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# Uncertainties in PSHA for Regions of Low-to-Moderate Seismic Potential: The Need for a Structured Approach

**Jon Ake**
**Division of Engineering**
**Office of Research**
**U.S. Nuclear Regulatory Commission**
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# Outline

- Objective of Seismic Hazard Analysis
- Specific Issues in Low-Seismicity Areas
  - Source Characterization
  - Ground Motion Prediction
- Structured Process
- Conclusions

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# Objectives of PSHA

- To produce a defensible, unbiased estimate of the mean seismic hazard at a specified site. The mean seismic hazard is sensitive to uncertainties in the component pieces that together form the hazard model.
- A modern, detailed PSHA must: (1) incorporate all relevant uncertainties, (2) include the range of diverse technical interpretations that are consistent with the available data, (3) consider any site-specific data and knowledge, (4) develop clear, complete documentation, and (5) conduct a detailed peer review process.

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# Source Characterization in Areas of Low-Moderate Seismic Potential

- Where are earthquakes likely to occur? Specify details of source location and geometry.
- What is the rate of occurrence? What is the maximum magnitude to be expected in a certain region or for a specific seismogeneic structure?

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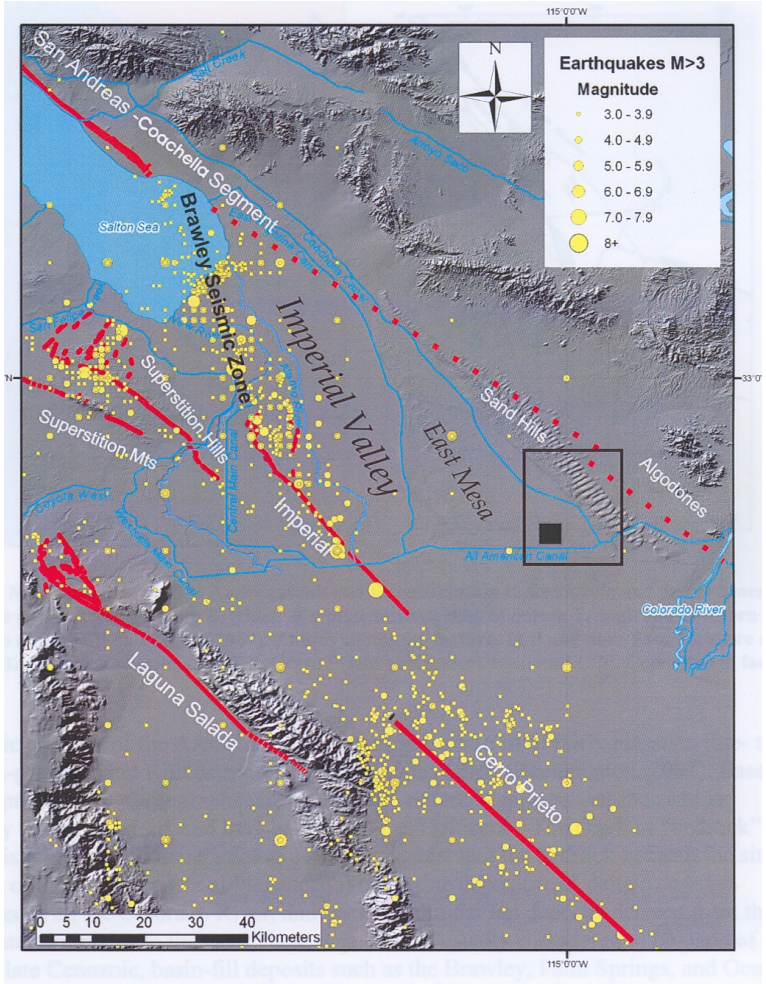
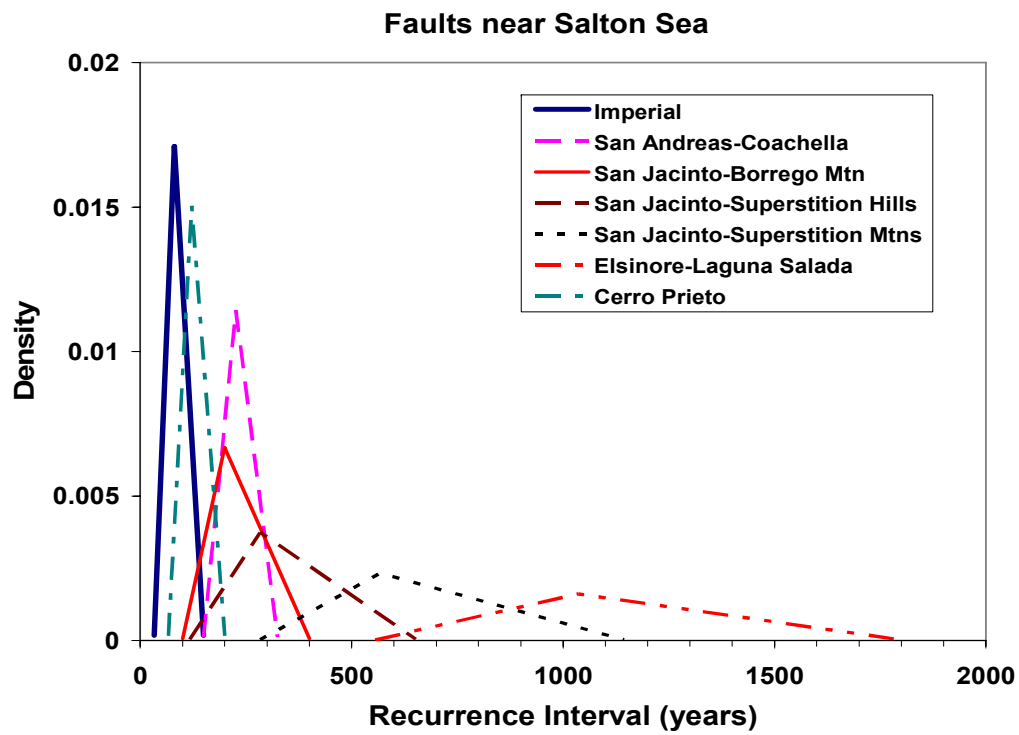
# Source Characterization

