Precarious Rocks, Shattered Rock, and Seismic Hazard at Low Probabilities for Yucca Mountain

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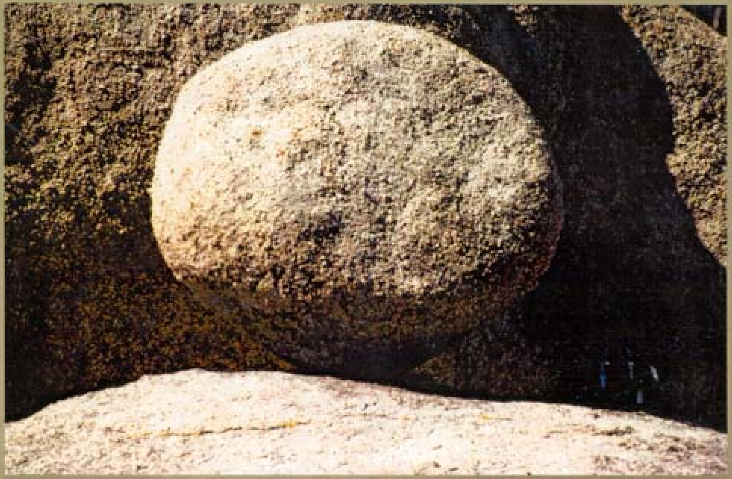

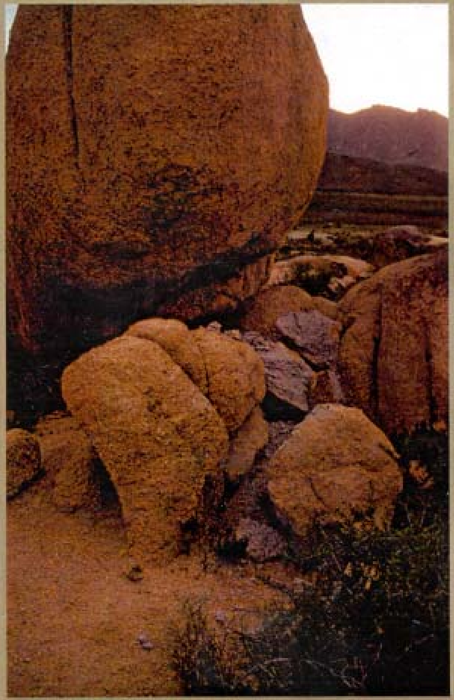

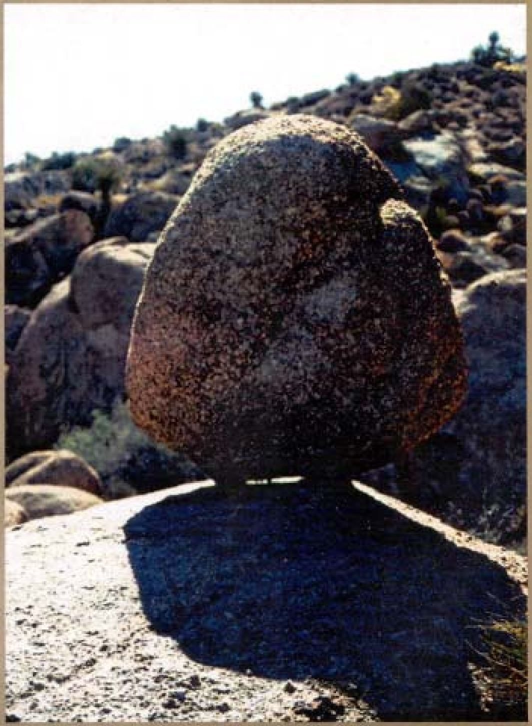

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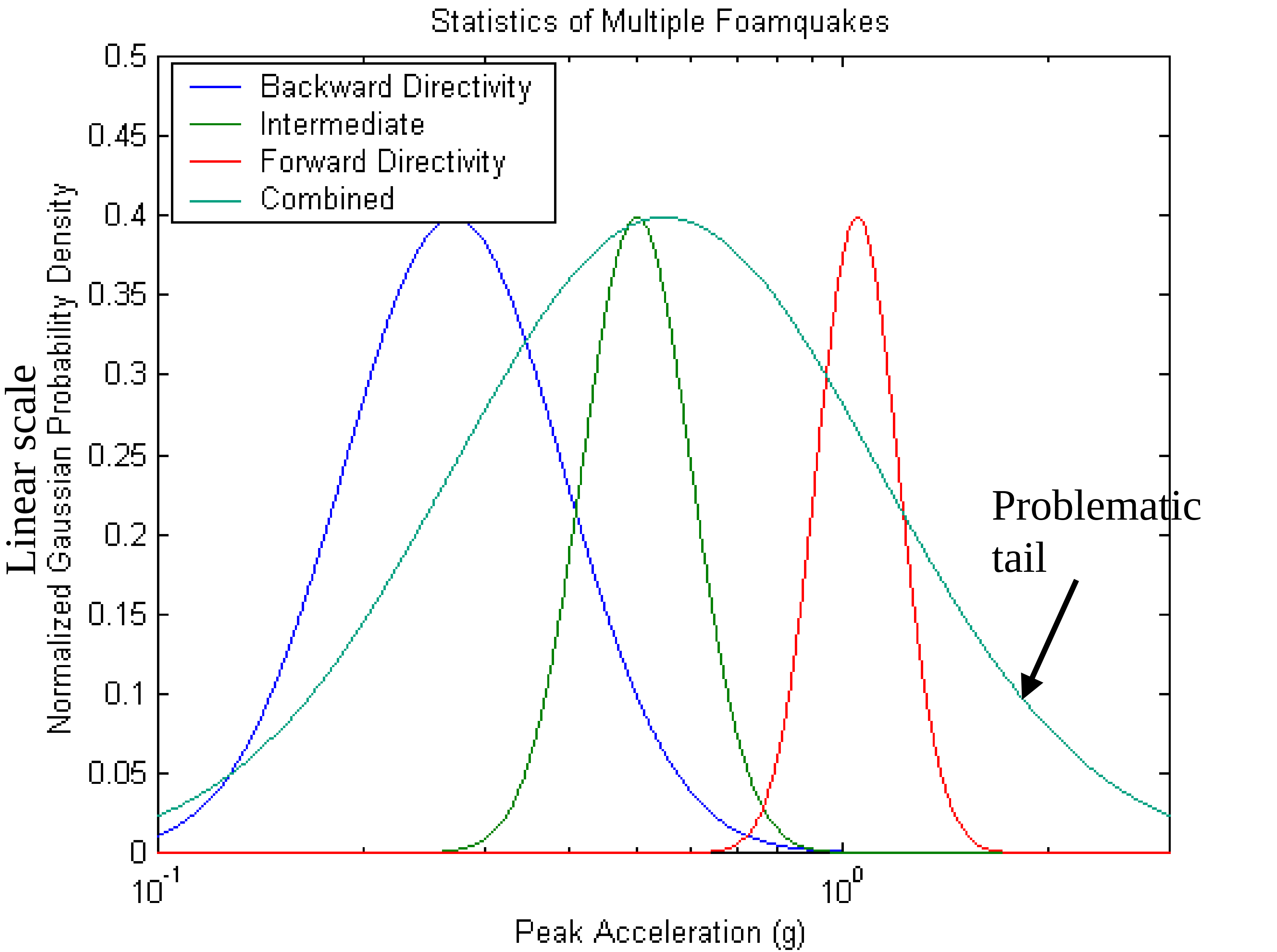
Ways probabilistic seismic hazard analysis (PSHA) could be wrong at low probabilities:

- Mean values of regressions are incorrect

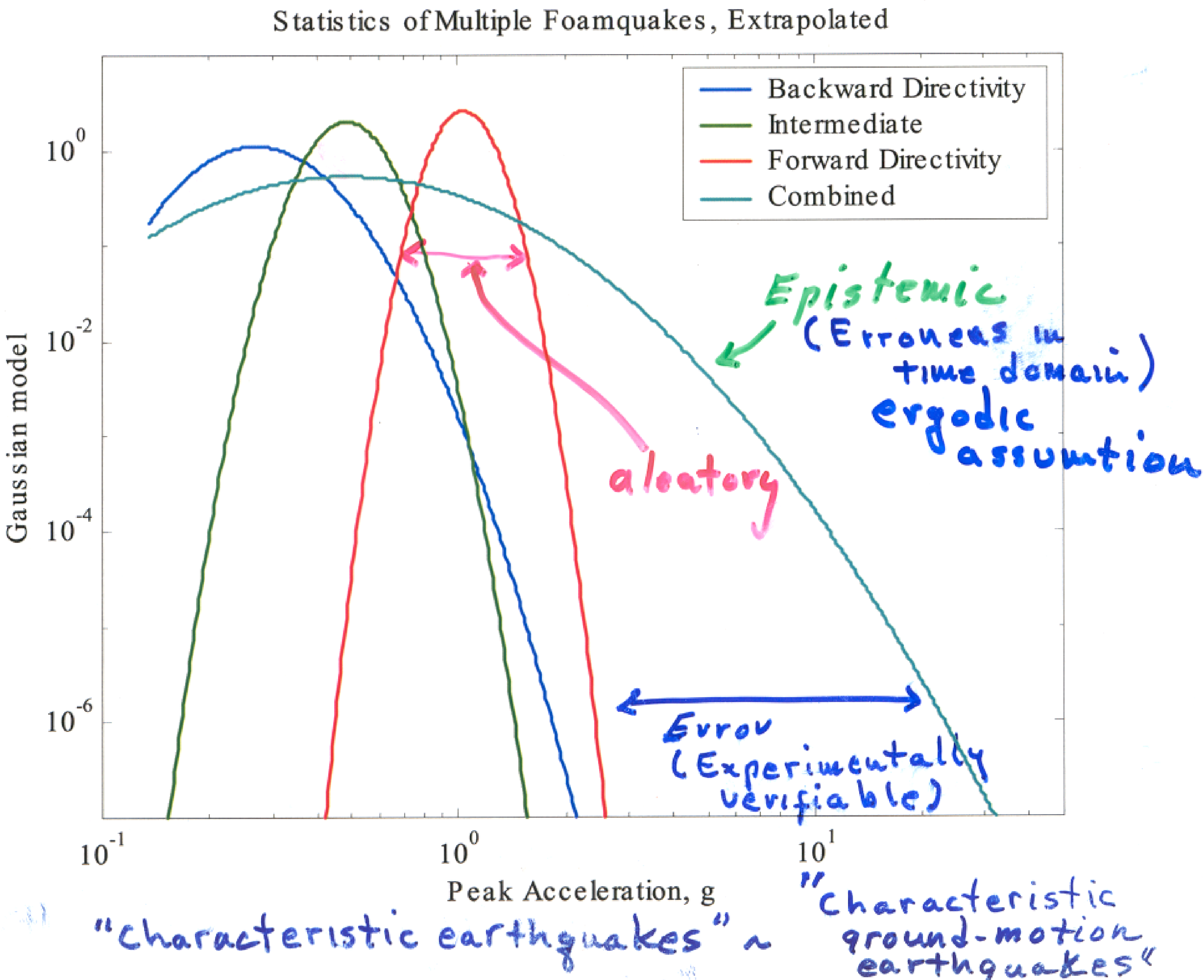
  or

- Uncertainty is not handled correctly.



Statistics of Multiple Foamquakes
Backward Directivity
Intermediate
Forward Directivity
Combined
Linear scale
Normalized Gaussian Probability Density
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
10^-1
10^0
Peak Acceleration (g)
Problematic tail

Logarithmic scale



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Uncertainty Issues

- SSHAC (1997) distinguished between aleatory and epistemic uncertainties, and showed how these should be treated differently in PSHA.
- Anderson and Brune (1999) proposed that, due to the ergodic assumption, aleatory uncertainty is overestimated and epistemic uncertainty is underestimated.

Definitions

- *Aleatory (random) uncertainty:* Uncertainty due to the inherent randomness in a physical process.
- *Epistemic (knowledge) uncertainty:* Uncertainty due to the lack of knowledge about the behavior of the system.

Ergodic process:

- A random process in which the distribution of a random variable in space is the same as the distribution of that same random function at a single point when sampled as a function of time.

Ergodic assumption in PSHA:

- Regression analysis derives a mean curve to predict ground motions, as a function of magnitude and distance (or other parameters), and infers the standard deviation of this ground motion by the misfit at multiple stations. The assumption that uncertainty of ground motions over time at a single point is the same as the standard deviation derived this way is an ergodic assumption.

