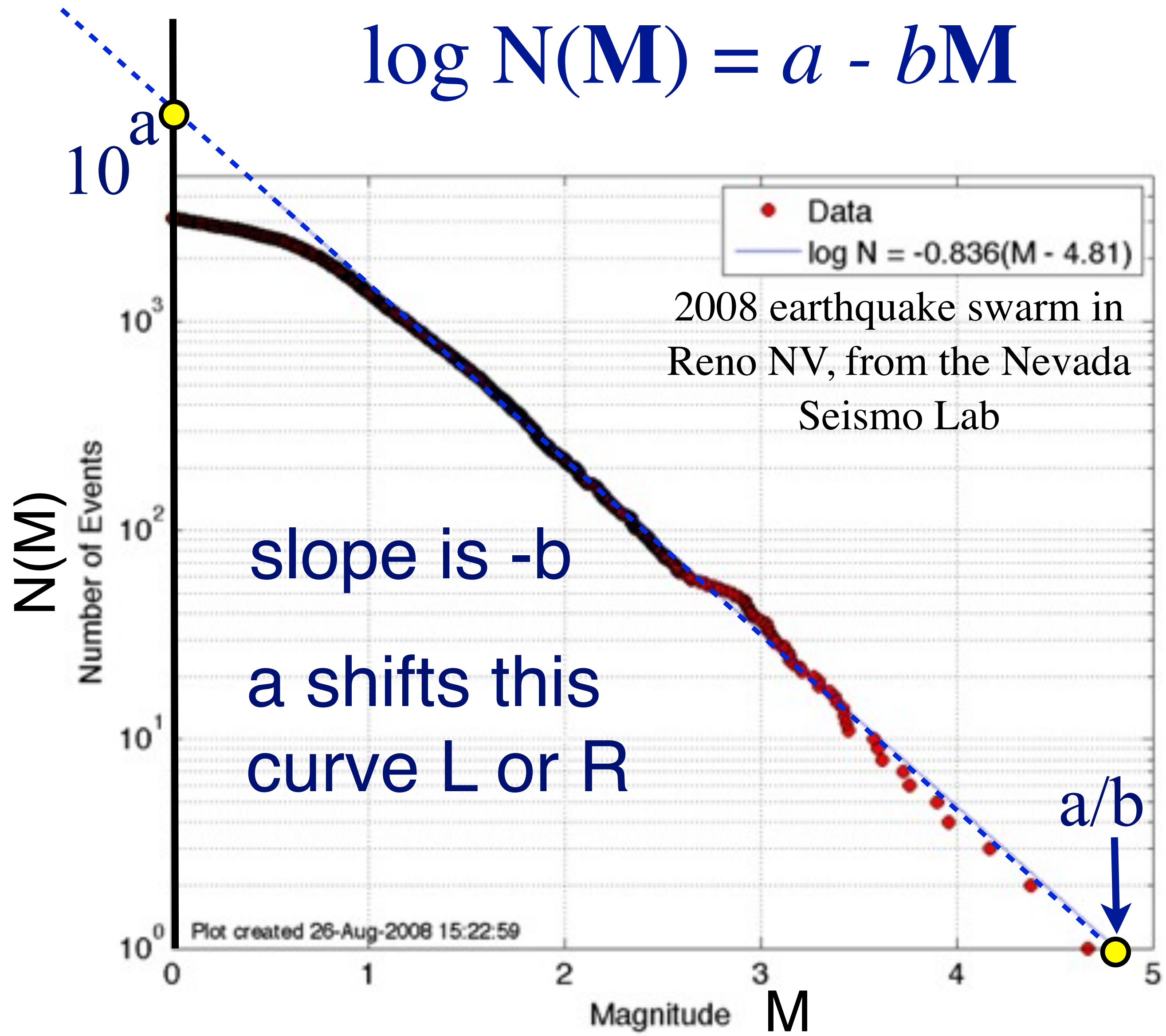
Gutenberg-Richter Relationship: Magnitude vs. frequency of occurrence

$$\log N(\mathbf{M}) = a - b\mathbf{M}$$



N(M) is number of earthquakes per year (usually) of magnitude M or LARGER

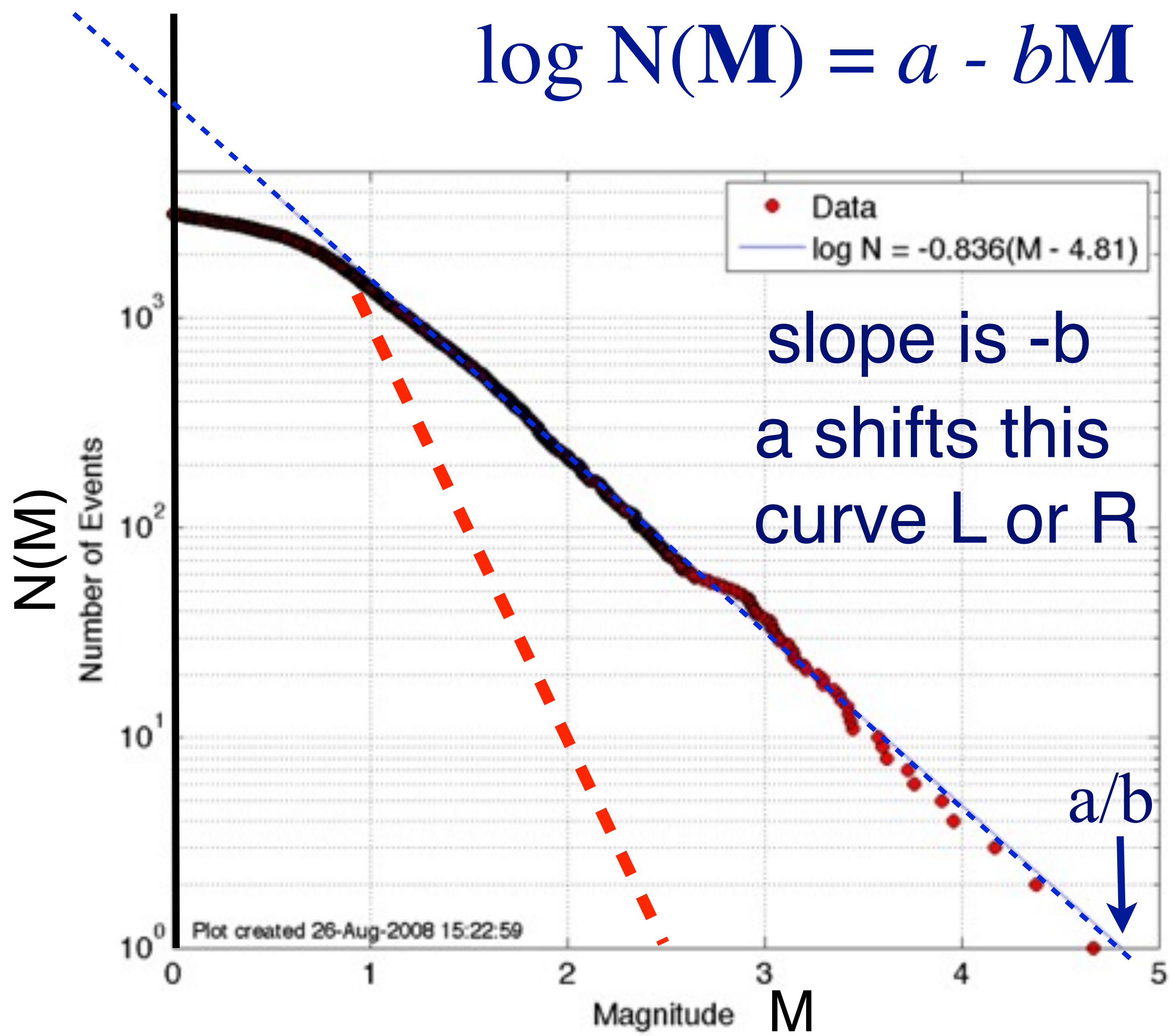
log is the base 10 log (not ln)

