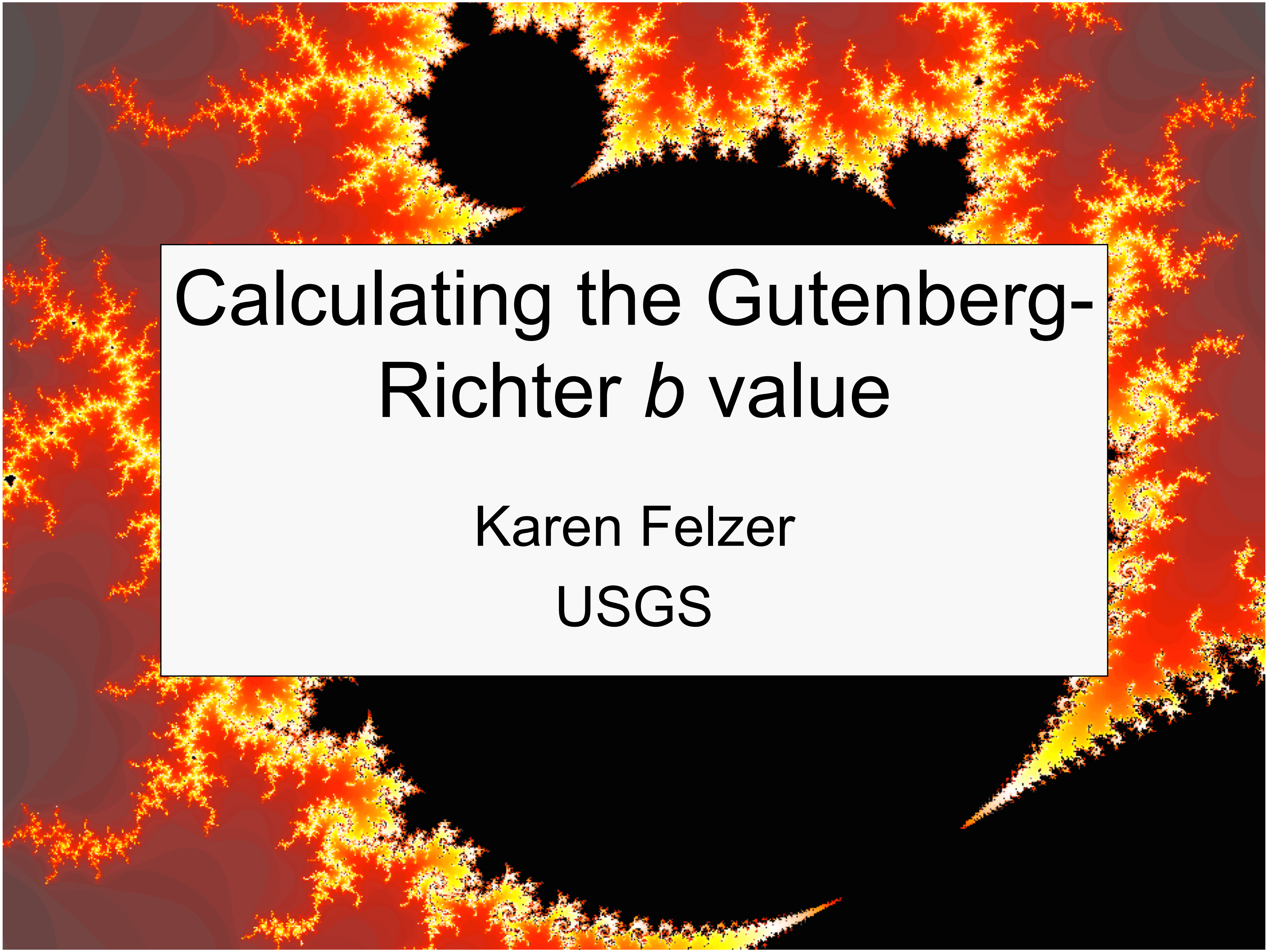
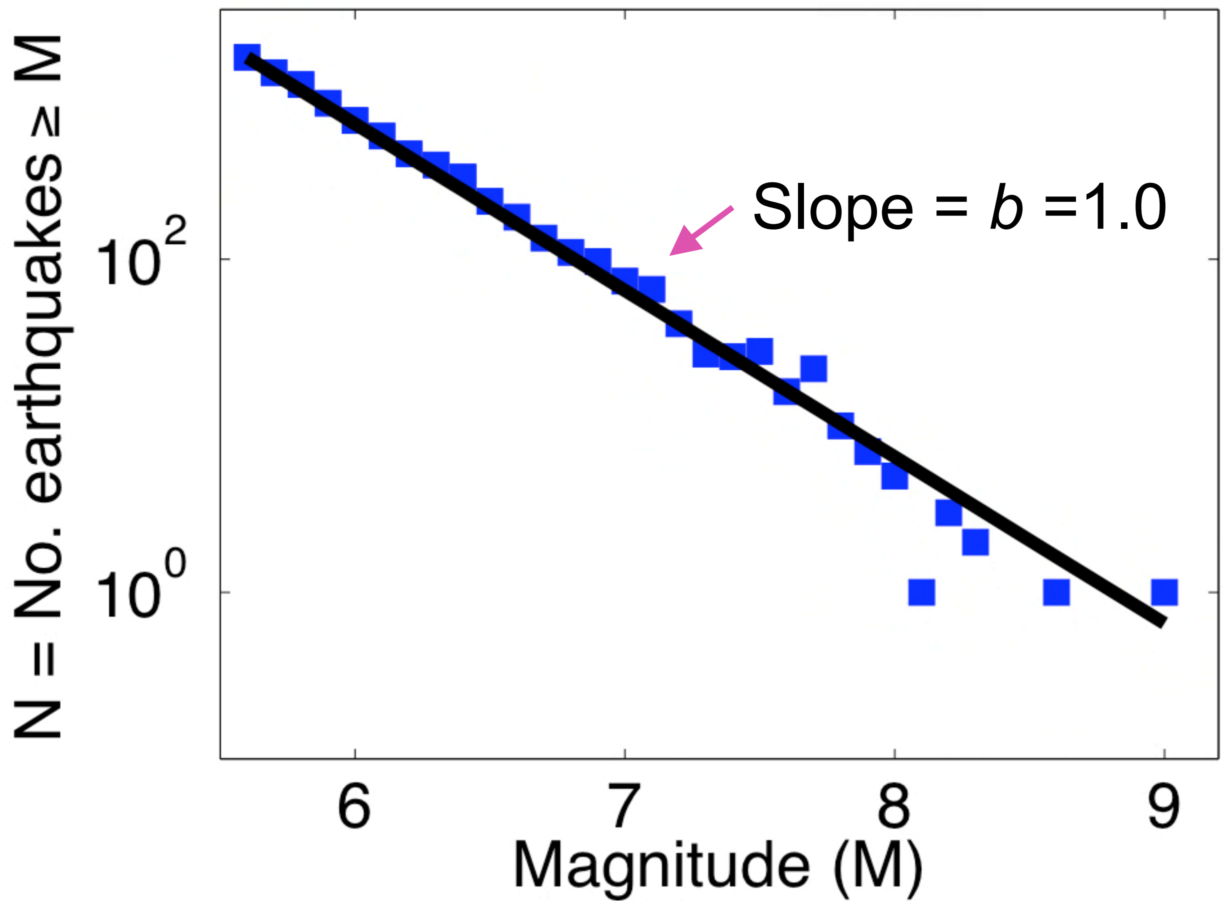