- In areas of high seismic activity, the availability of data allows for more confident specification of source location and characteristics.



# Source Characterization

- As recurrence interval decreases (i.e. slip rate increases) the uncertainty in rate and source characteristics also decreases.



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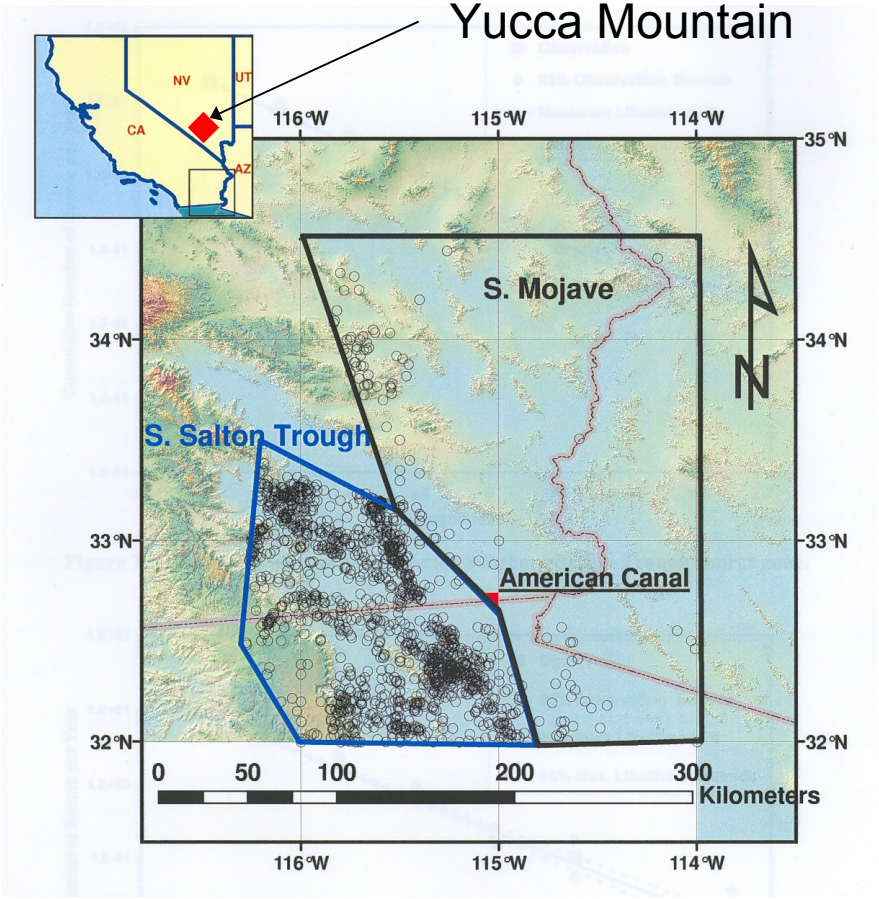
# Source Characterization

- In areas with low rates of activity, source characterization becomes problematic.