b is usually about 1 for tectonic earthquakes.
If data are for one year, then **a** tells us that on average once per year, a quake of magnitude (**a/b**) or bigger happens (**a** if b = 1).

How does a affect the total # of quakes?

Gutenberg-Richter Relationship: Magnitude vs. frequency of occurrence

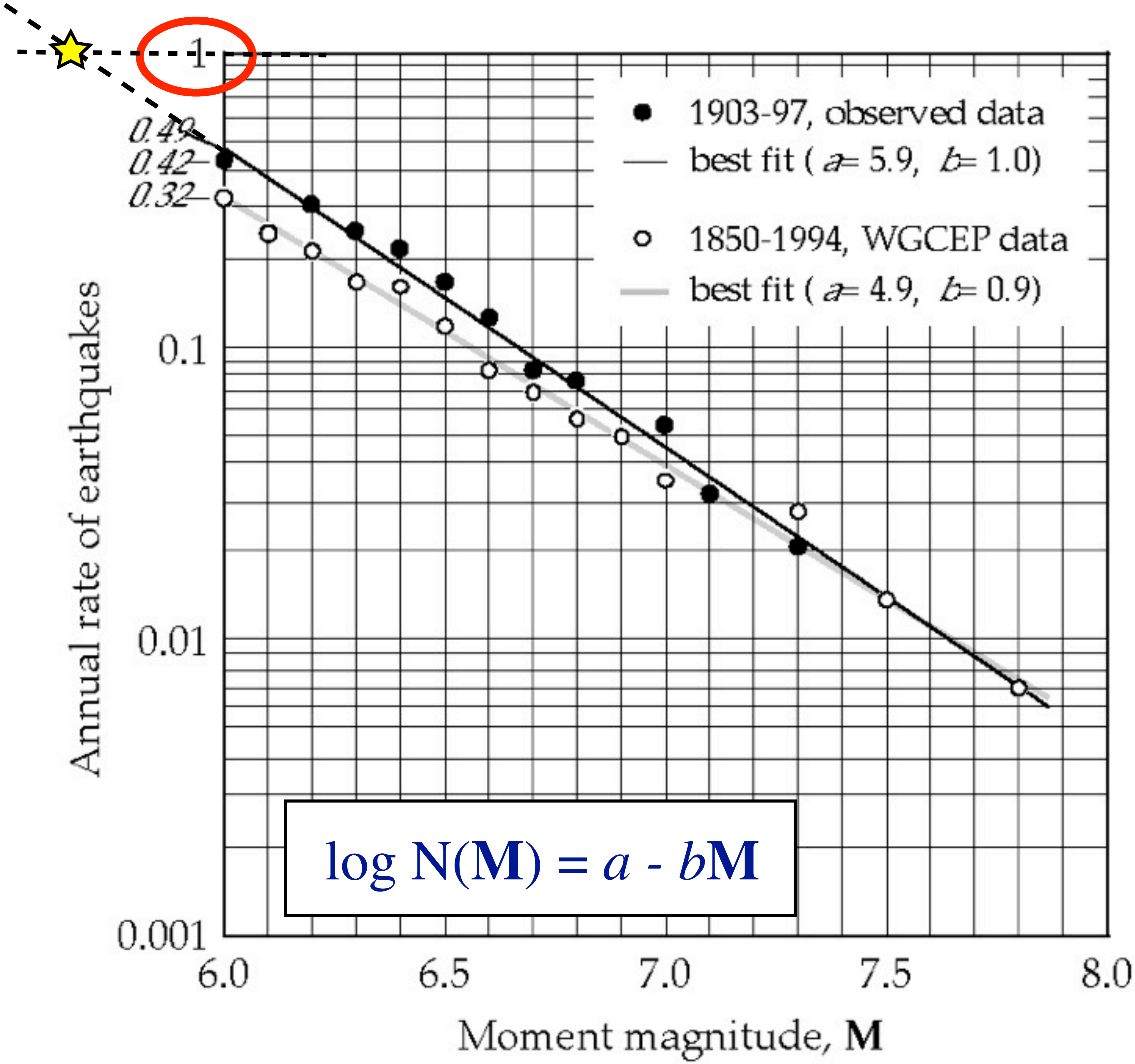
$$\log N(\mathbf{M}) = a - b\mathbf{M}$$



N(M) is number of earthquakes per year (usually) of magnitude M or LARGER

log is the base 10 log (not ln)

b is about 1 for tectonic earthquakes. It is about 2 for volcanic earthquakes and some earthquake swarms. What does this tell us about the distribution of earthquake sizes on volcanoes?