Calculating the Gutenberg-Richter *b* value

Karen Felzer
USGS

The Gutenberg-Richter magnitude frequency relationship

1976-2005 Global CMT catalog

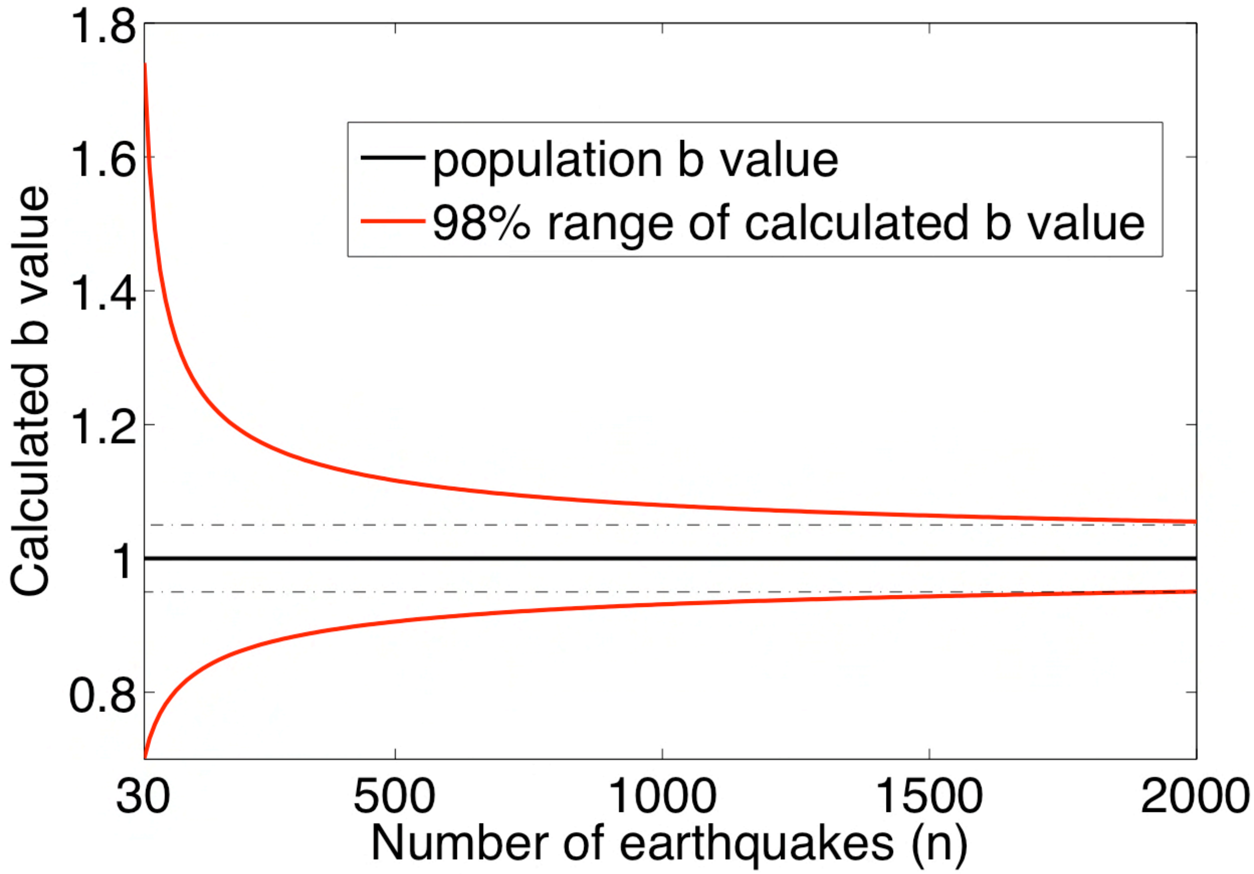


$\log(N) = a - bM$

Common Errors in *b* value Calculation

1. Fitting data with linear least squares (LSQ) rather than the simple maximum likelihood (MLE) method (**read *Aki* (1965)**)
2. Data set is too small
3. Using earthquakes smaller than the catalog completeness threshold
4. Using data with magnitude errors