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# Maximum Magnitudes, Slip Rates, and Recurrence Intervals for Local Faults-Yucca Mountain PSHA

| Fault | $M_{MAX}$ | Slip Rate (mm/yr) | Recurrence (in 1000's-yrs) |
|---|---|---|---|
| Bare Mountain | 5.8-7.5 | .005-.025 | 20-200 |
| Crater Flat-South | 5.4-7.0 | .002-.02 | 40-180 |
| Crater Flat-North | 5.5-7.0 | .001-.005 | 120-160 |
| Fatigue Wash | 5.5-7.3 | .002-.02 | 50-250 |
| Paintbrush Canyon | 5.9-7.4 | .002-.03 | 20-270 |
| Solitario Canyon | 5.6-7.4 | .002-.04 | 35-180 |
| Stagecoach Road | 5.3-7.1 | .01-.07 | 5-75 |
| Windy Wash | 6.6-7.5 | .01-.027 | 35-100 |

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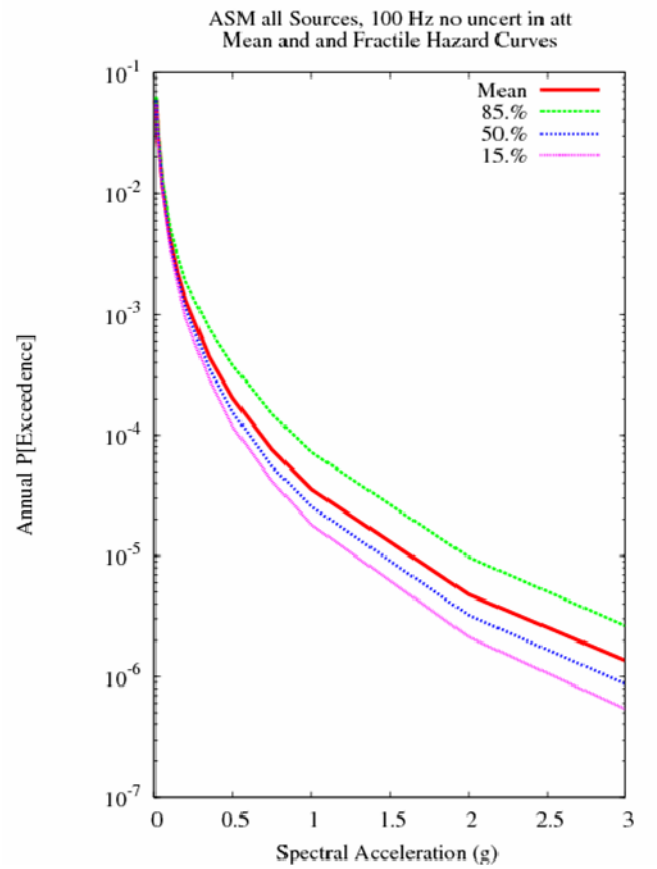
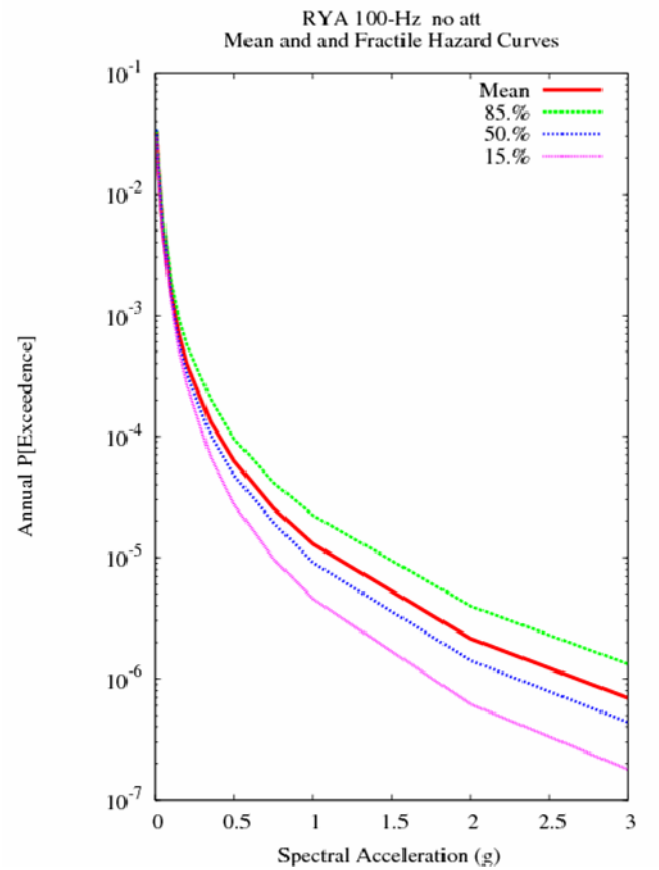
# Uncertainty in Source Characterization: Yucca Mountain PSHA