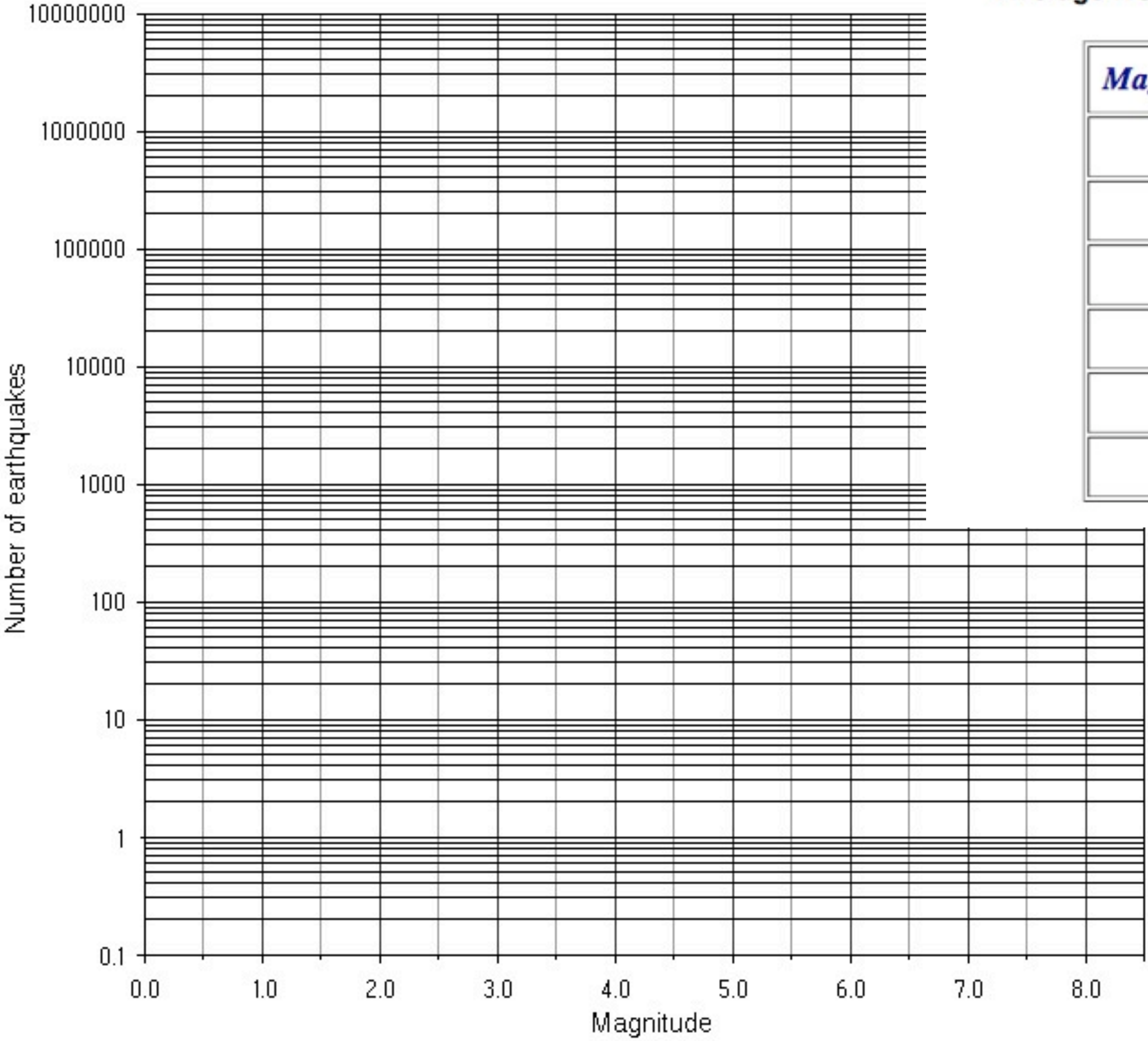
Southern California earthquake data R. Stein and T. Hanks, USGS

Here, note that M = **a/b** is off to the left (these data are for quakes that happen less than once per year).

What's the magnitude of the once per year quake for each dataset?

Use of these plots: predicting how often big ones occur (we need to know the maximum size)

Make the G-R plot for worldwide earthquakes



Average Worldwide Seismicity Totals for a Single Year

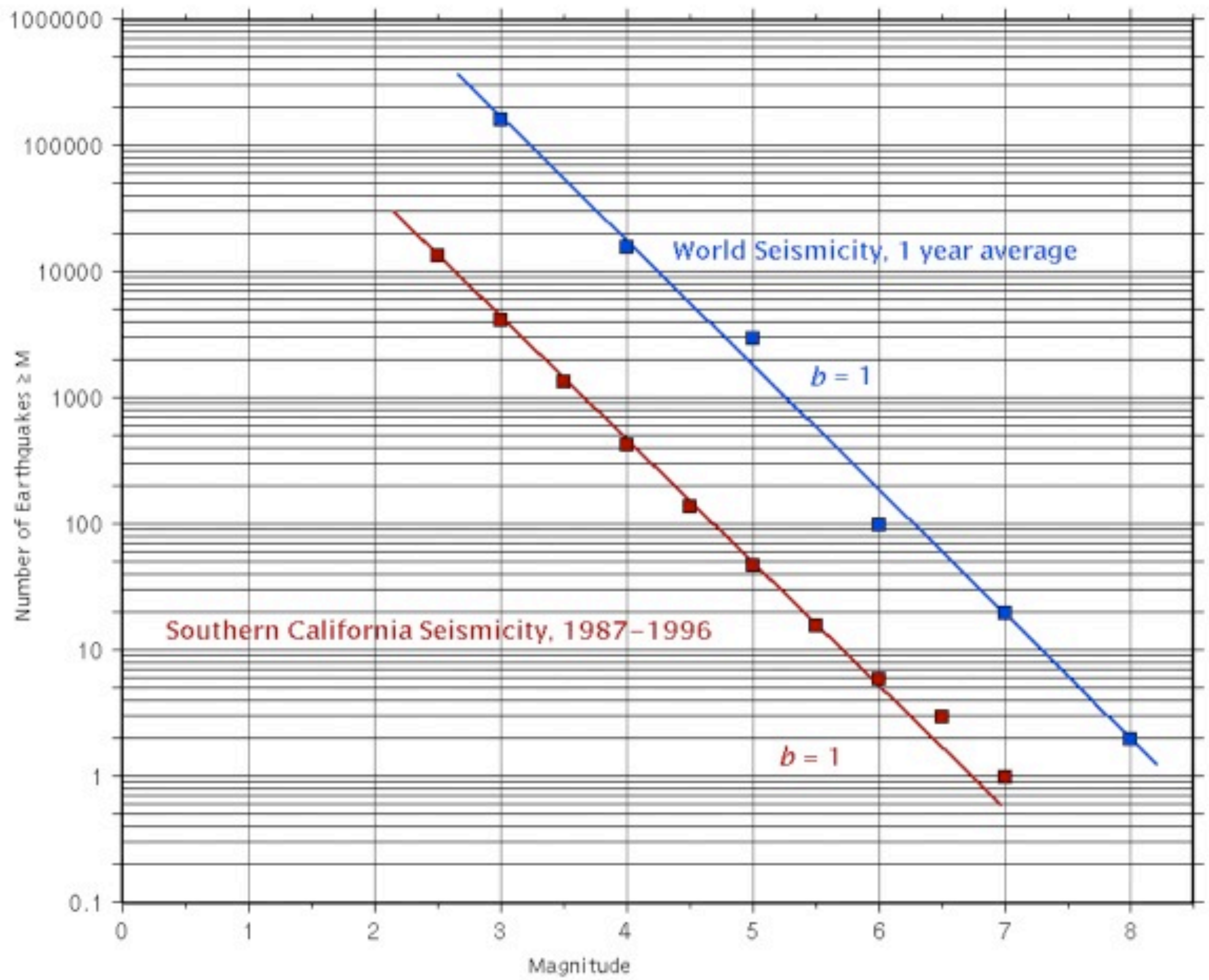
Magnitude (M)	***# Greater Than M***
3.0	100000 +
4.0	15000
5.0	3000
6.0	100
7.0	20
8.0	2