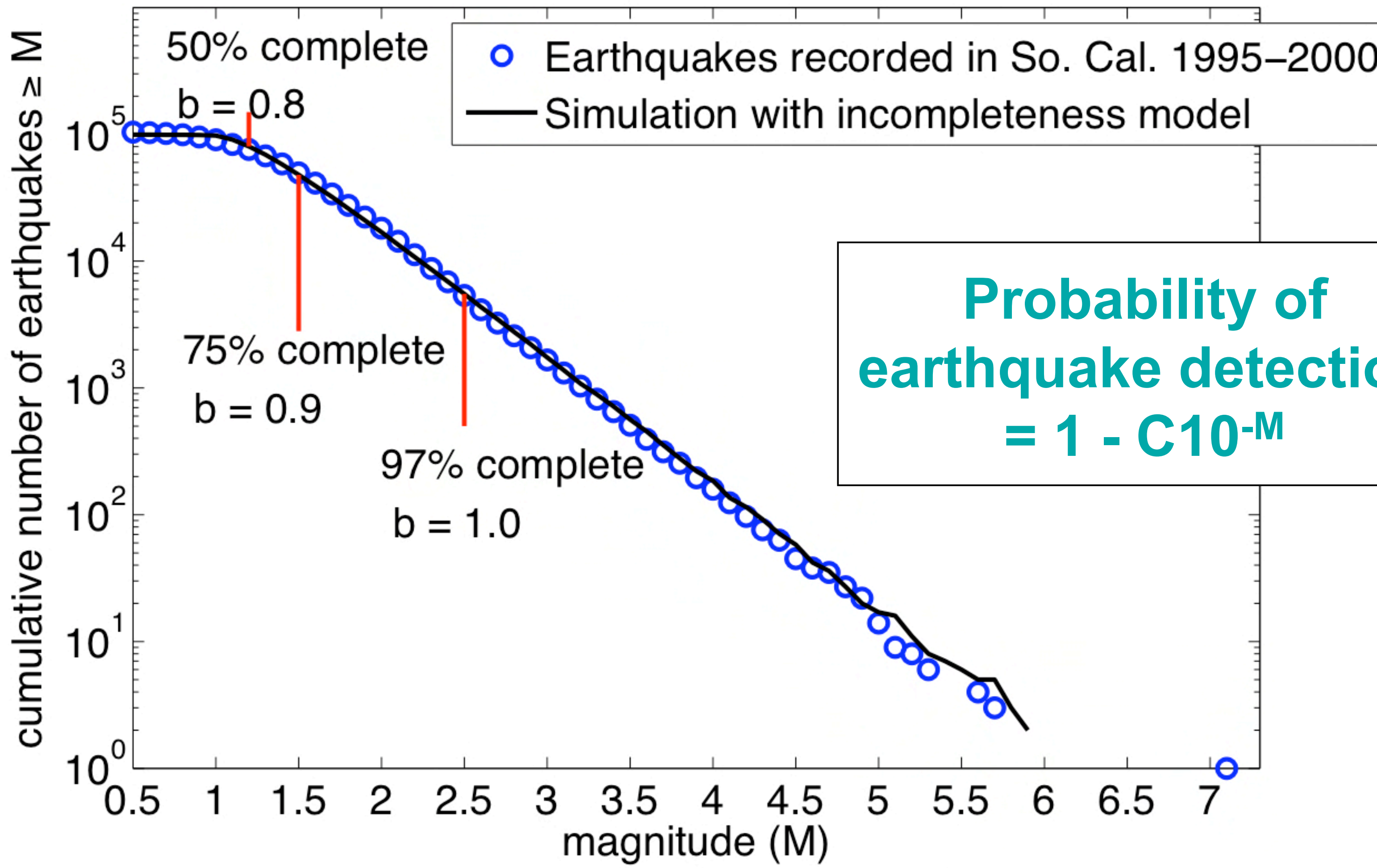
Error: Data set too small



n	*b* range
30	0.7 - 1.74
50	0.5 - 1.49
100	0.86 - 1.20
500	0.91 - 1.12

>2000 good quality earthquakes are required for 98% confidence errors < 0.05

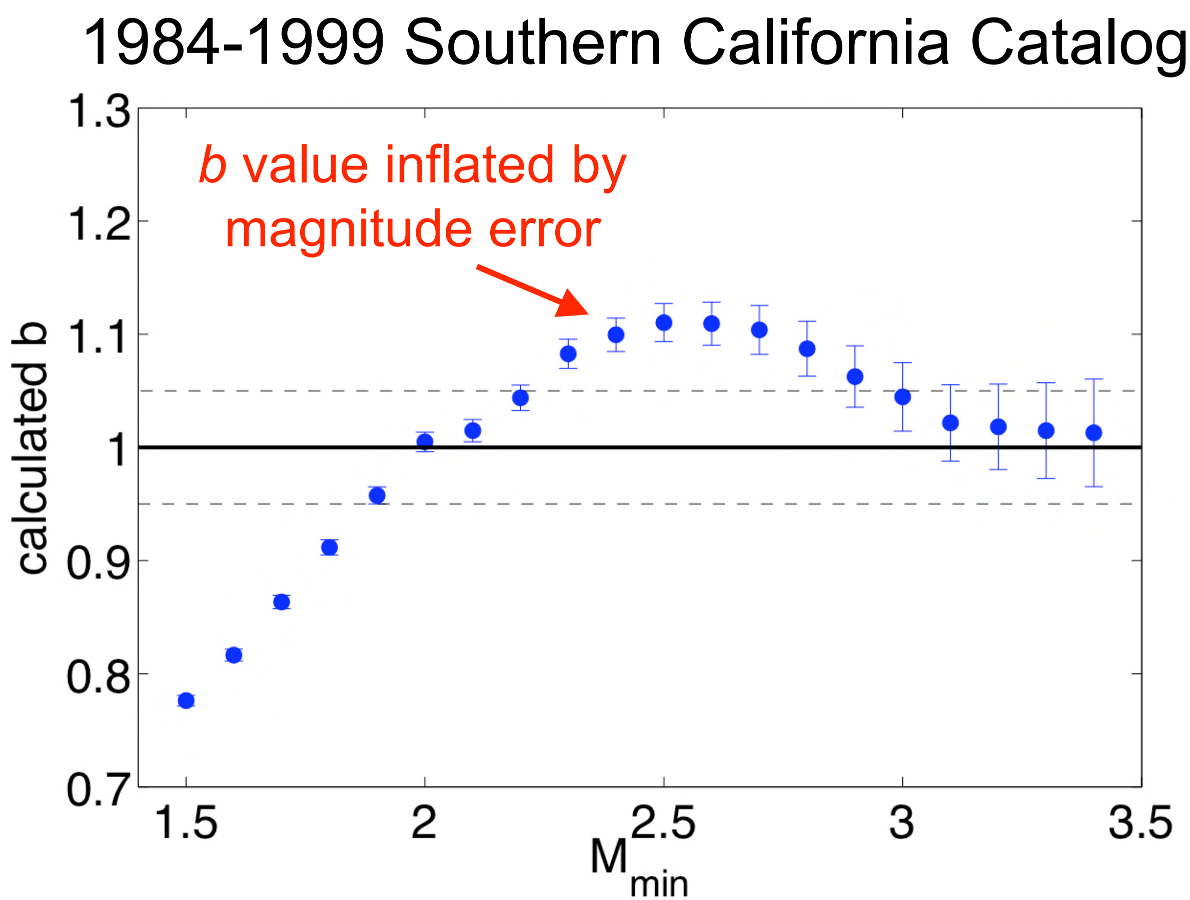
Error: Using earthquakes smaller than the catalog completeness threshold



Probability of earthquake detection $= 1 - C10^{-M}$

Setting the catalog completeness threshold by eye can lead to *b* value underestimation by 0.1 to 0.2.

Error: Using data with magnitude errors

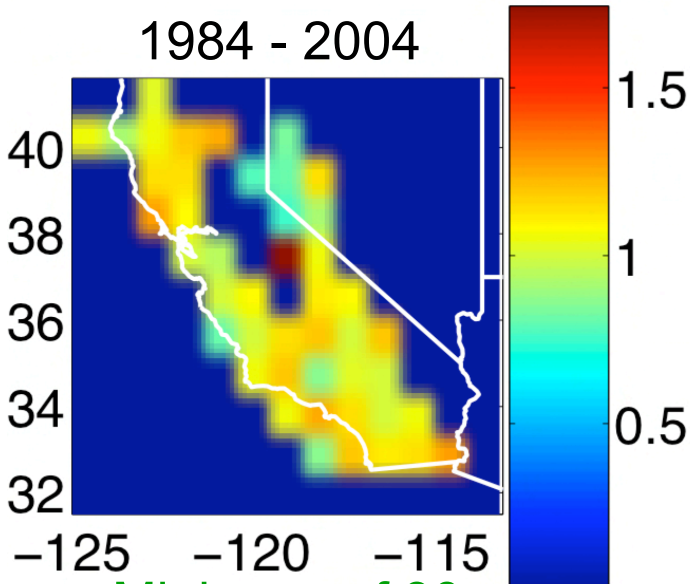


- Larger magnitude errors for smaller earthquakes inflate *b*
- *b* is best fit at the largest reasonable minimum magnitude