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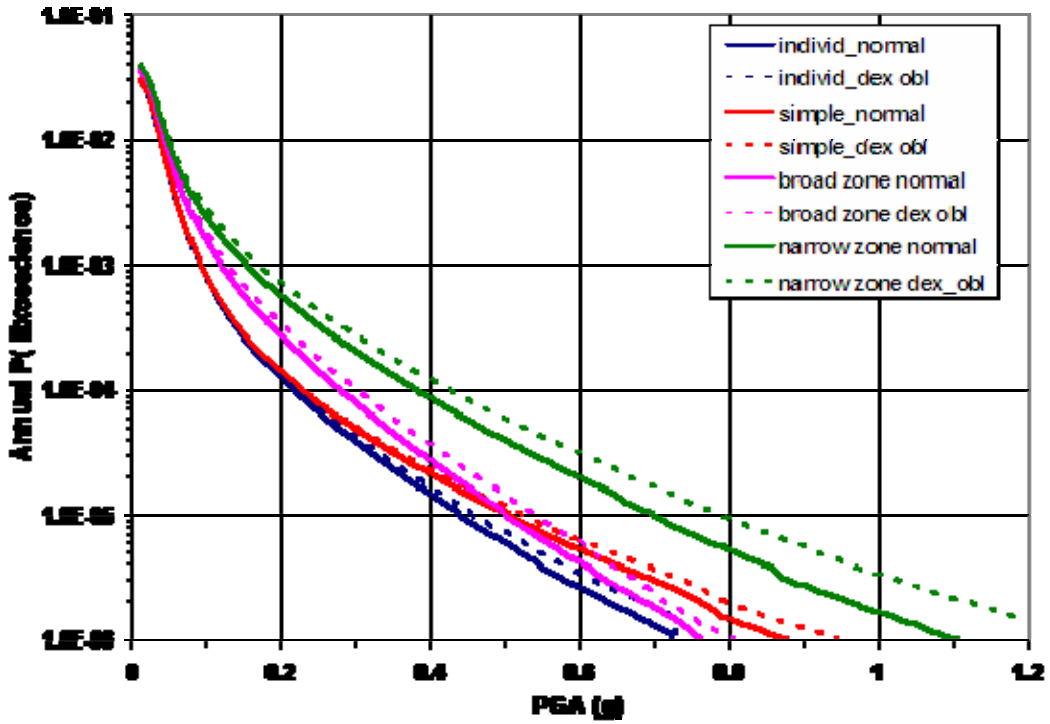
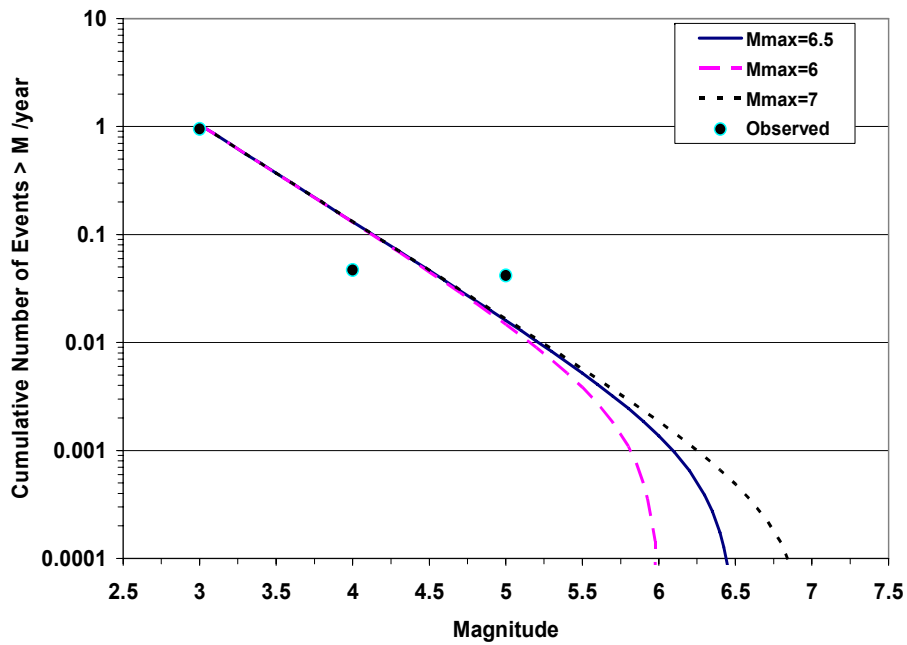
# Source Characterization: Uncertainty Due to Seismotectonic Model