$$\log N(\mathbf{M}) = a - b\mathbf{M}$$

What is b?
What is a/b?
What is a?

Each year there is one quake with magnitude ___ or higher (on average).

Southern California Earthquake Center



$$\log N(\mathbf{M}) = a - b\mathbf{M}$$

Southern California Earthquake Center

Quakes per year. Major = 7-7.9; Great = 8 or larger.

Year	Major quakes	Great quakes
1969	15	1
1970	20	0
1971	19	1
1972	15	0
1973	13	0
1974	14	0
1975	14	1
1976	15	2
1977	11	2
1978	16	1
1979	13	0
1980	13	1
1981	13	0
1982	10	1
1983	14	0
1984	08	0
1985	13	1
1986	05	1
1987	11	0
1988	08	0

Year	Major quakes	Great quakes
1989	06	1
1990	18	0
1991	16	0
1992	13	0
1993	12	0
1994	11	2
1995	18	2
1996	14	1
1997	16	0
1998	11	1
1999	18	0
2000	14	1
2001	15	1
2002	13	0
2003	14	1
2004	13	2
2005	10	1
2006	9	2
2007	14	4
2008	12	0
2009	16	1
2010	21	1

http://earthquake.usgs.gov/earthquakes/eqarchives/year/eqstats.php

characteristic earthquake

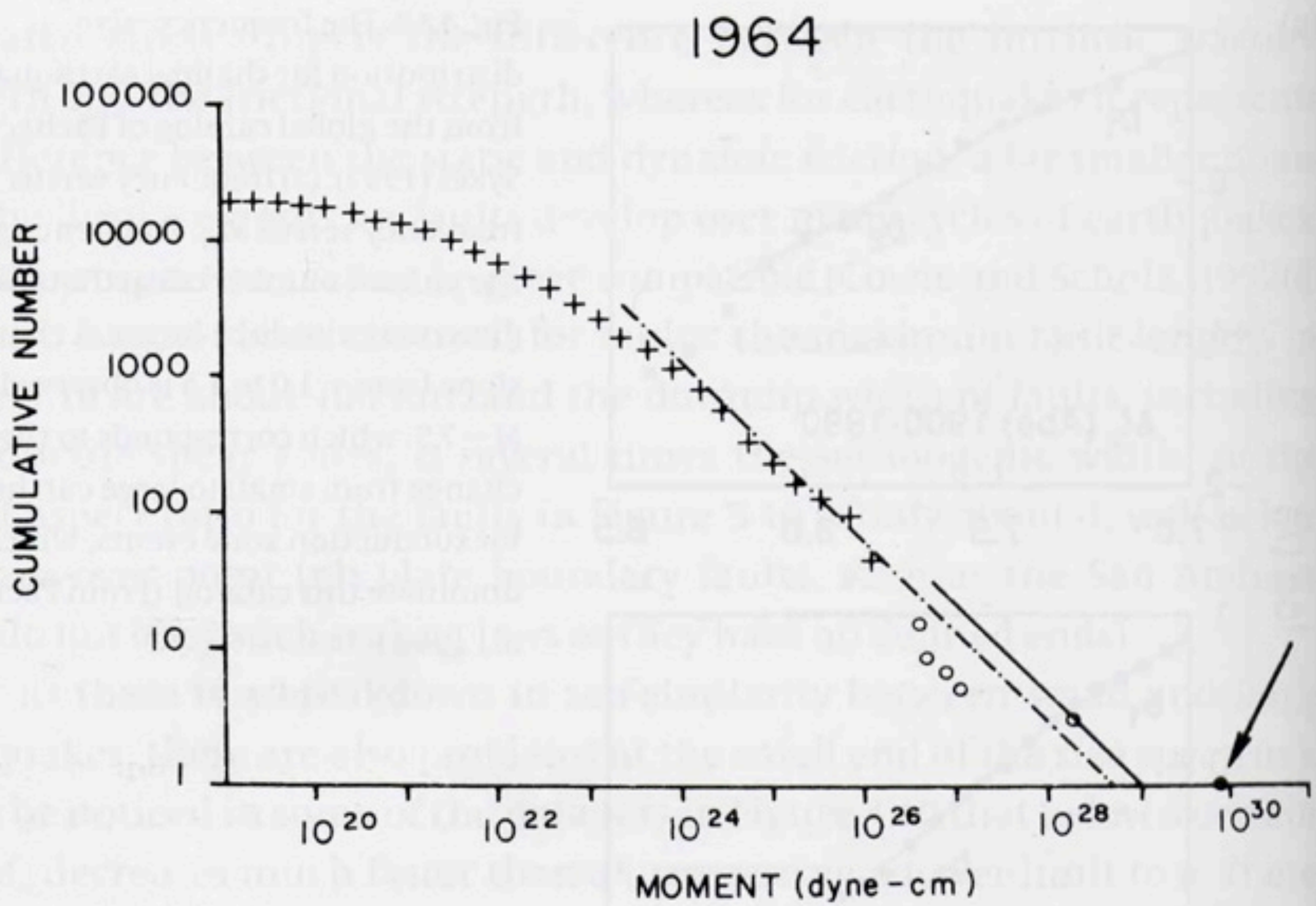


Fig. 4.13. Distribution of small earthquakes within the rupture zone of the 1964 Alaska earthquake, normalized to the recurrence time of that earthquake. The 1964 earthquake is indicated by an arrow. Notice that it is about 1½ orders of magnitude larger than the extrapolation of the small earthquakes would indicate. The rolloff at $M_0 < 3 \times 10^{23}$ dyne cm is caused by the loss of perceptibility of smaller events. (From Davison and Scholz, 1985.)