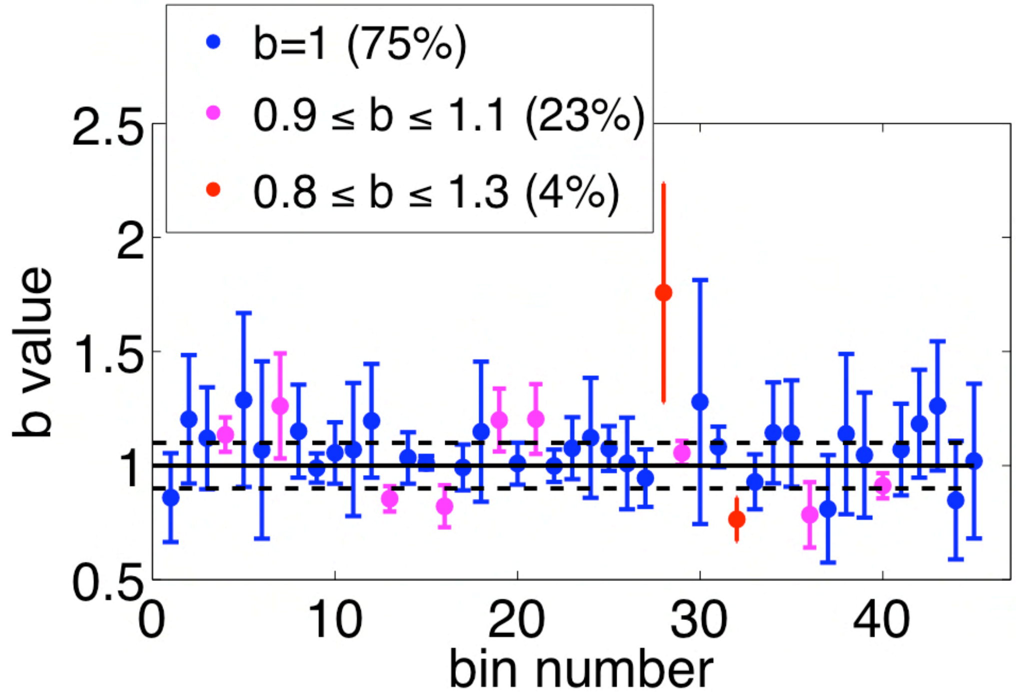
Two Important Questions

- Does b value vary with location? (*Wiemer and Wyss*, 1997; *Schorlemmer and Wiemer*, 2004…)
- Does the magnitude-frequency distribution vary on and off of major faults? (*Wesnousky et al*. 1983; *Schwartz and Coppersmith*, 1984…)

Location: We calculate *b* values in 1° x 1° bins throughout California



Minimum of 30 earthquakes/calculation



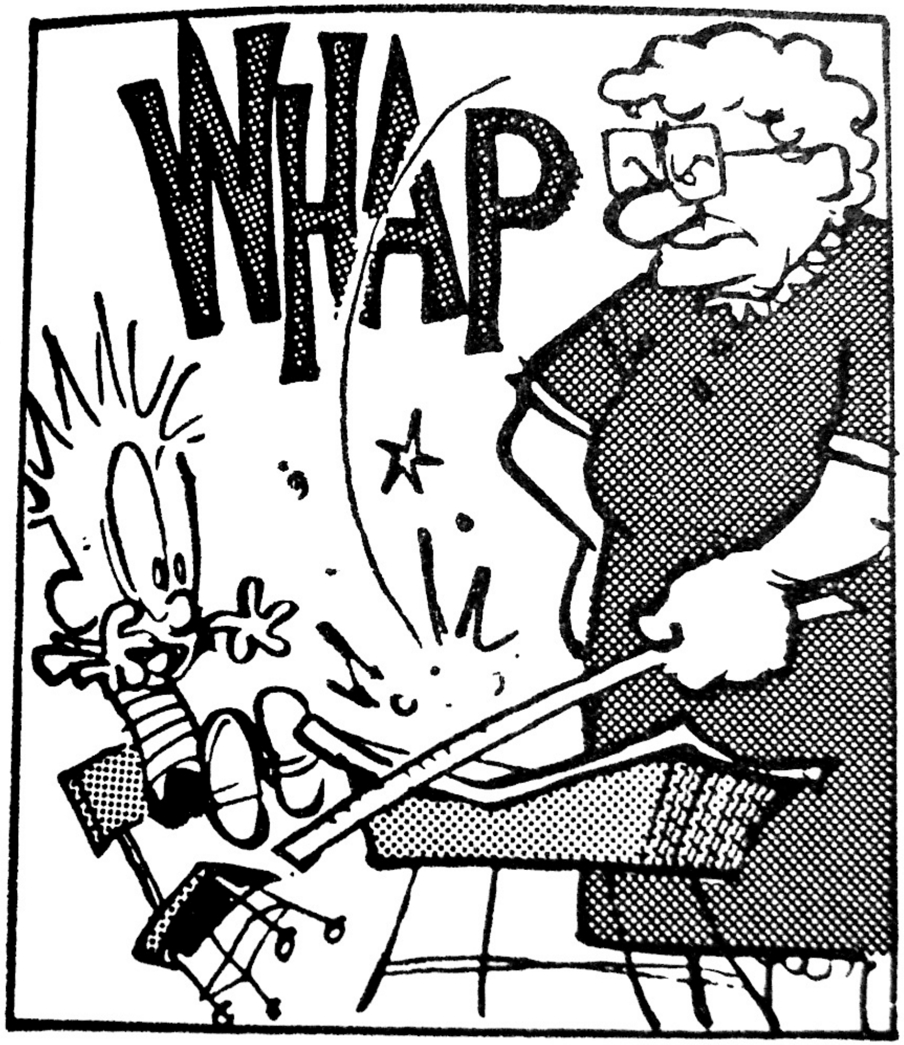
Assuming no magnitude error and uniform catalog completeness to M 2.6, **all values are 0.9 ≤ *b* ≤1.1.**

Same for 0.5 °x 0.5 °, 0.25 °x 0.25 °, 0.1° x 0.1 ° bins

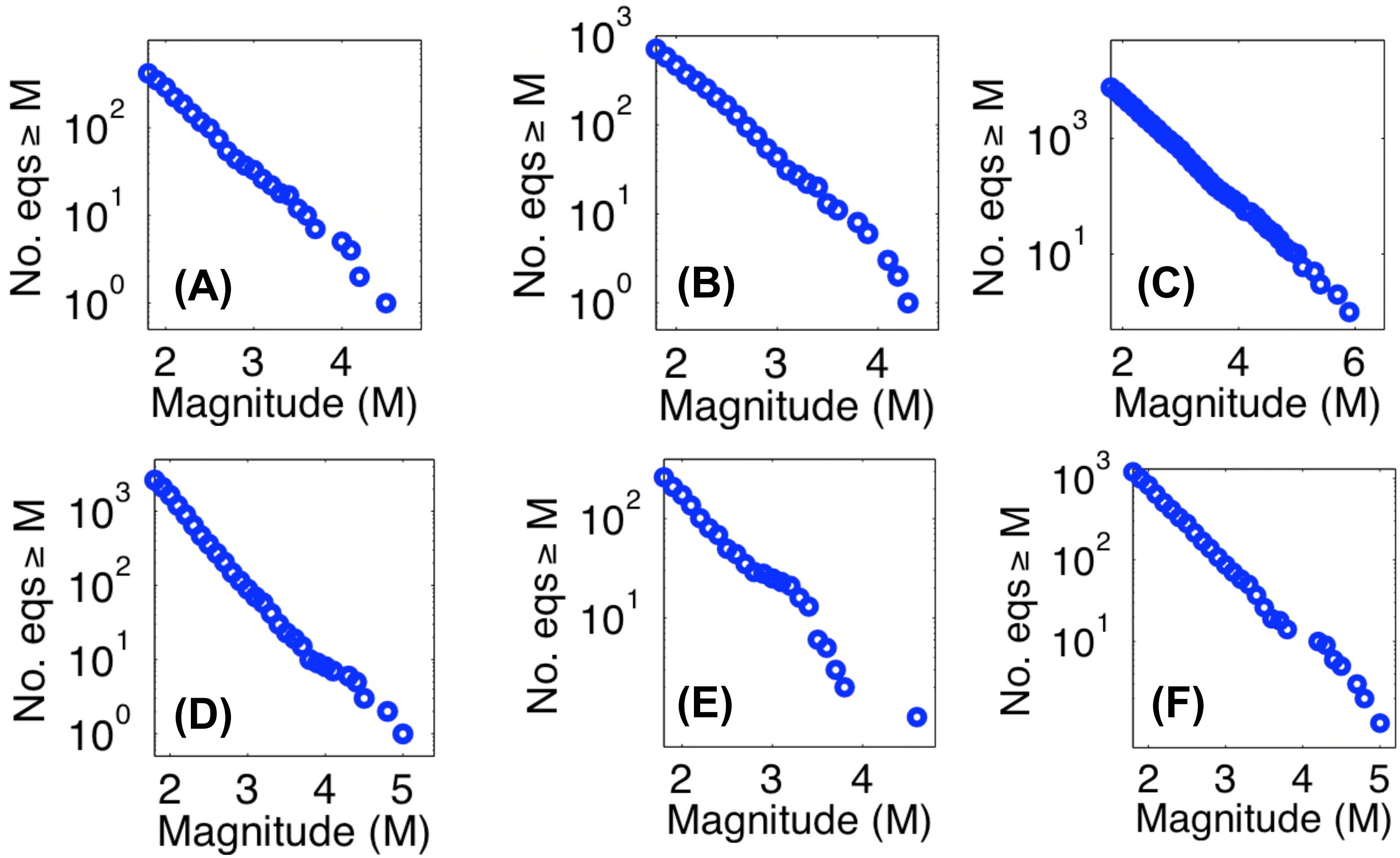
Is the magnitude-frequency distribution different on and off of major faults?