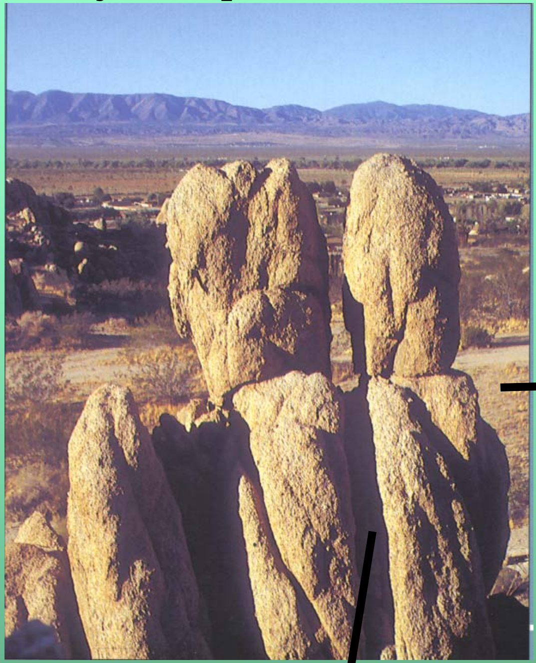
Characteristic Ground Motion Earthquake

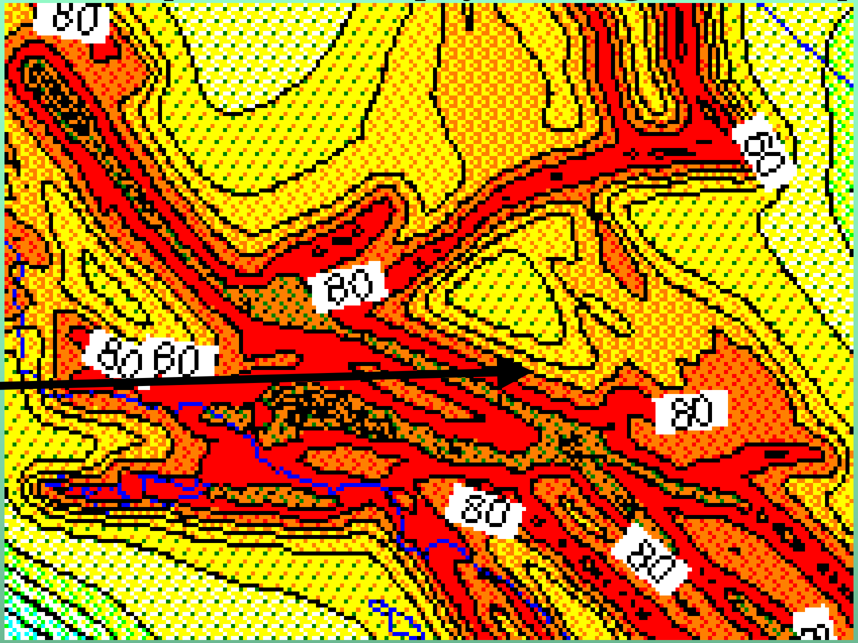
- Repeats identically in both static offset and dynamics of rupture, resulting in identical ground motions every time.
- Our conclusions from considering the model:
  - Aleatory uncertainty should only include effects that vary in time, i.e. differences from one earthquake to the next on the same fault.
  - All effects of spatial variability of ground motion during a single earthquake should go into the epistemic category.

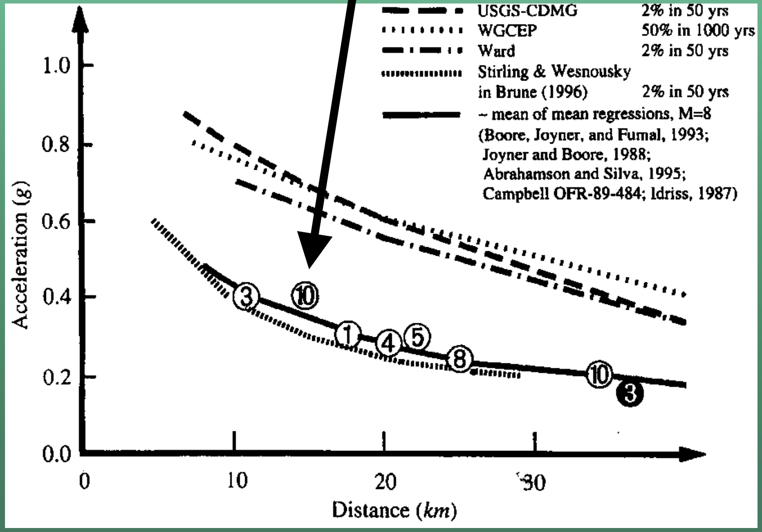
Assumptions

- We assume that a plausible physical model is that:
  - 1. The experts are approximately correct in their estimates of mean ground acceleration, but the low probability tails on the distribution curves are suspect.
  - 2. The appropriate statistical model is likely to be somewhere between the ergodic extreme and the anti-ergodic extreme (characteristic ground motion model).
- Given this we need to look for field evidence to determine the more appropriate models.

Precarious rocks are one of the few ways to check on probabilistic seismic hazard.
They appear to suggest that psha overestimates the hazard in some locations.
They also place constraints on earthquake source physics in great earthquakes.







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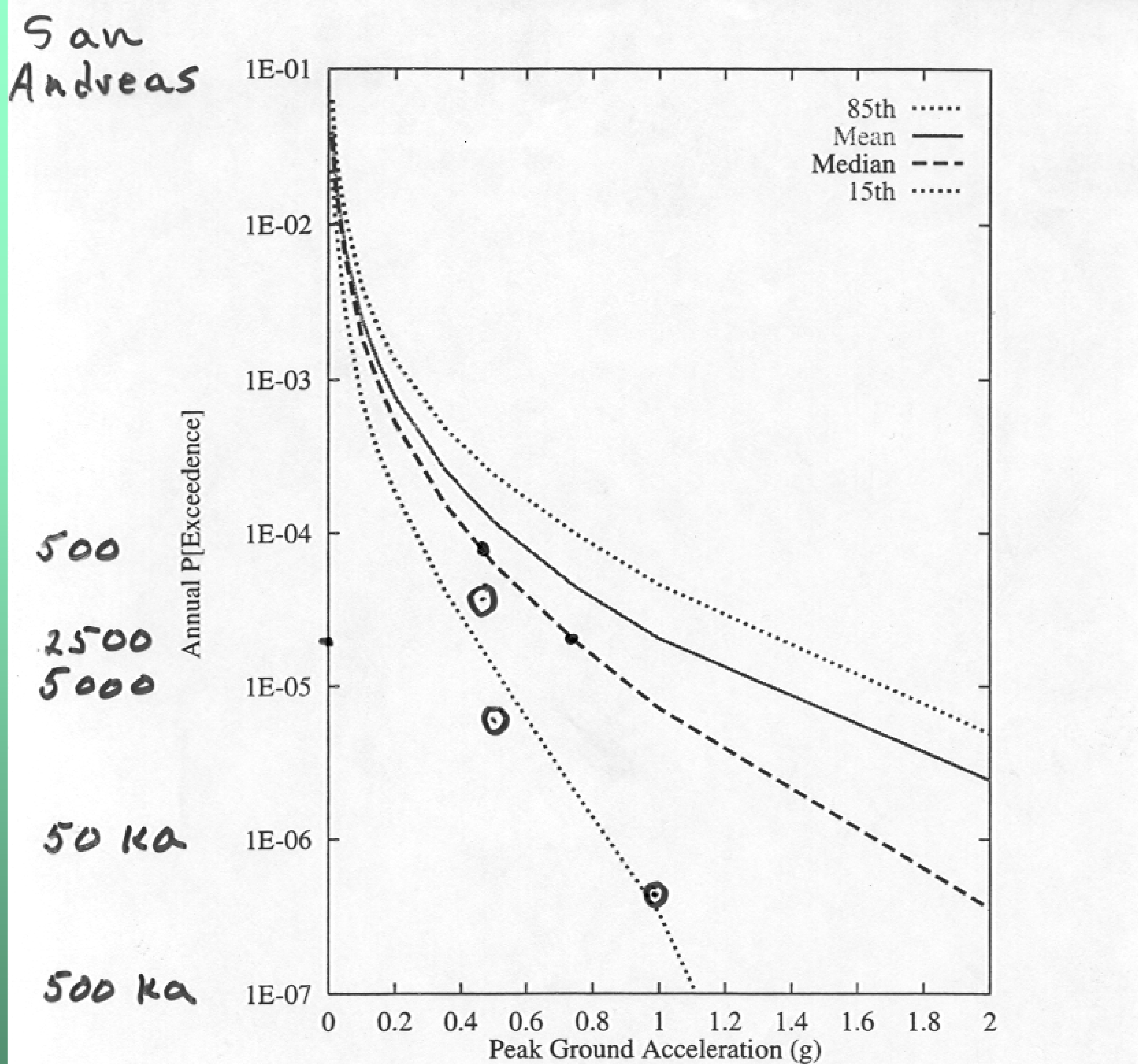
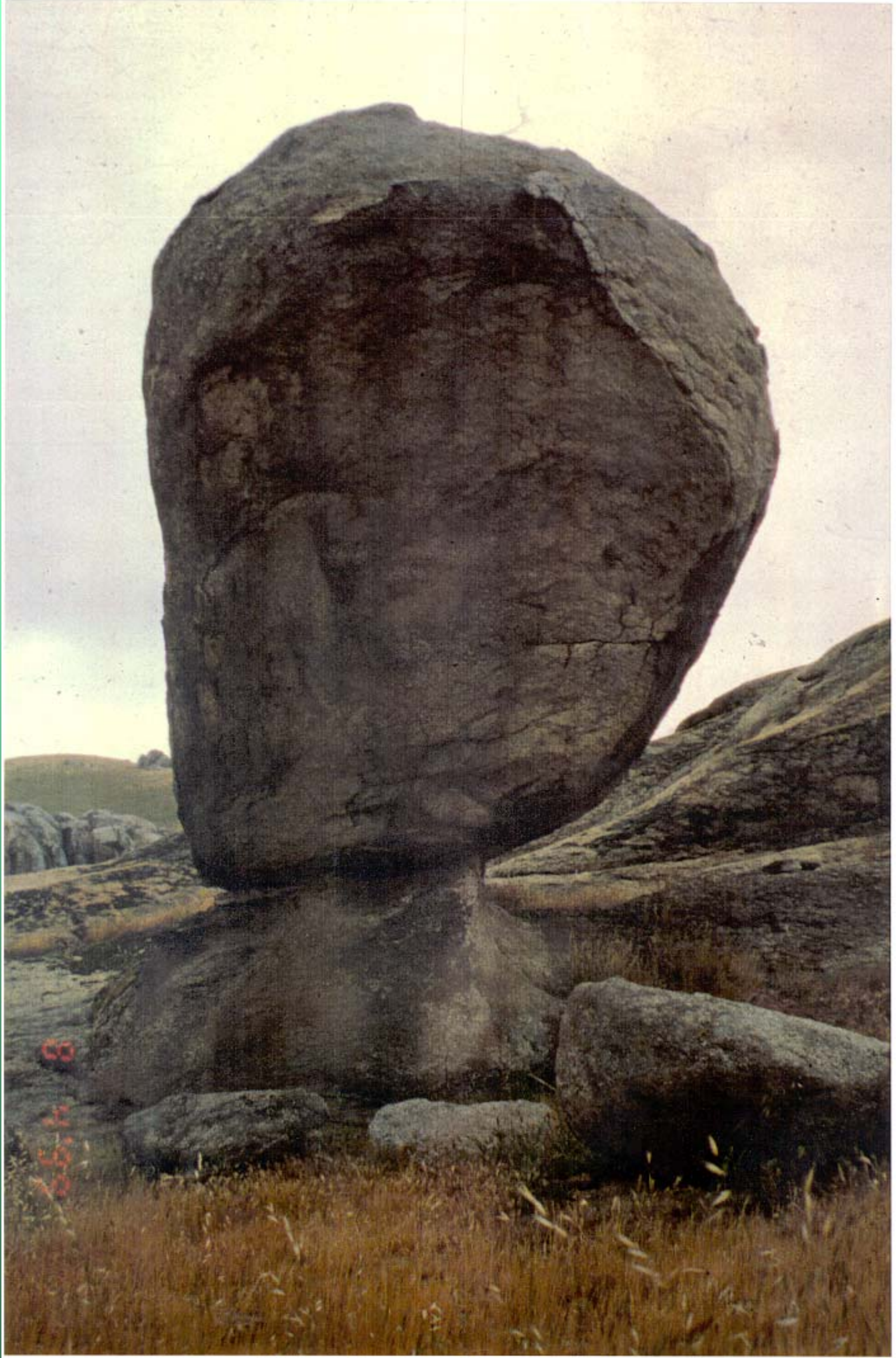