Scholz 2002

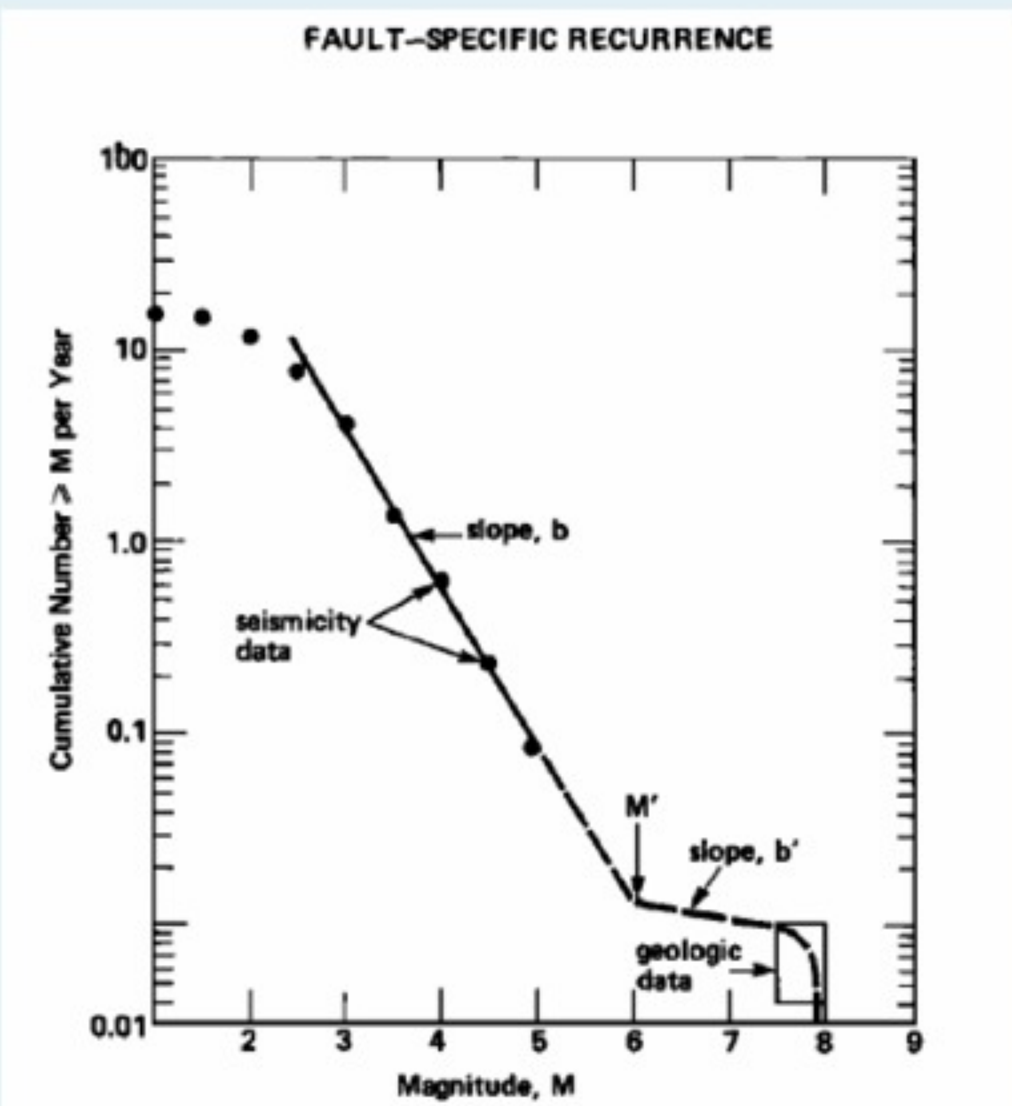
characteristic earthquake

on faults with characteristic earthquakes, G-R seismicity statistics work for all but the giant "characteristic earthquake"

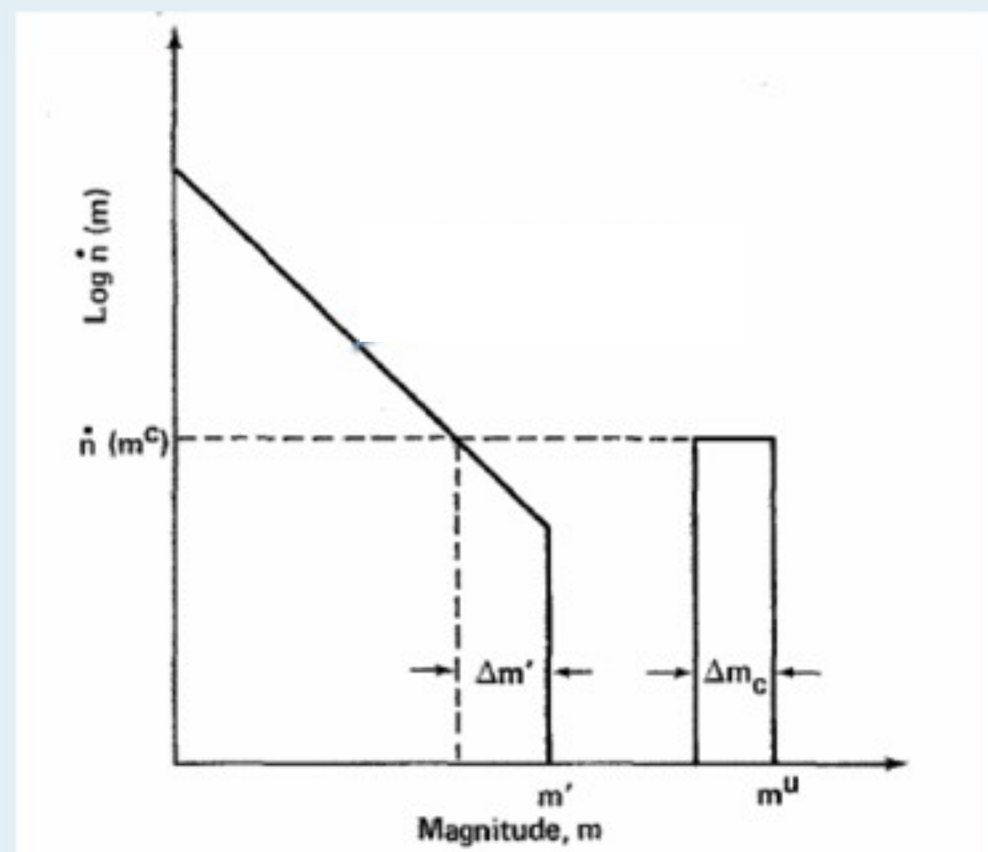
this earthquake has a characteristic magnitude and occurs more frequently than GR would suggest