?

Quiz!

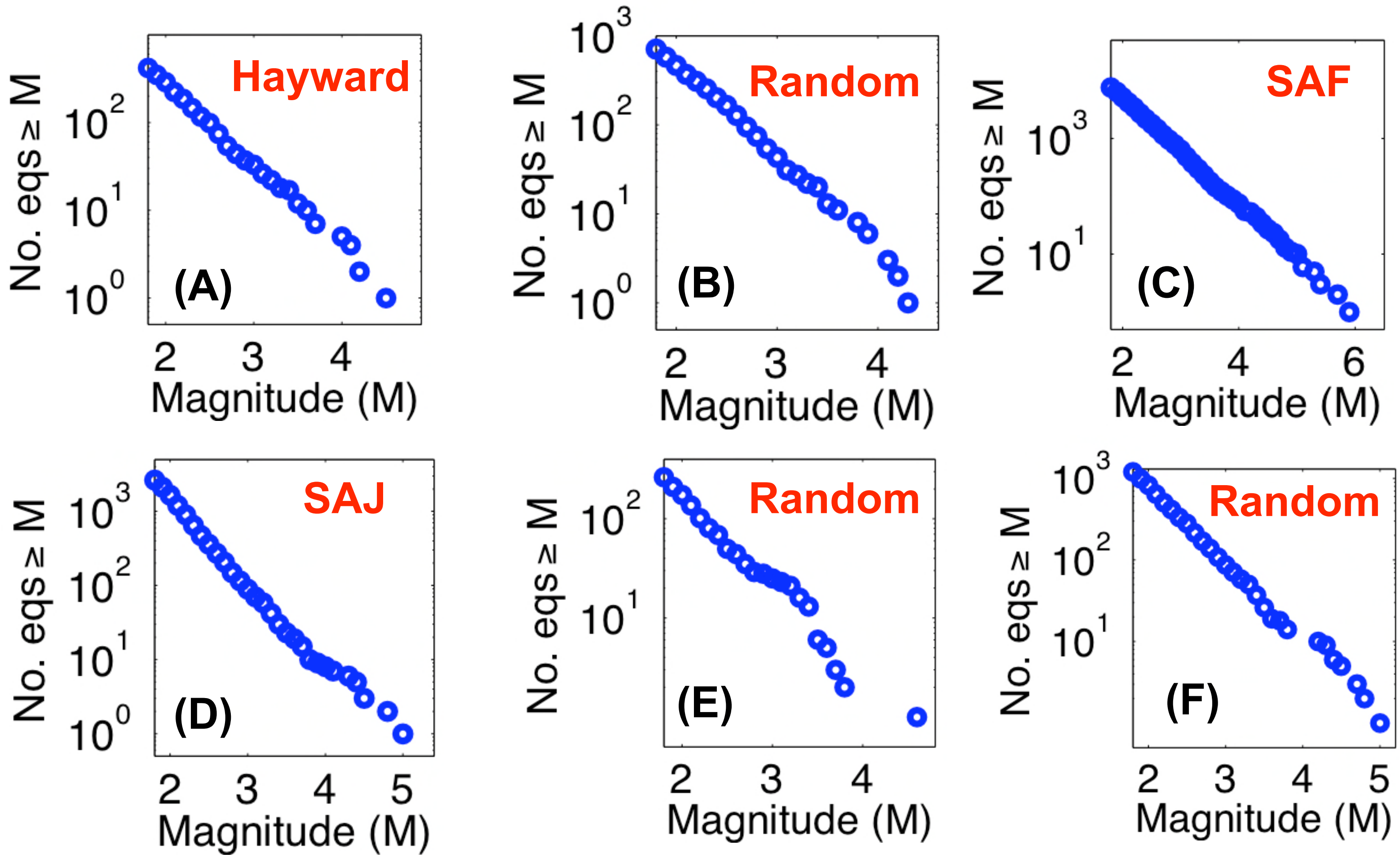


Identify the distributions taken from major fault zones*



Fault zone: +-2 km from entire surface trace of mapped fault. All data from California, 1984-2004