Figure 7-4 Integrated seismic hazard results: summary hazard curves for horizontal PGA

* Non-Shattered Rock

Shattered rock, hanging wall, thrust fault



Precarious rock, unshattered, foot wall, thrust fault.

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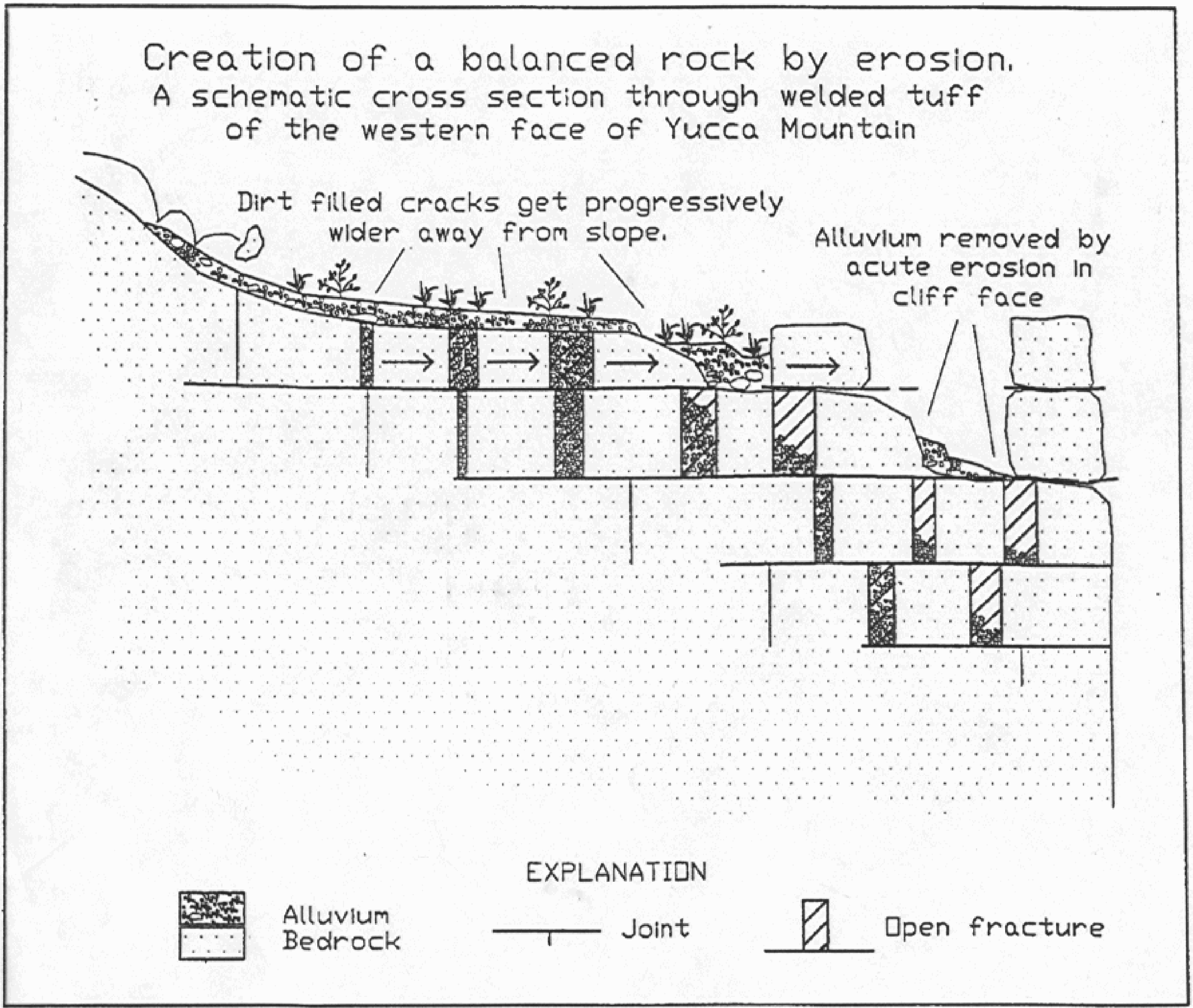
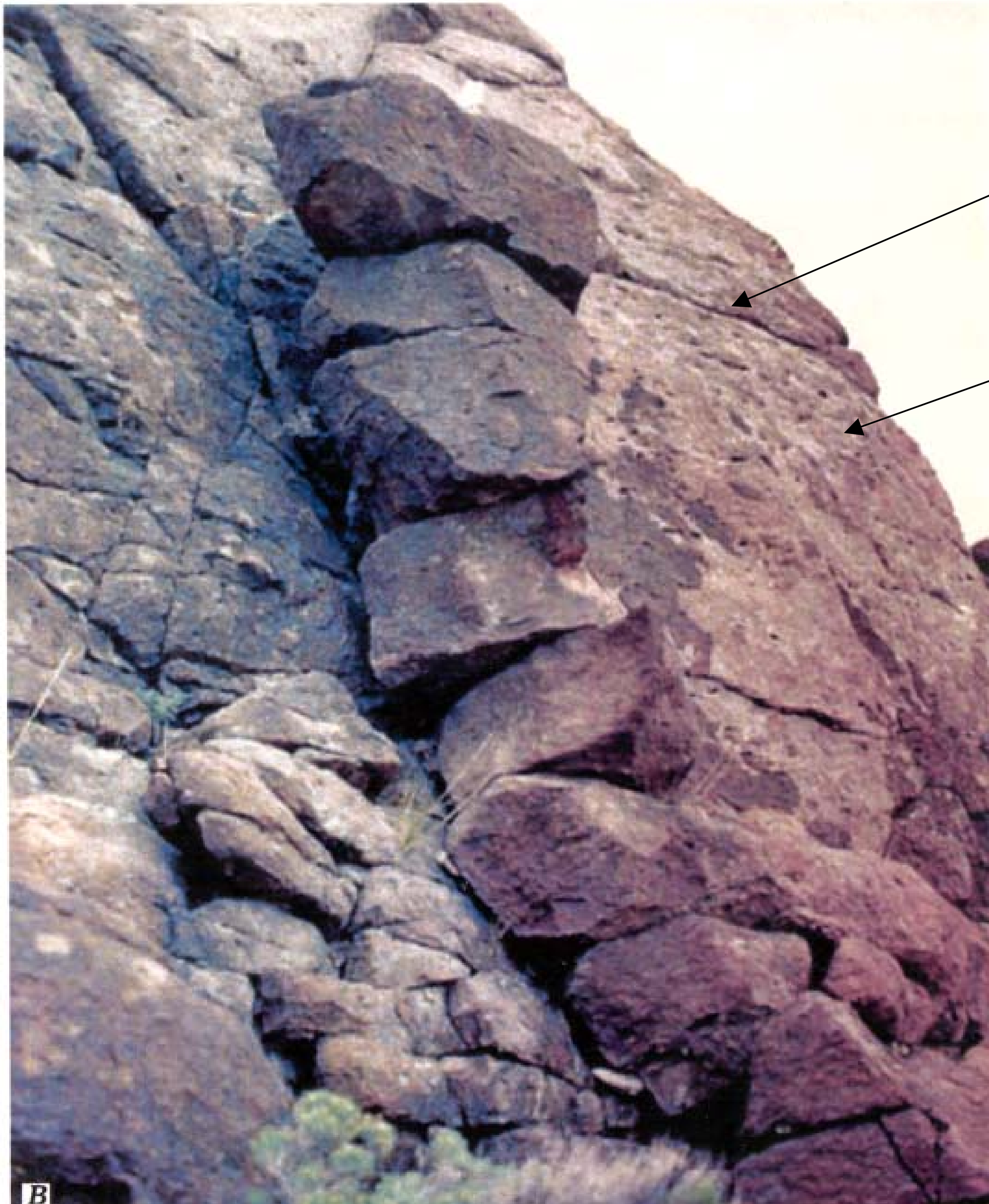
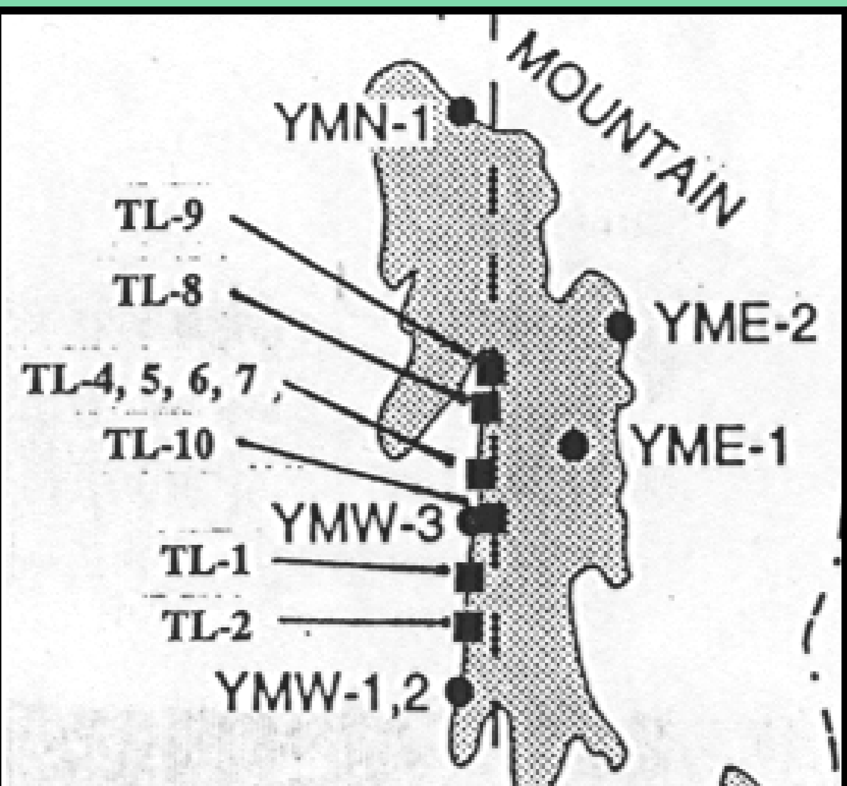
YUCCA MOUNTAIN