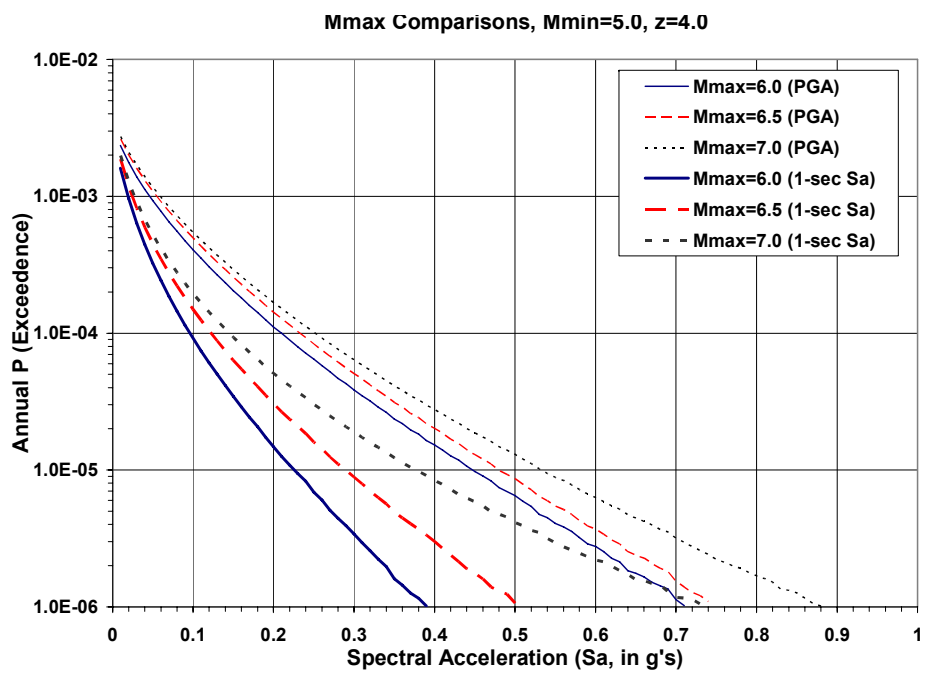
# Source Characterization: Uncertainty in $M_{MAX}$

- For low seismic rate areas, few larger magnitude events in catalog, very few with instrumental magnitudes (mostly intensity based).
- This leads to uncertainty in $M_{MAX}$



# Implication of Uncertainty in $M_{MAX}$

- Alternative $M_{MAX}$ scenarios result in uncertainty in mean hazard curves, the effect is frequency dependent.



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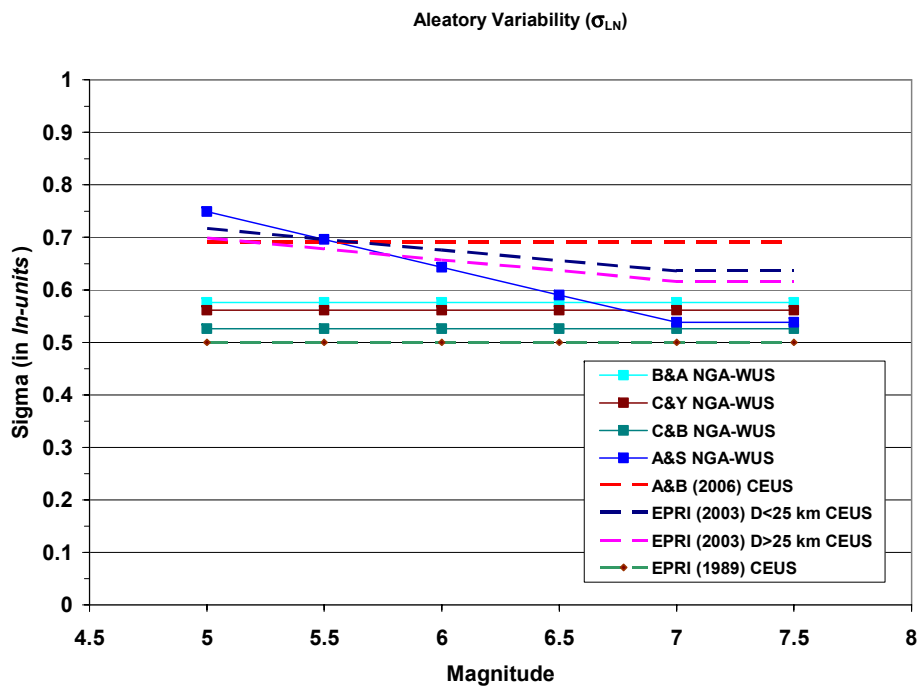
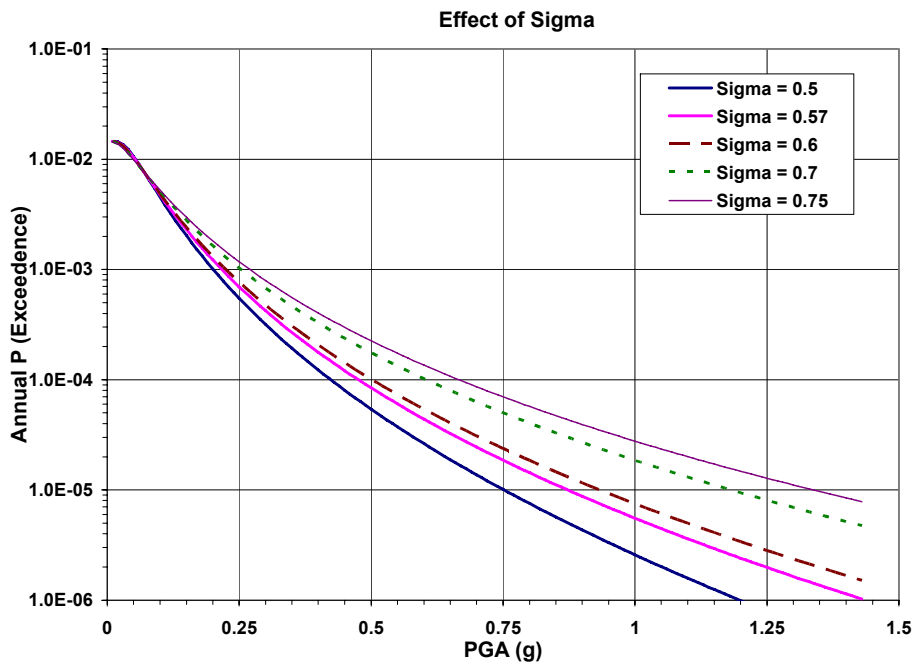
# Uncertainty in Ground Motion Prediction