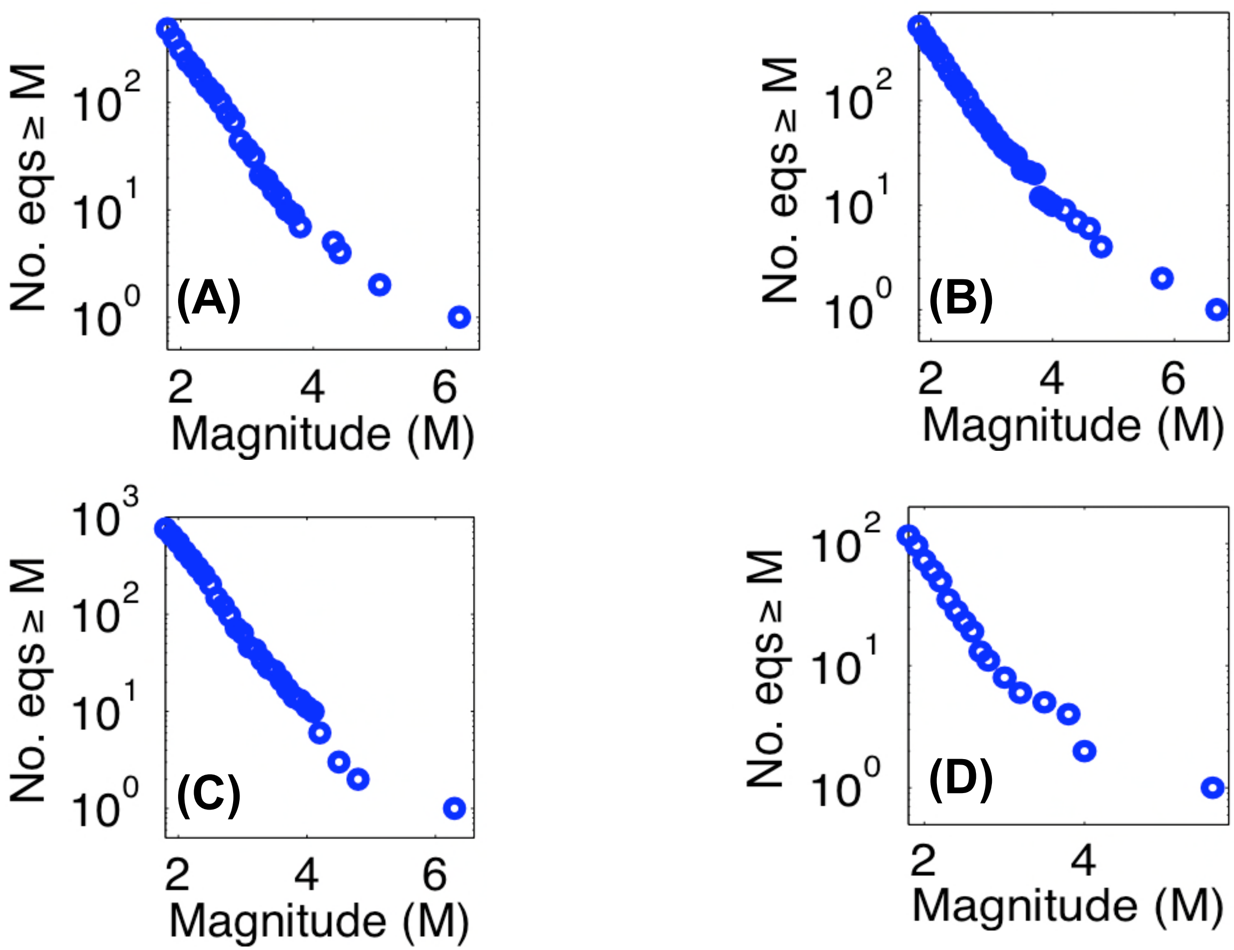
Identify the distributions taken from major fault zones*



Fault zone: +-2 km from entire surface trace of mapped fault
All data from California, 1984-2004

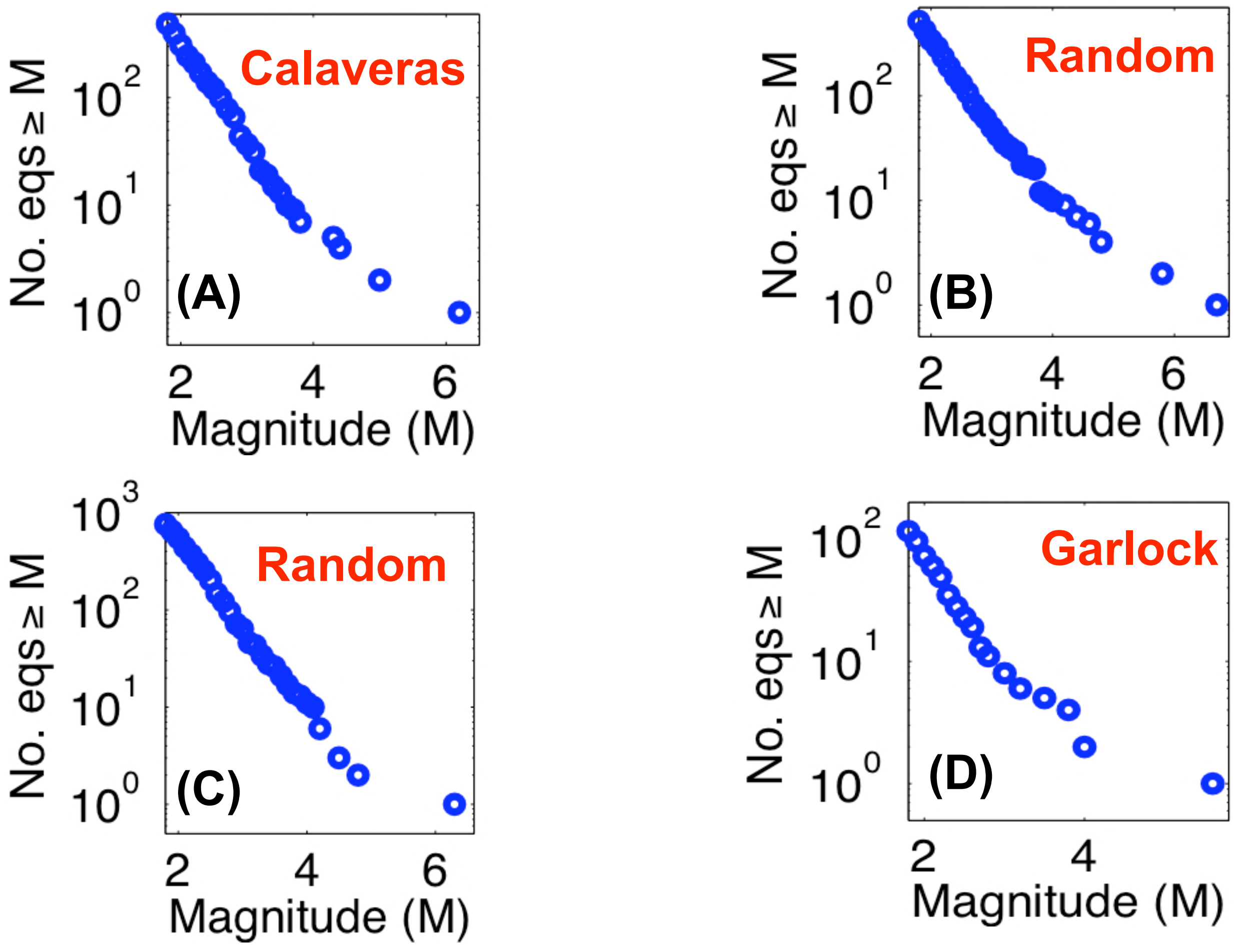
Quiz #2!