Fracture age ~10Ma

Not shattered



Varnish Microlamination Sites

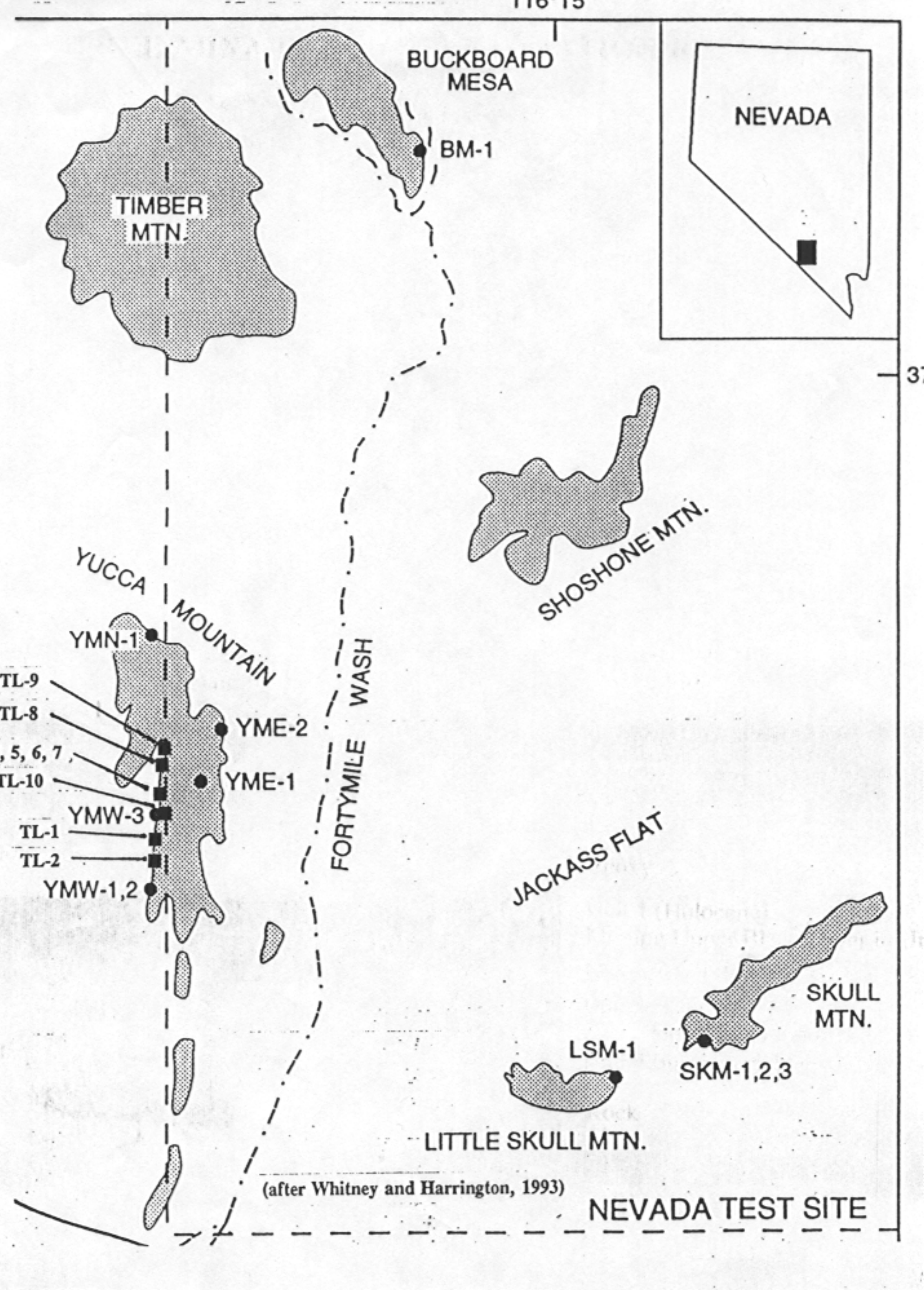


Table 2: Field and laboratory toppling accelerations

Label	Rock ID#	Toppling Acceleration/g	
		Rock	Model
A	92 JB NC 01	0.14	0.10 – 0.16
B	93 RC SC 83	0.18	–
C	92 JB 8T 02	0.17	0.13
D^1	92 JB 8T 01	0.34	0.32
D^2	92 JB 8T 01	0.22	–
E	93 JB 8T 02	–	0.3

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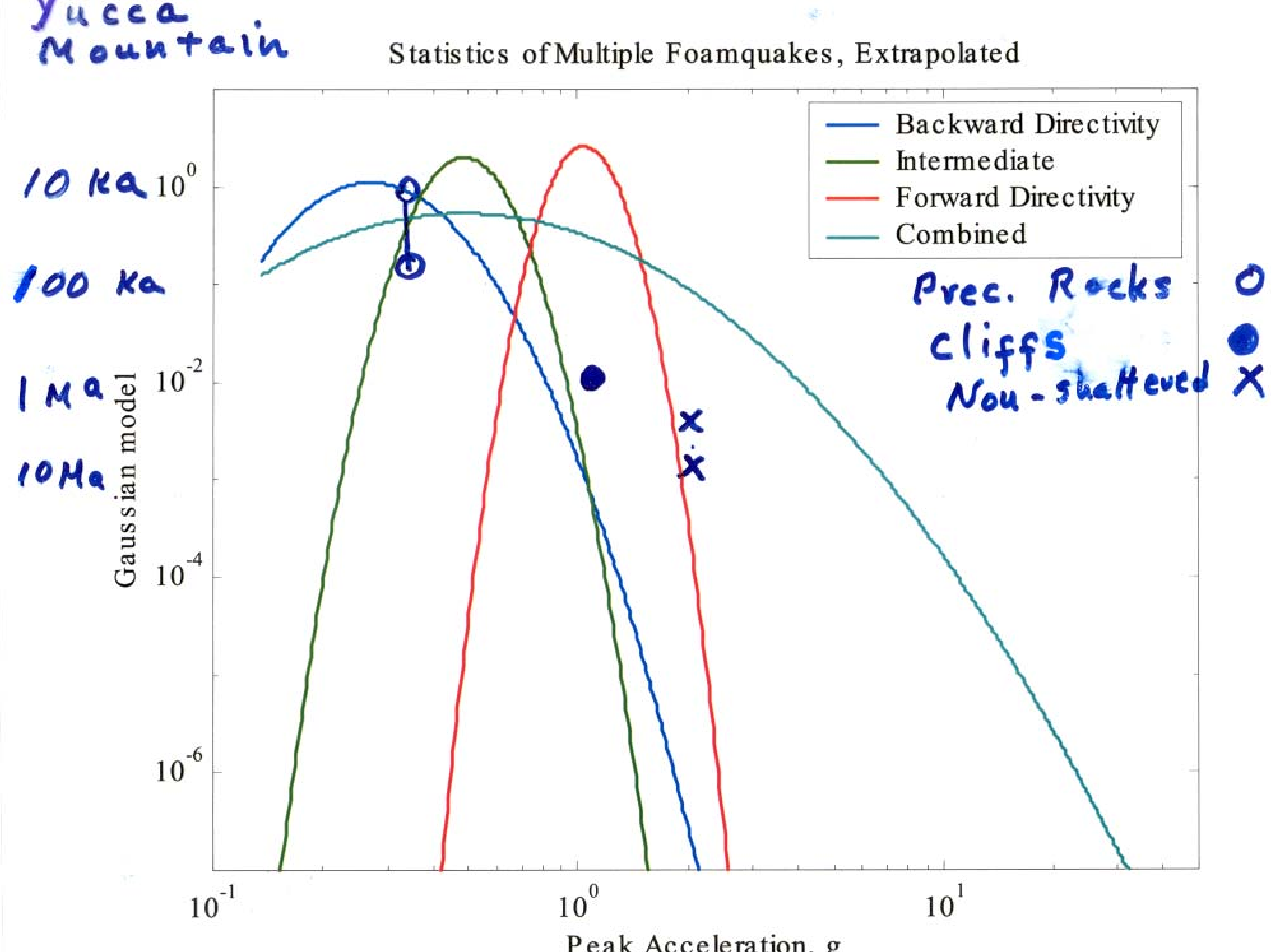
Approximate Ages of Precarious Rock Pedestals at Yucca Mountain

Sample	Age
Whitney 1	242 ka
Whitney 2	56 ka
Whitney 3	88 ka
Len 4	81 ka
Len 5	79 ka
Len 6	74 ka
7-CBD	174 ka
8 CBD	154 ka
9 ACRS	32 ka