- Estimating the aleatory variability ($\sigma_{ln}$) is challenging.
- Made more difficult in regions with sparse empirical data, need to combine uncertainties from empirical data and theoretical calculations.



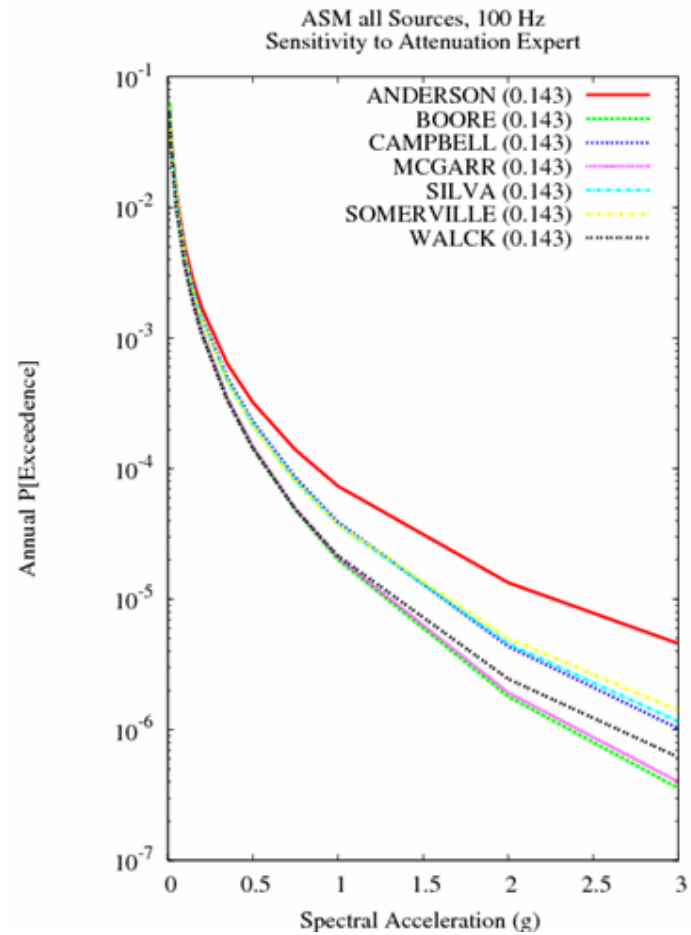
# Implications of Uncertainty in $\sigma_{ln}$

- Effect of uncertainty in $\sigma_{ln}$ can be significant. Results in change in hazard (for a fixed ground motion) as well as the slope of the hazard curve.



# Uncertainty in Ground Motion Prediction

- Significant epistemic uncertainties exist in the prediction of ground motions for regions of low-to-moderate seismic activity
- Often the dominant source of uncertainty in hazard



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# Structured PSHA: Senior Seismic Hazard Analysis Committee (SSHAC) Report

- The seismic hazard (the annual frequency of exceeding a specified ground motion level) is a derived product that contains significant uncertainty in results due to the uncertainties inherent in the data and models used. ***The limited information available can be legitimately interpreted differently by well qualified experts.***
- This observation led to a study in the 1990's to evaluate the conduct of PSHAs (SSHAC).