Identify the distributions taken from major fault zones



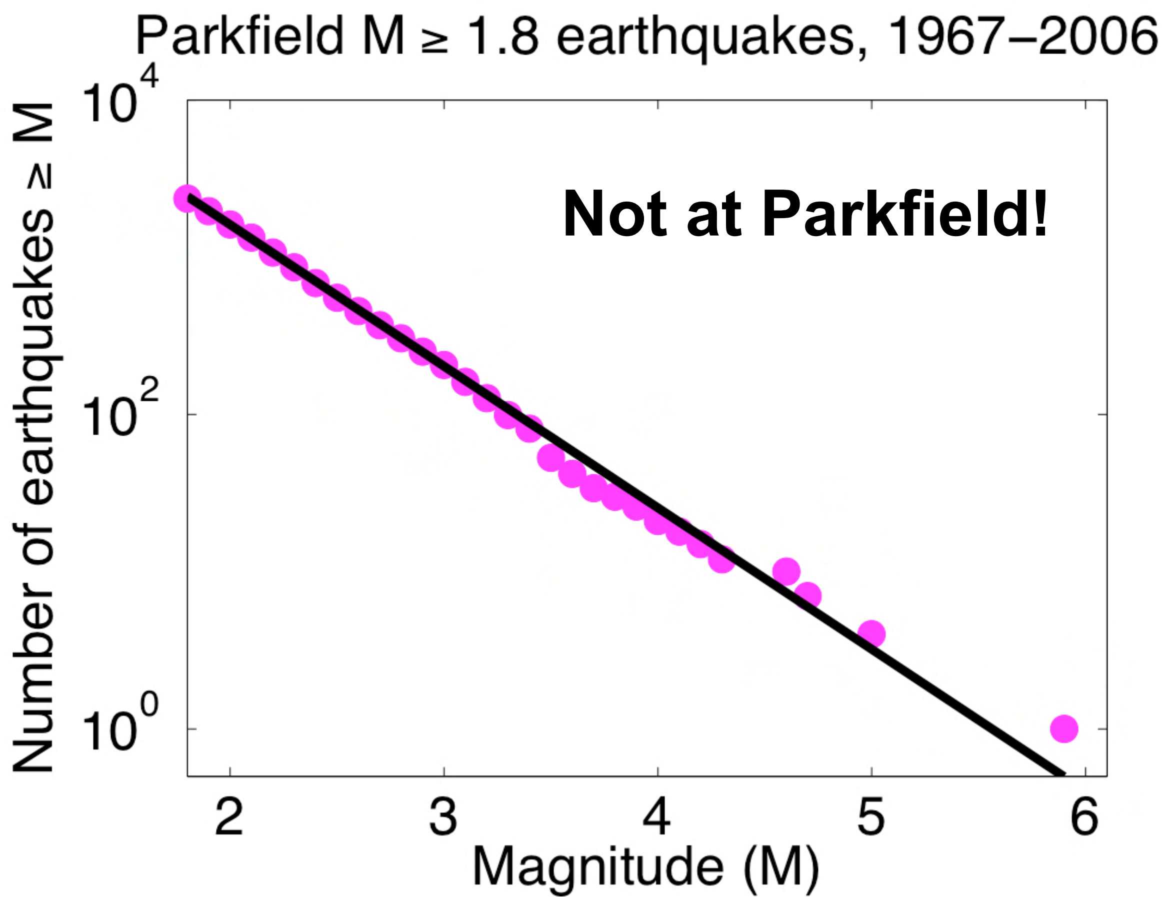
All distributions are purposely chosen around a large earthquake. All data from California, 1984-2004

Identify the distributions taken from major fault zones



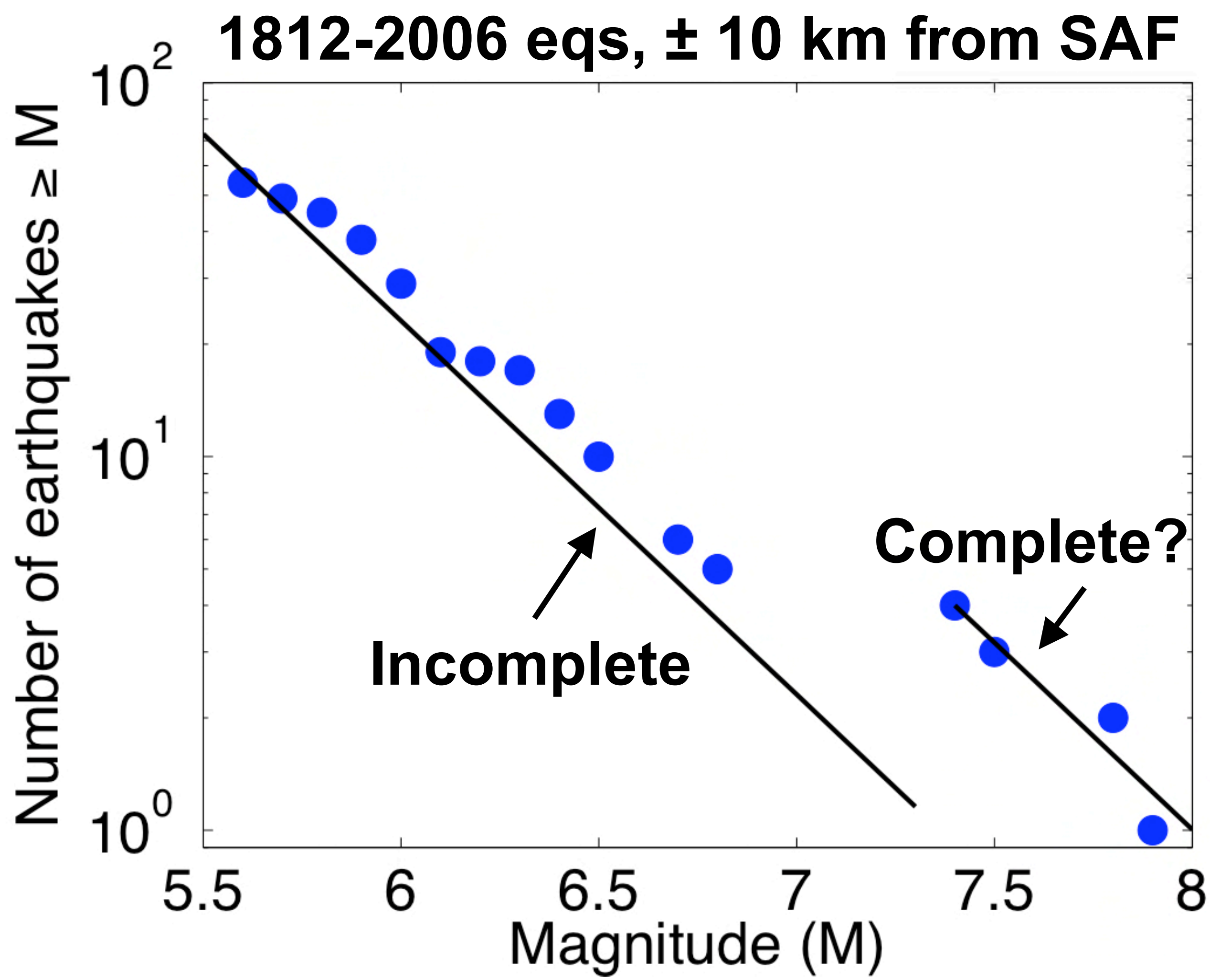
All of these earthquake distributions are purposely centered around a large earthquake in the catalog

But isn't the San Andreas clearly characteristic?