example: Cascadia subduction zone: M9+ earthquakes

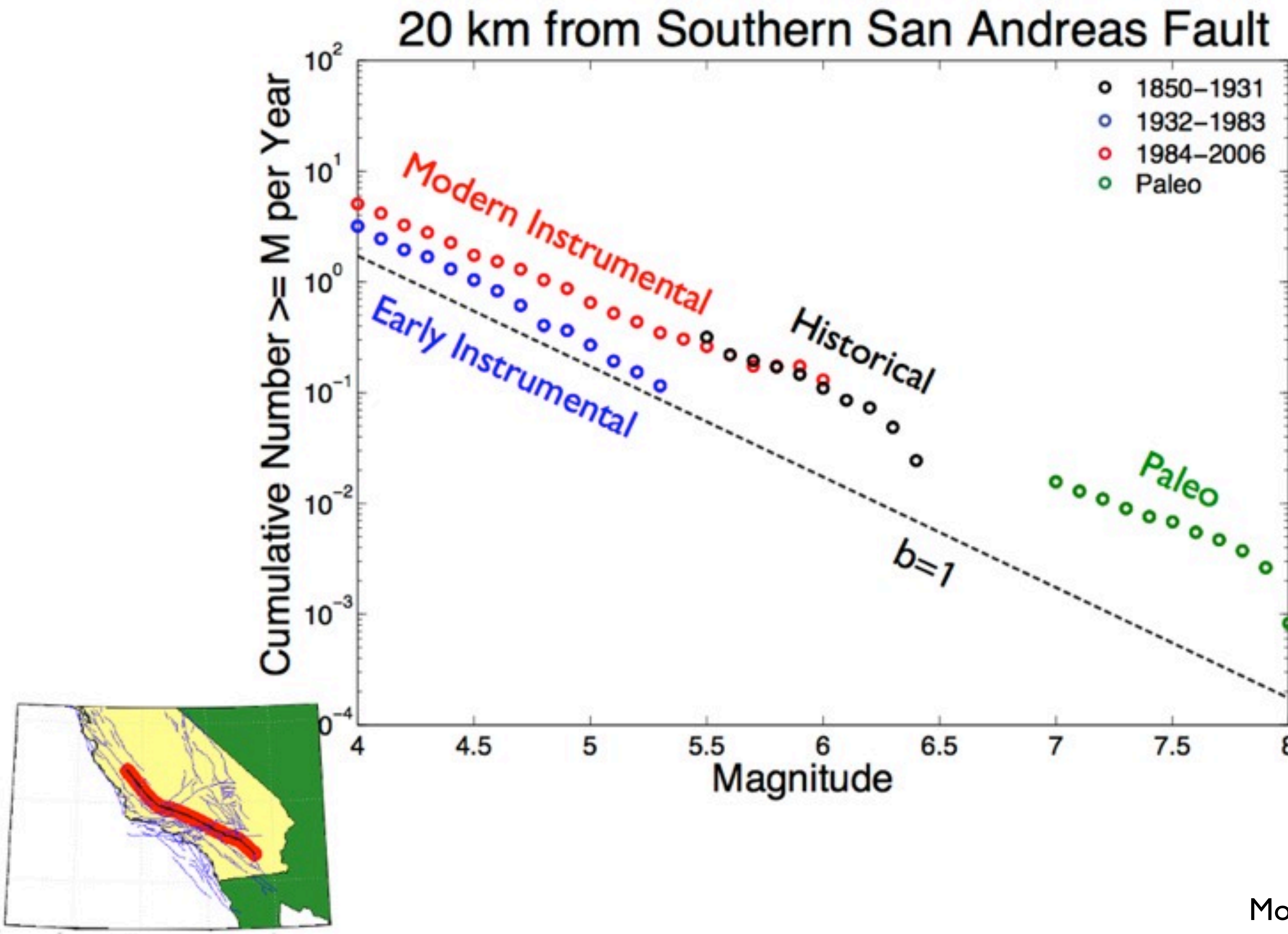
Schwartz and Coppersmith (1984)



Youngs and Coppersmith (1985)



People are still arguing about whether the SAF has characteristic earthquakes or not. Seems to depend on which quakes you count (just on the fault? or in some region surrounding the fault, too?) Reason to count off-fault quakes: a big SAF quake could start on another nearby fault (several recent examples)



Morgan Page, 2010

Why does the curve flatten for small magnitudes?