Yucca Mountain
Statistics of Multiple Foamquakes, Extrapolated
Backward Directivity
Intermediate
Forward Directivity
Combined
10 ka
100 ka
1 Ma
10 Ma
10^{0}
10^{-2}
10^{-4}
10^{-6}
Gaussian model
Prec. Rocks O
cliffs ●
Non-shattered X
10^{-1}
10^{0}
10^{1}
Peak Acceleration, g

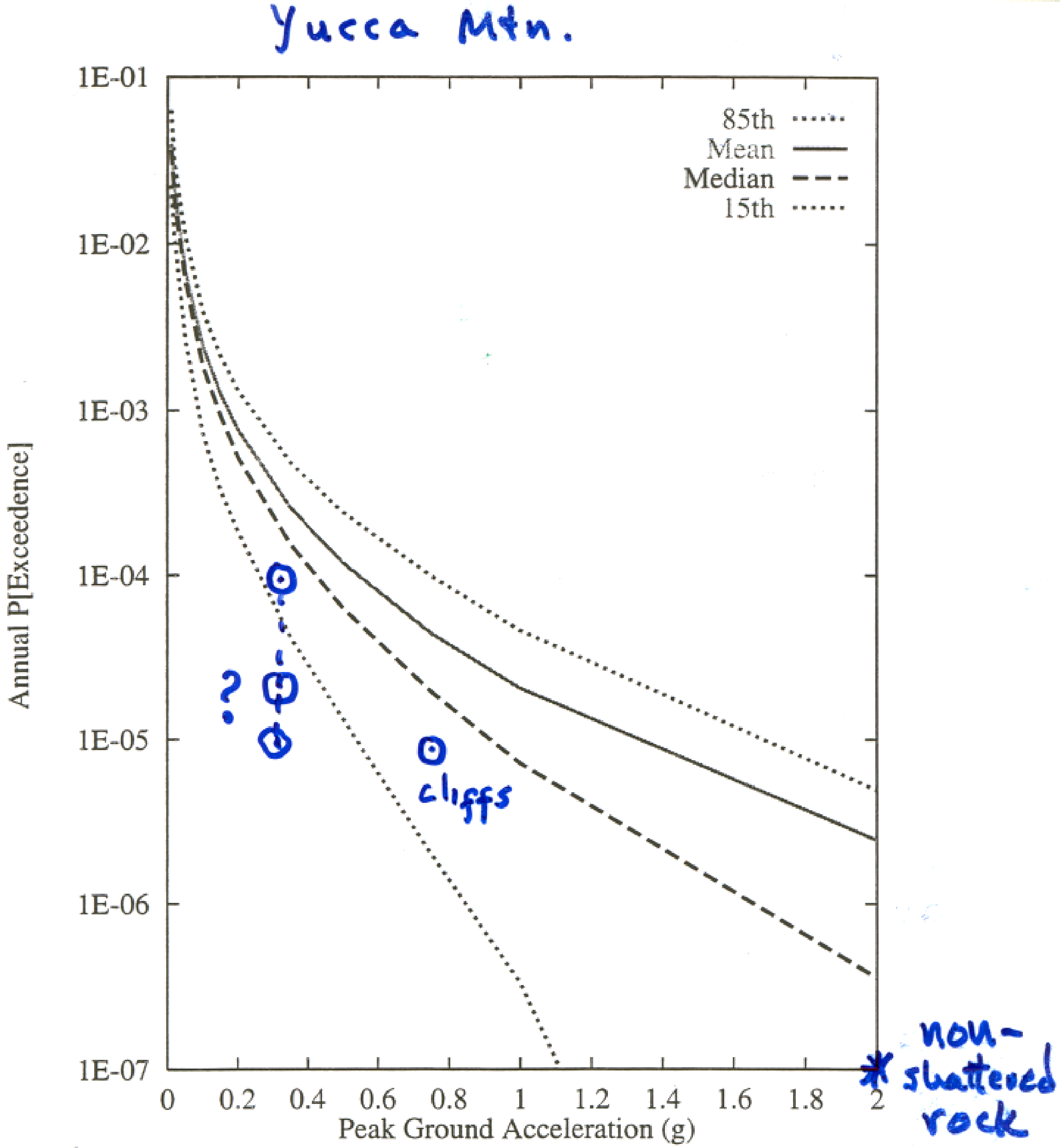


Figure 7-4 Integrated seismic hazard results: summary hazard curves for horizontal PGA

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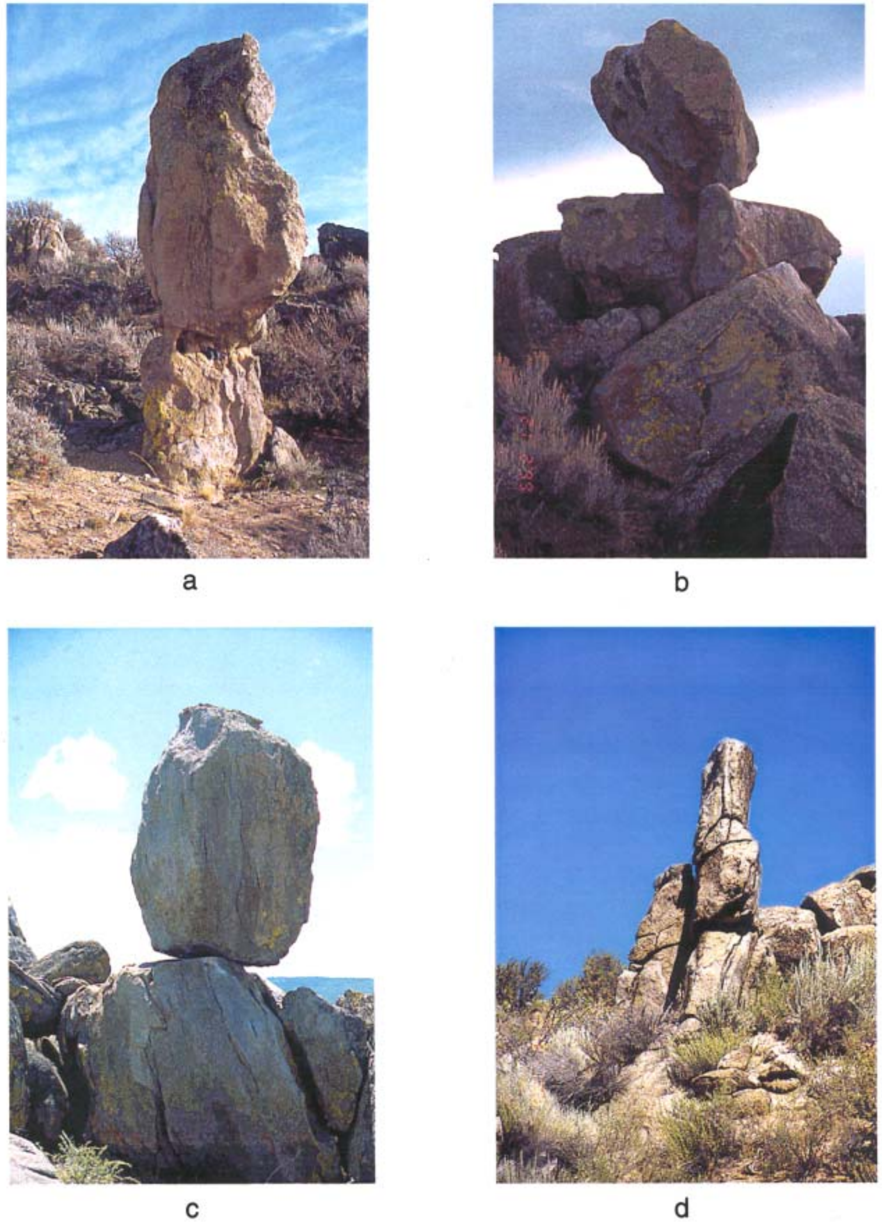

Examples of precarious rocks found in the vicinity of Honey Lake fault.