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# Structured PSHA: Conclusions from the SSHAC Report

- The differences between PSHA studies are often related to differences in initial assumptions and in the information gathering, dissemination and assessment processes. ***The way in which a PSHA is structured is at least as critical to its success as the technical details.***
- The report defined a hierarchy for studies based on the technical complexity and political sensitivity of the major issues. The most detailed studies (Level 3 and Level 4) utilize an entity (either as an individual or as a group) termed the ***Technical Integrator (TI) or Technical Facilitor/Integrator (TFI)*** to perform the integration and oversight in the study.

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# Current NRC Research Project to Augment the SSHAC Report, Preliminary Results:

- Acknowledge the distinction between the SSHAC process of expert assessment (i.e., interaction and learning) and formal expert elicitation.
- The attributes of a good evaluator should be identified and considered in the selection of experts.
- Following a structured process can properly quantify sources of uncertainty and represent the broader community position enhancing regulatory stability, public defensibility, and longevity. Is it possible to reap some of those benefits with a more focused and less-resource intensive approach?
- Additional guidance needs to be developed for the updating of major PSHA studies (How and Why).

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# Project to Augment the SSHAC Report, Preliminary Results:

- A composite model that captures the essence of all significant uncertainties, but is computationally more manageable, is needed for many subsequent applications (such as sensitivity studies).
- Active, aggressive participatory peer reviews are effective means of dealing with difficult process and technical issues.
- The sponsors of a major hazard study need to have sufficient technical expertise to understand and clearly specify the desired products, to understand the process being followed, and to interpret the results. They must become co-owners of the study, not just the underwriters.

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# Conclusions-PSHA:

- Objective: to provide an ***unbiased*** representation of the informed scientific community's view of the important input components (both data and models) and the site-specific hazard. The PSHA must appropriately separate and account for the various uncertainties.
- ***The goal is not to search for artificial consensus, but to search for a defensible representation of the range of technically supportable interpretations of the informed technical community***, and an assessment of the credibility of the differing hypotheses across that range.
- The likelihood of achieving this goal and defending the results is improved by formally involving a large number of the members of the community in a major study.

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# Conclusions-PSHA: cont'd

- A study that only performs a rigorous multi-expert assessment of key or critical portions of the seismic hazard models and/or inputs, with strong peer review may achieve a high-quality, defensible product. ***There is a tradeoff between the effectiveness of a high-level study with the efficiency of a reduced scope study.***
- ***The participation and review by well-informed project sponsors is very important and contributes to overall success of a major project.*** If actively involved, the project sponsors better understand the conduct of the study, minimize the likelihood of "surprises" in the results, and enhance a sense of ownership in the process and product.

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# Conclusions: PSHA in Regions of Low Seismic Activity

- In regions of low-to-moderate seismic activity, the need for a disciplined and structured approach is especially important, ***the lack of data will lead to fewer constraints on plausible interpretations***. This range of interpretations represents an epistemic uncertainty that needs to be reflected in the final hazard estimates.
- Seismotectonic models, activity rates, $M_{MAX}$, and both epistemic uncertainty and aleatory variability in ground motion prediction models are important sources of uncertainty in these areas.

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# BACKGROUND

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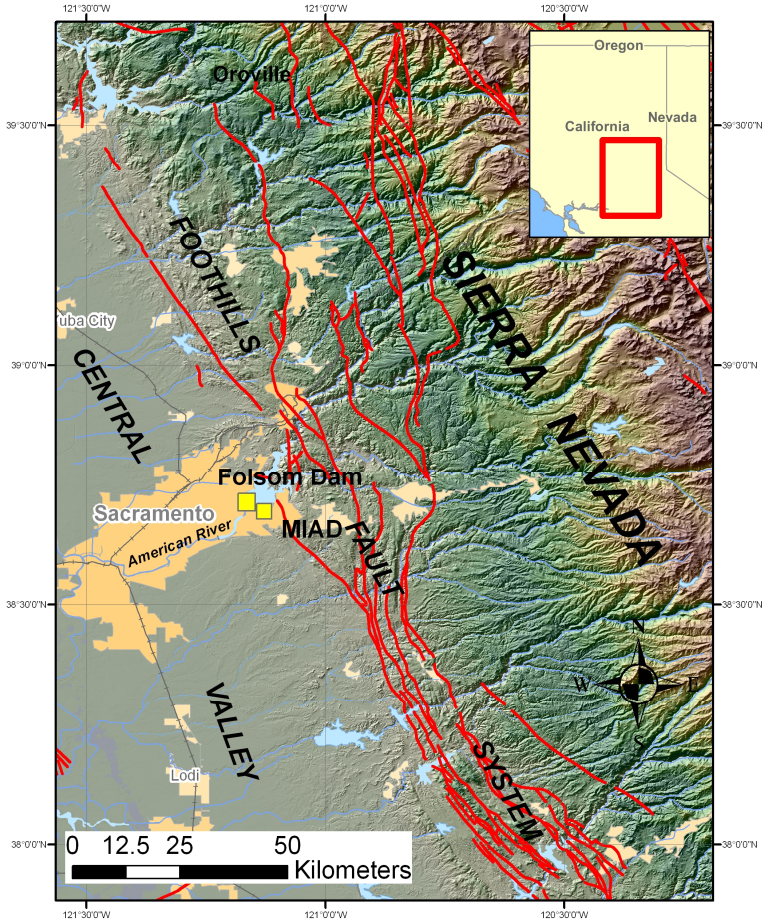
# Seismotectonic Model