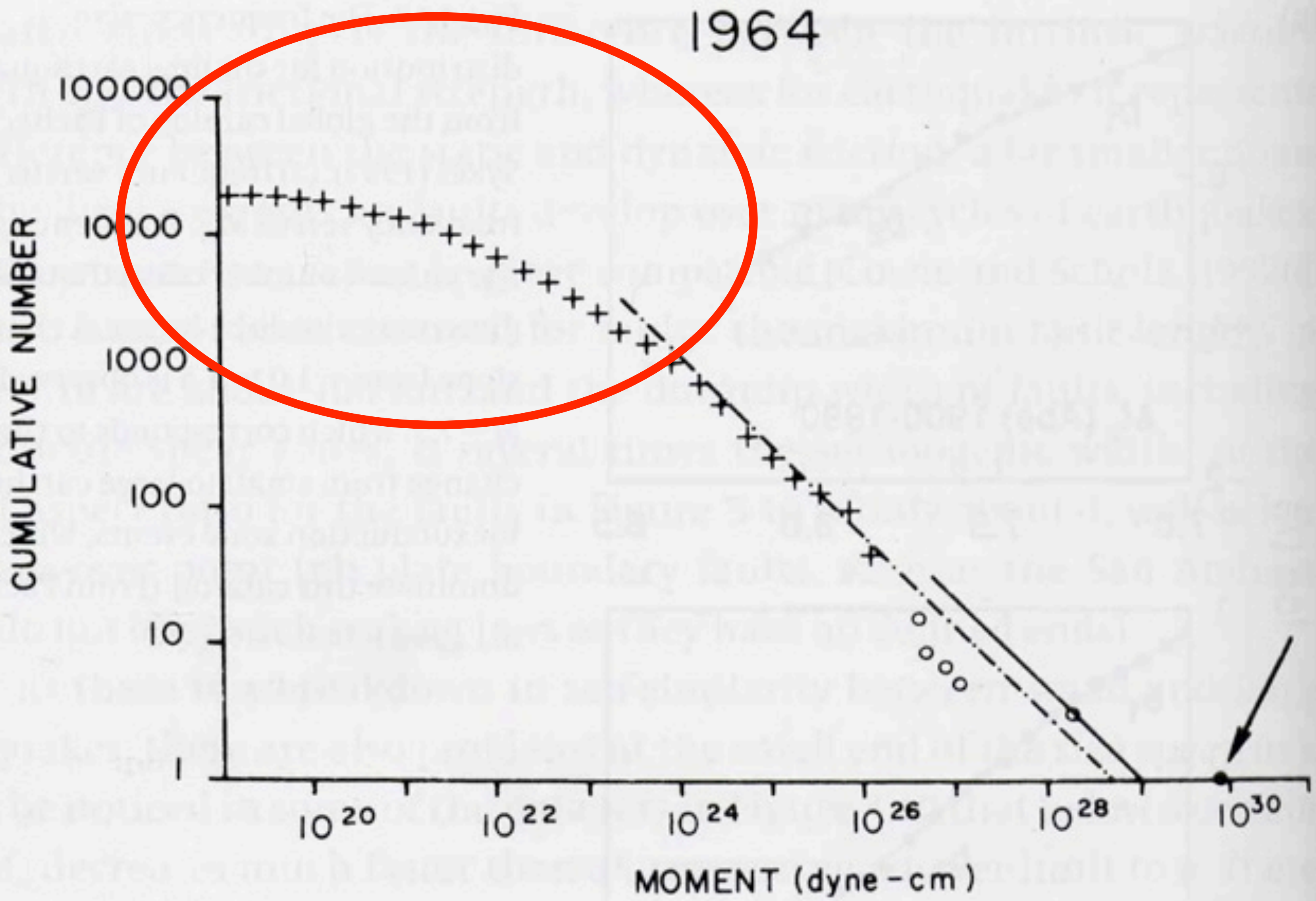
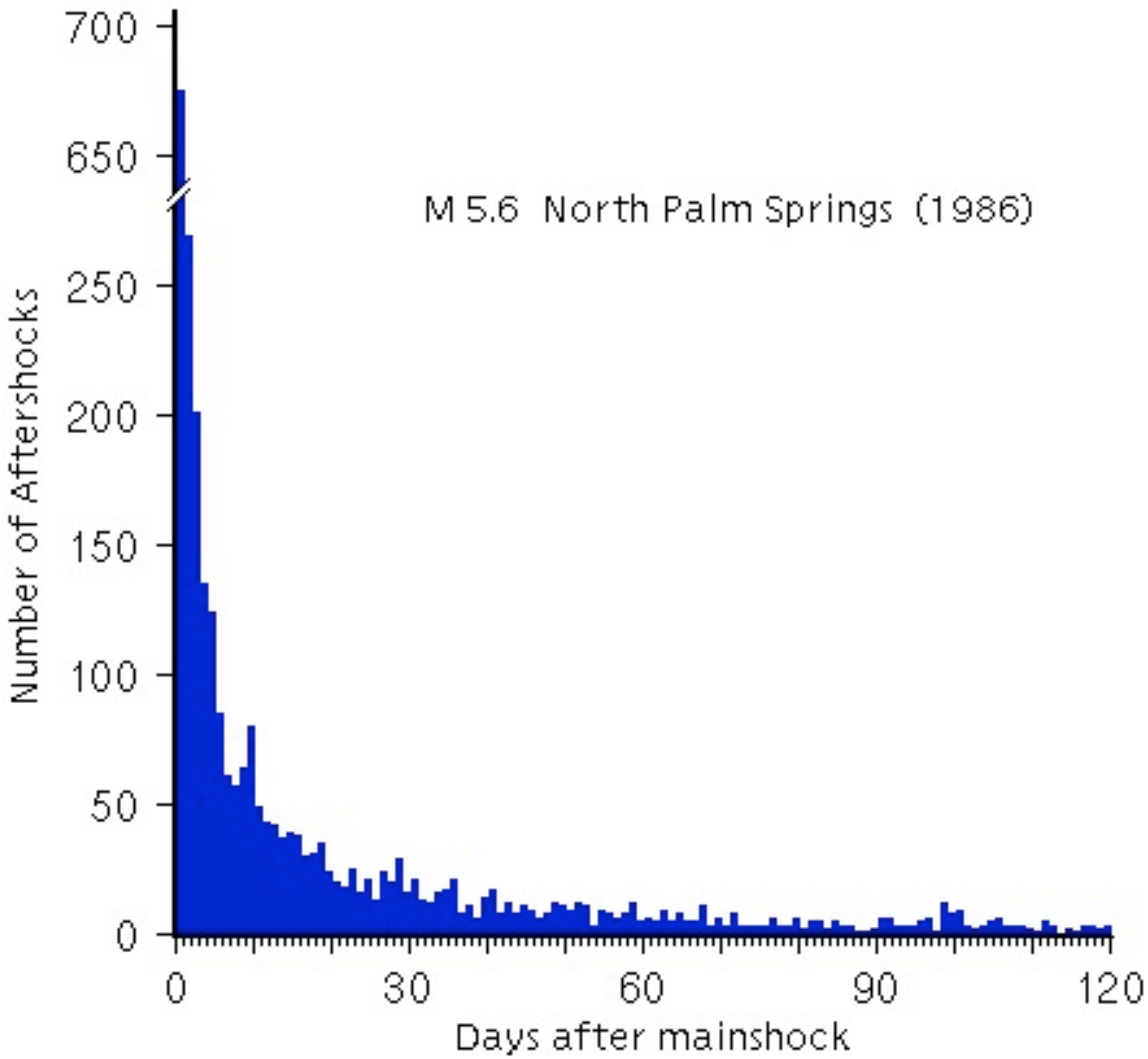


Fig. 4.13. Distribution of small earthquakes within the rupture zone of the 1964 Alaska earthquake, normalized to the recurrence time of that earthquake. The 1964 earthquake is indicated by an arrow. Notice that it is about 1½ orders of magnitude larger than the extrapolation of the small earthquakes would indicate. The rolloff at $M_0 < 3 \times 10^{23}$ dyne cm is caused by the loss of perceptibility of smaller events. (From Davison and Scholz, 1985.)

Aftershocks: Omori's Law

$$N_{(t)} = \frac{k}{(t+c)^p}$$

p is approximately 1 (can vary)
c is small (keeps the denominator above zero)
k is the number of aftershocks on day one (1st 24 hours)



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If k is 100 then 100 on Day 1

100/2 = 50 on Day 2

100/3 = 50 on Day 3

100/4 = 50 on Day 4

What is k on this plot?