M 6 Parkfield earthquakes are simply an expected part of the G-R distribution (*Jackson and Kagan*, 2006)

The historic record along the full SAF



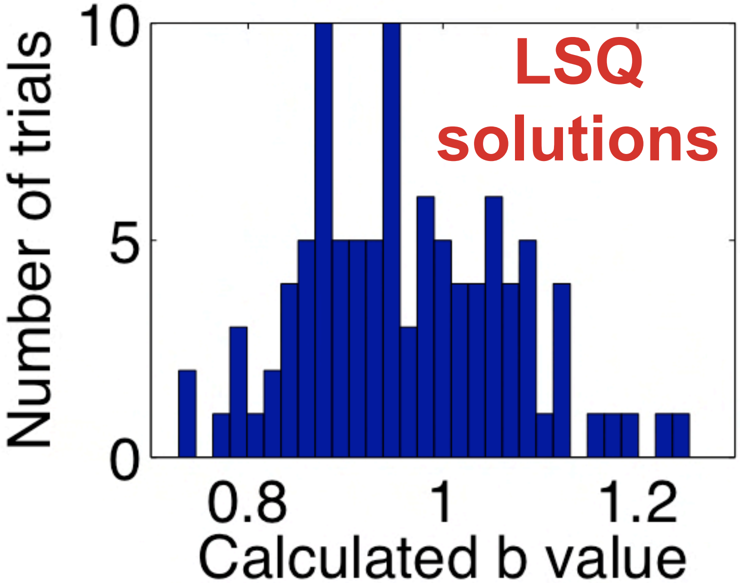
Catalog is too incomplete, short, and error-prone, but Gutenberg-Richter is suggested

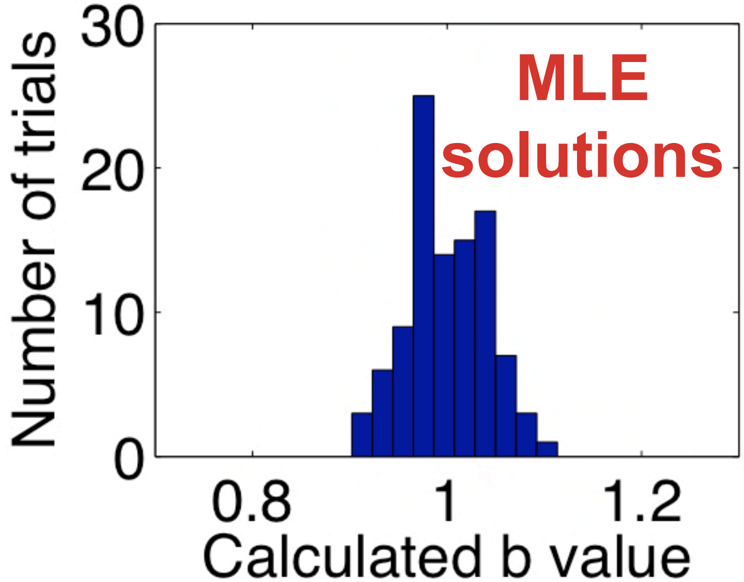
Conclusions

- Calculating an accurate *b* value is critical for hazard analysis, physical understanding.
- *b* value should be solved for with MLE and >2000 quality earthquakes above the catalog completeness threshold.
- There is no evidence for significant *b* value variation with location or on/off of major faults in California.

Error #1: Fitting with least squares rather than MLE

***b* value solved from 100 trials with 500 simulated earthquakes each; true *b*=1.0.**





- MLE solutions are closer to the true value of *b*

Why the value of *b* is important

Hazard Analysis: Small changes in b => large changes in projected numbers of major earthquakes

Example

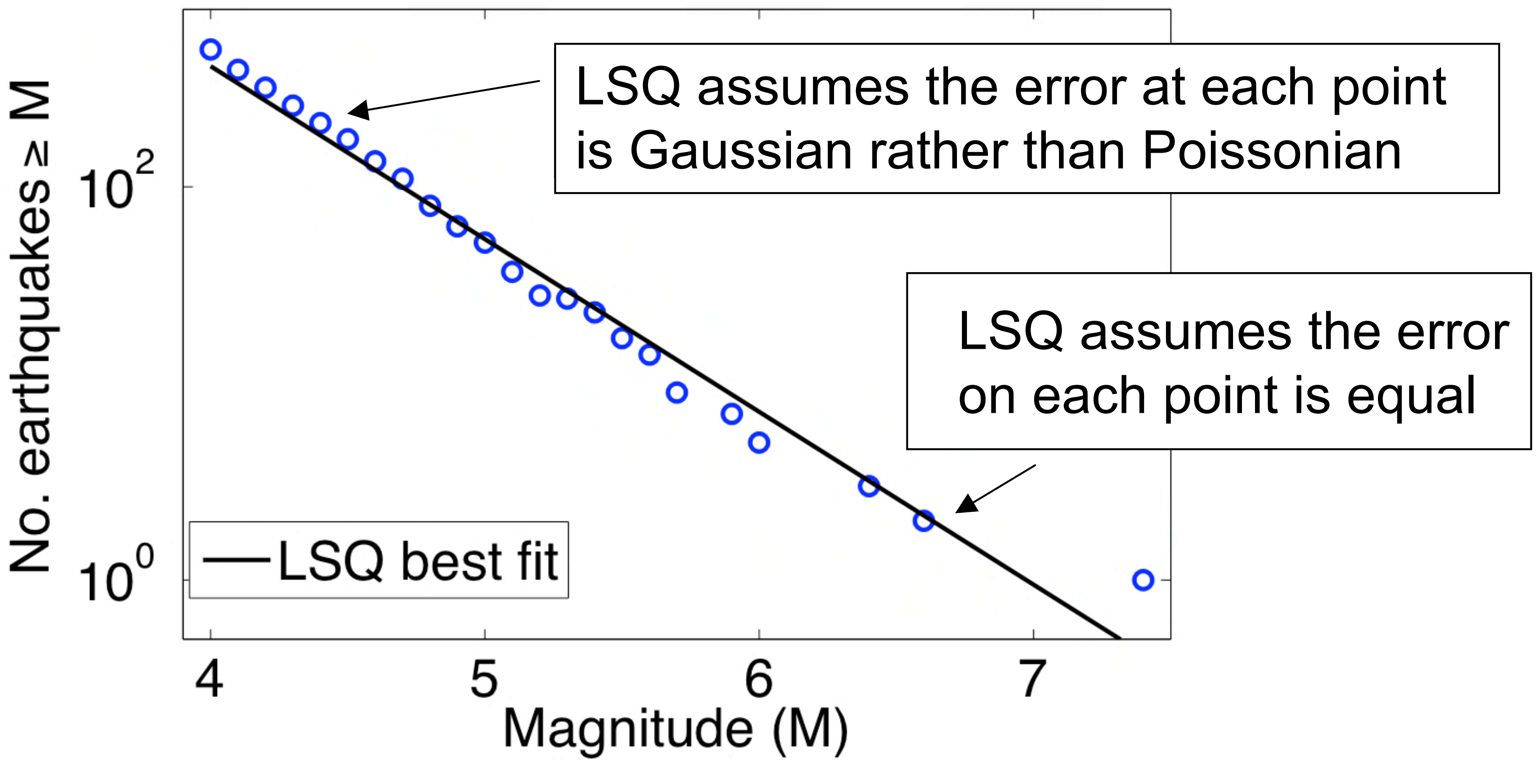
10,000 M ≥ 4 earthquakes

→ *b* = 1.0 → **10** M ≥ 7 eqs

→ *b* = 0.9 → **20** M ≥ 7 eqs

Earthquake Physics: The magnitude distribution reflects fundamental properties of how earthquakes grow and stop.

Error #1: Fitting with linear least squares (LSQ) rather than MLE



- LSQ is disproportionately influenced by the largest earthquakes
- MLE weighs each earthquake equally