- Uncertainty in appropriate geometry of sources- short individual faults, longer simplified faults, broad or narrow zone of deformation
- Sense of slip: normal or dextral-oblique (impacts slip rate estimate)



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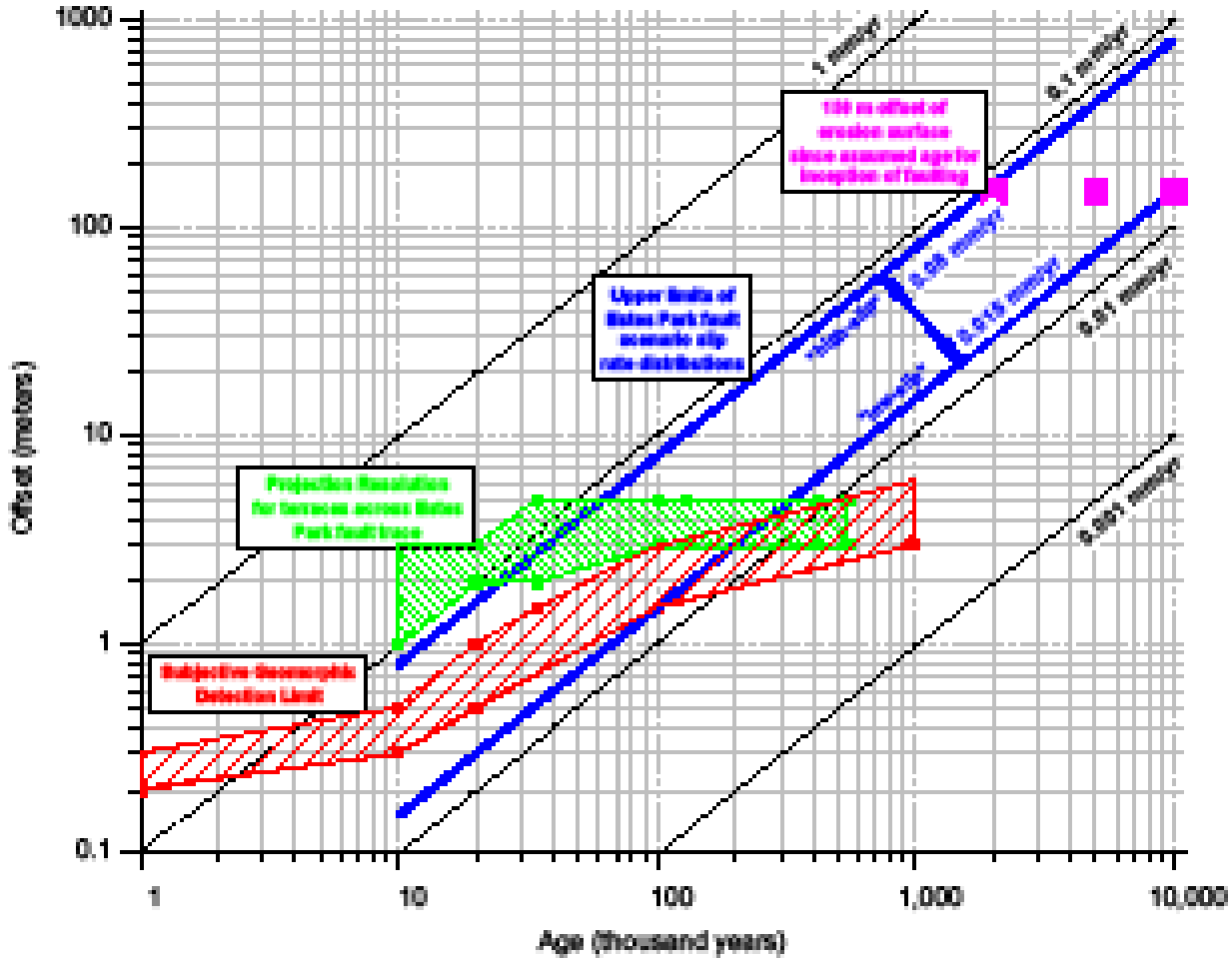
# Geomorphic Resolution in Low Rate Areas