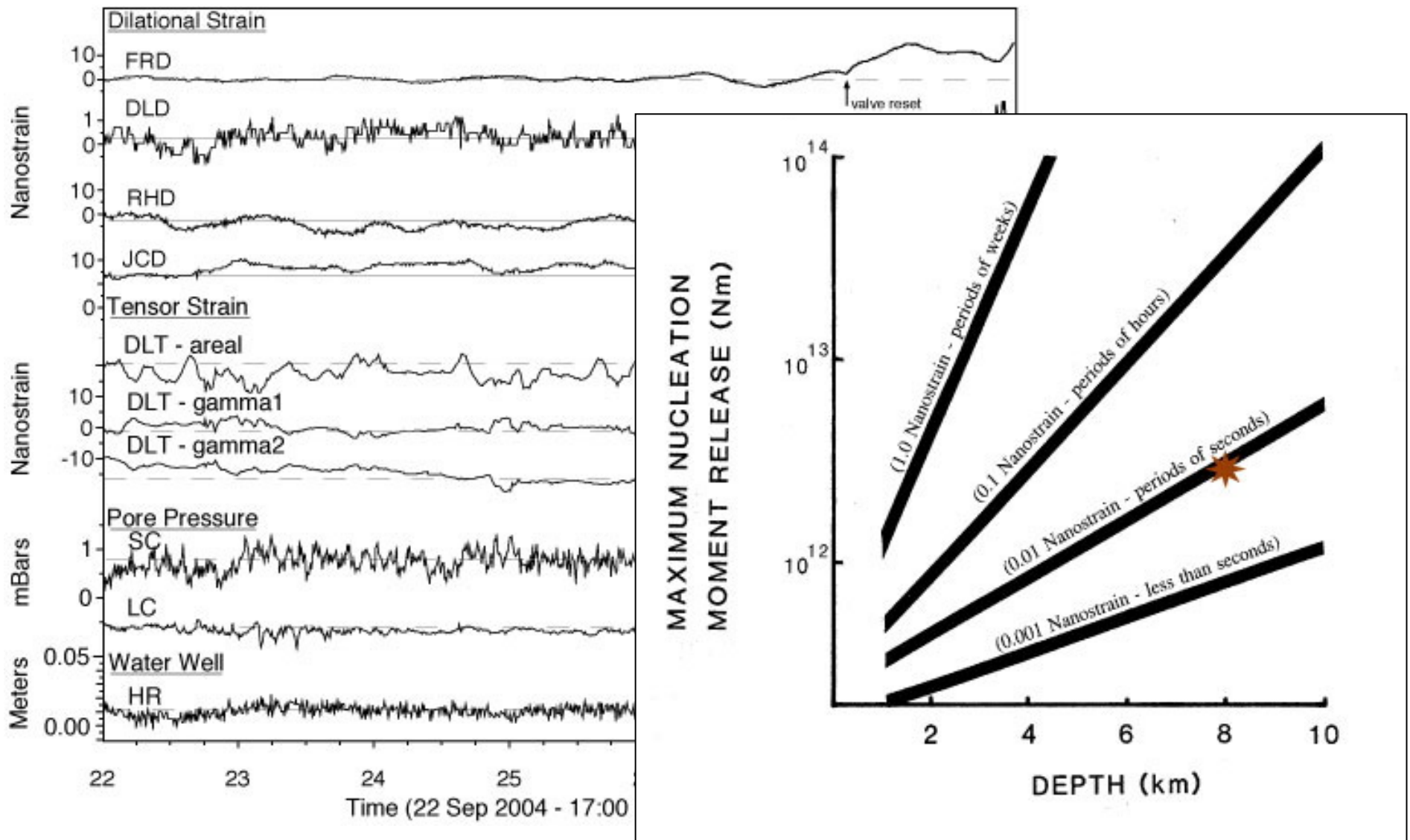
Lessons from Parkfield

- Earthquake magnitude and location were predicted
  - …but hypocenter was not
- Earthquake sequence is periodic
  - …but with sizeable aperiodicity
- Time-predictable model didn't help
- No observable precursors
  - Strain, creep, water, EM
- Nucleation patch or volume is very small
  - Moment of process, if any, was below detection threshold
- Slip and energy release are highly variable

Physical models

– Does the physical model make good sense?

– Is the model plausible (or likely), given observations to date about the earth?

– From the model, what testable hypotheses may be drawn?

– What observations are needed to invalidate the model?

– Consider the signals caused by the mainshock.

Scholz, 1973

Earthquake Prediction Is Hard
(and may be impossible)

- **Sobering hypothesis 1**: There is no pre-seismic process that produces observable or distinguishable signals.

- **Sobering hypothesis 2**: An observable pre-seismic process exists, but is the same for both large and small earthquakes.

Rules of the Road

- Experiments must rigorously adhere to the scientific method.

- Prediction hypotheses must be unambiguous.

- Testing must be rigorous, dispassionate, transparent, reproducible and employ appropriate statistics.

Goal: Disprove Models and Reject Methods.

Collaboratory for the Study of Earthquake Predictability (CSEP) *(see Jordan, SRL 2006)*

- Benefits to participating researchers:

  - Provides clear rules, guidance, sophisticated tools, and stable environment for posing and testing hypotheses.

  - Assures the skeptical scientific community that the prediction tests were fair, rigorous, reproducible and clean.

- Benefits to scientific community:

  - Promotes rigor and adherence to scientific method.

  - Encourages (and demonstrates the need for) patience.

  - May provide community to discard non-sensible models and not-working methods, and focus on promising ones.

  - May aid prediction evaluations by NEPEC and SESAC.

NEPEC on CSEP

- The CSEP is very worthwhile and should lead to progress in evaluating seismicity-based models.

- CSEP demonstrates a proper approach and shows the need for, and benefits of, rigor & patience.

- CSEP is an important research activity that is relevant to your Stafford Act responsibility.

- The usefulness of CSEP would be increased with the capability to evaluate alarm-based predictions for larger earthquake magnitudes.

- USGS should play a part in supporting the CSEP testing center.

Conclusions

- Earthquake prediction is hard, if even possible.

- The hurdles for acceptance and adoption of prediction methods are *appropriately* high.

- The value of mitigation is obvious.
  The value of short-term earthquake prediction, which some find obvious, is more subtle.

- It is imperative that Federal agencies, and publically funded PI's, be rigorous, dispassionate and patient.

- Several Federal agencies support prediction research.

- The earth science community is organizing itself to promote and support rigorous prediction research.