Constraints on Normal and Trans-tensional Faulting

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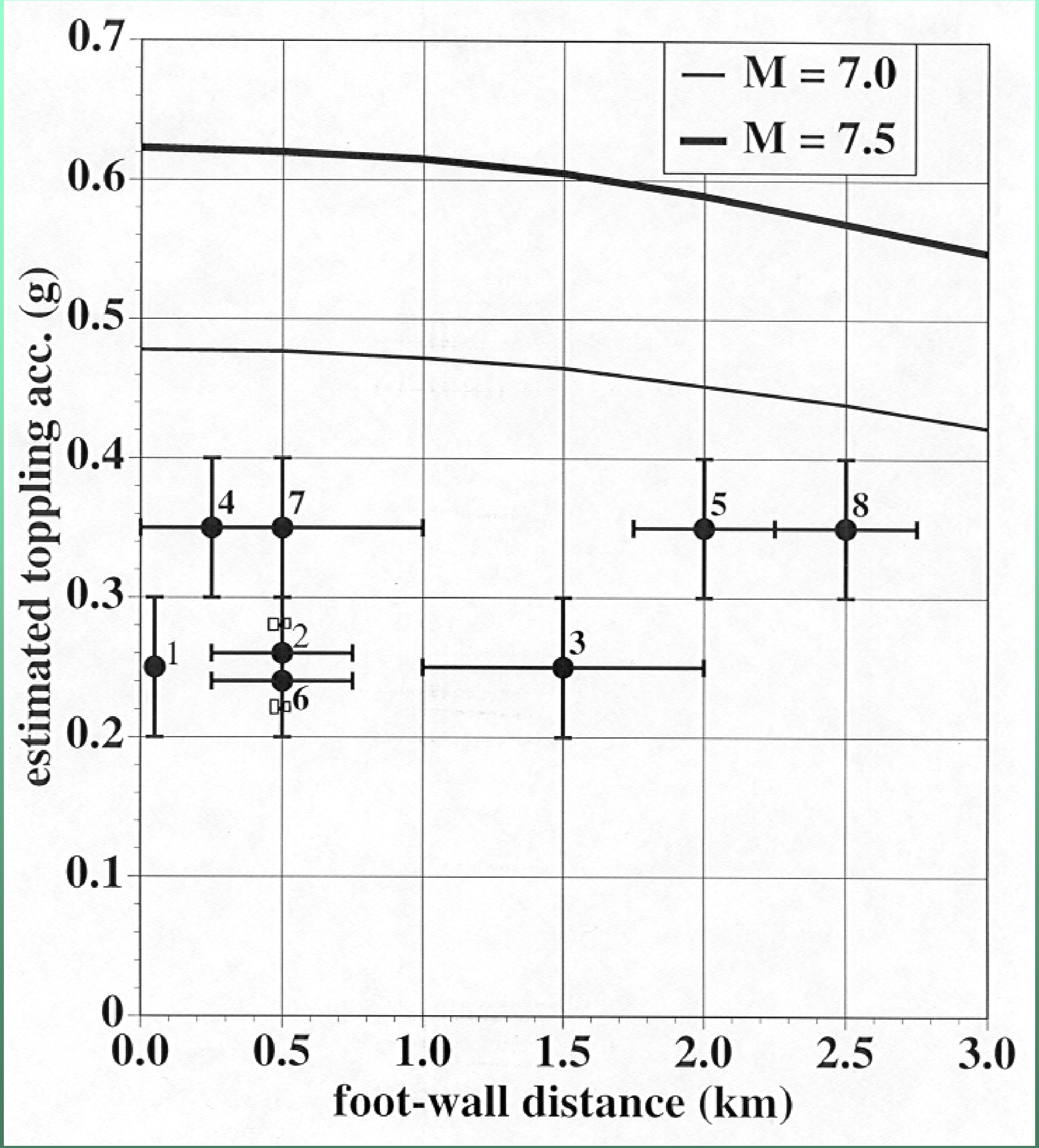
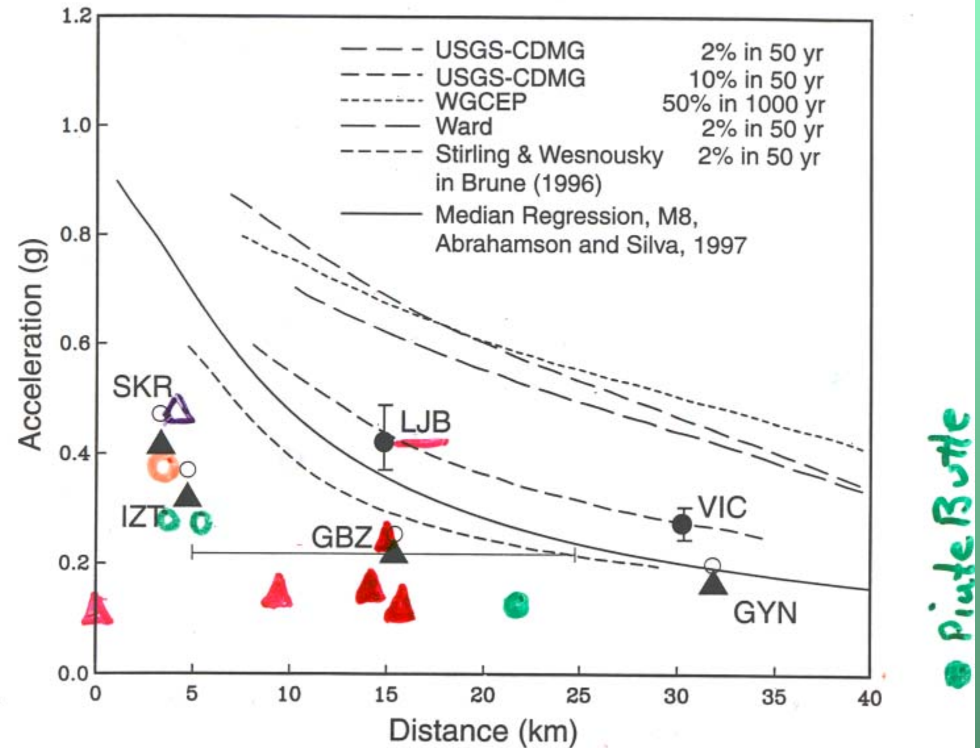


Foot wall of normal faults

Precarious rock constraints compared with recent strong motion data

Δ Punchbowl 1812, 1857



Trans-tensional?

▲ M=7.4 Aug 17 } Turkey 1999

▲ M=7.2 Nov. 12 } Seeber et al

○ Honey Lake

○ Beaumont

○ Antelope Buttes 1812 1857

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Conclusions

- The precarious rocks possibly provide constraints on low-probability ground motions at Yucca Mountains.
- The ground motions implied by the precarious rocks are smaller than those determined by the PSHA.