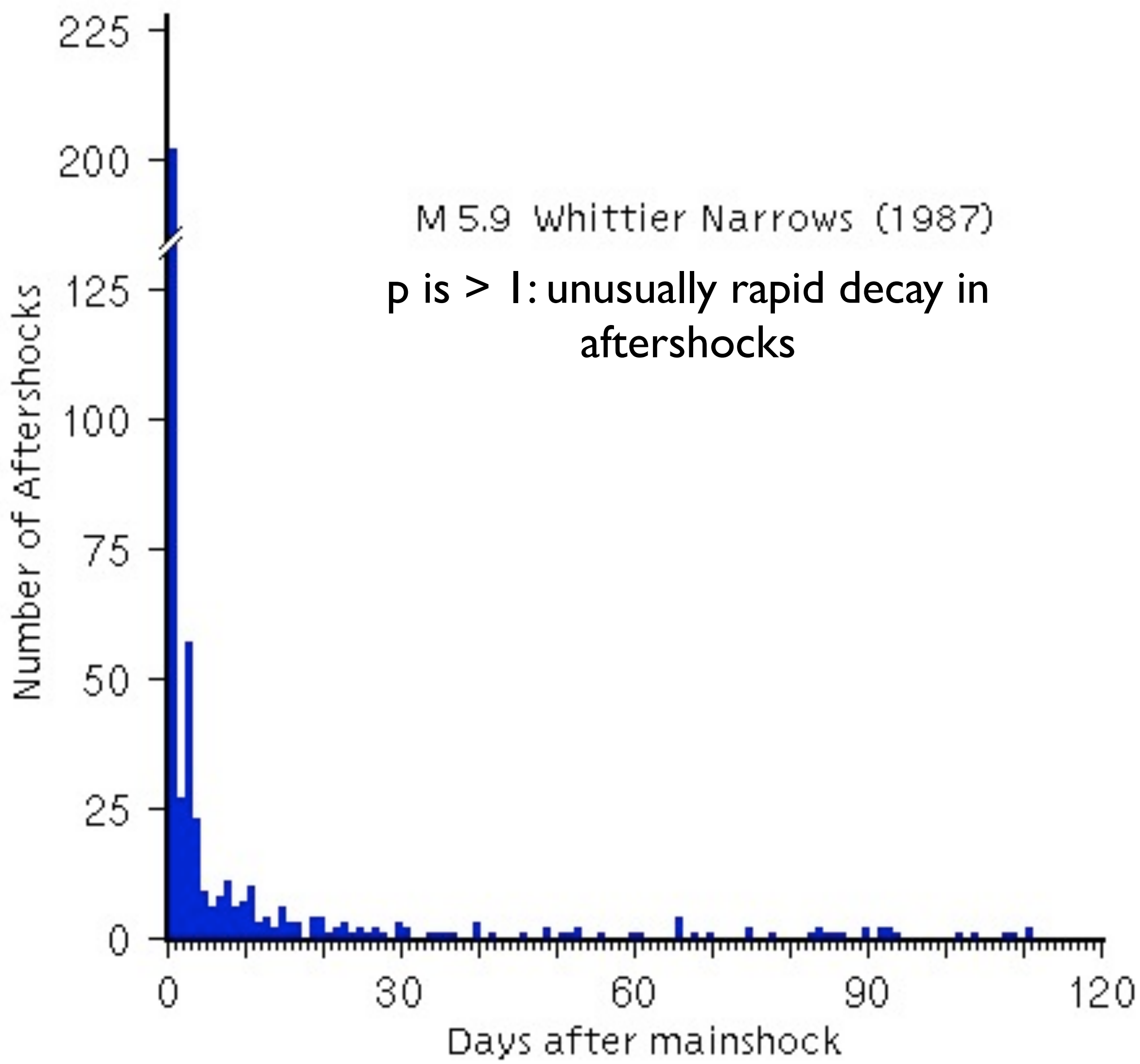
How many quakes per day one week later, according to Omori's Law?

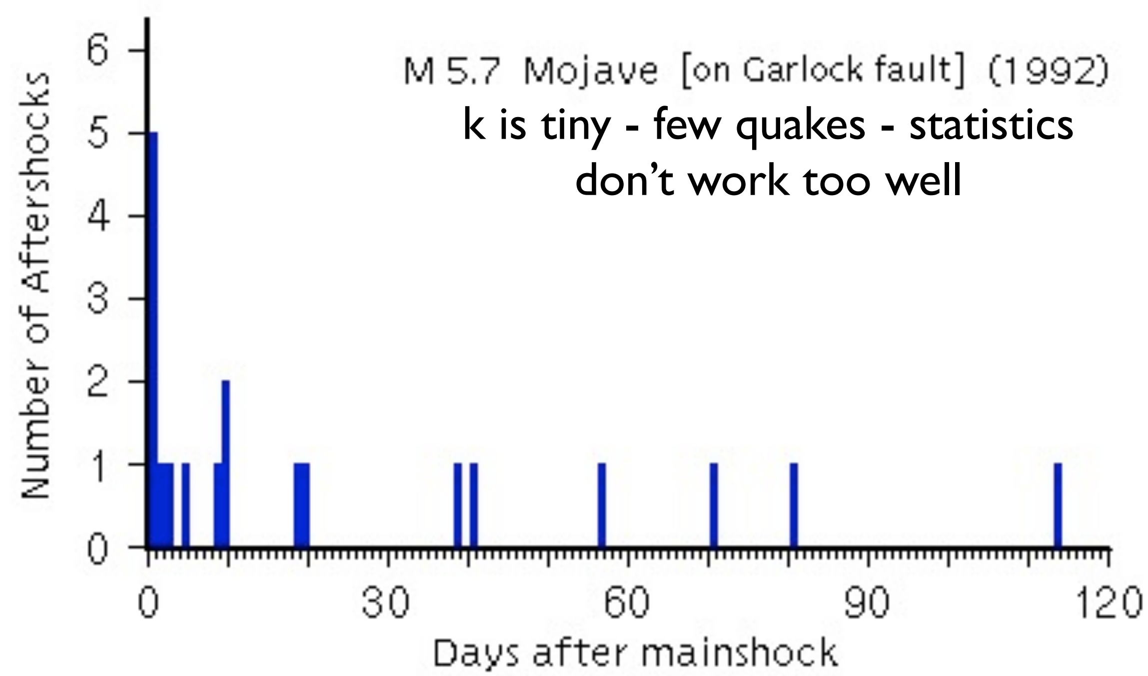
How many quakes per day one month later? Consistent with the data?

YMMV: different quakes have different aftershock productivity (and sometimes different decay rate)

$$N_{(t)} = \frac{k}{(t+c)^p}$$

p is approximately 1 (can vary)
c: small number (keeps the denominator above zero)
k is the number of aftershocks on day one





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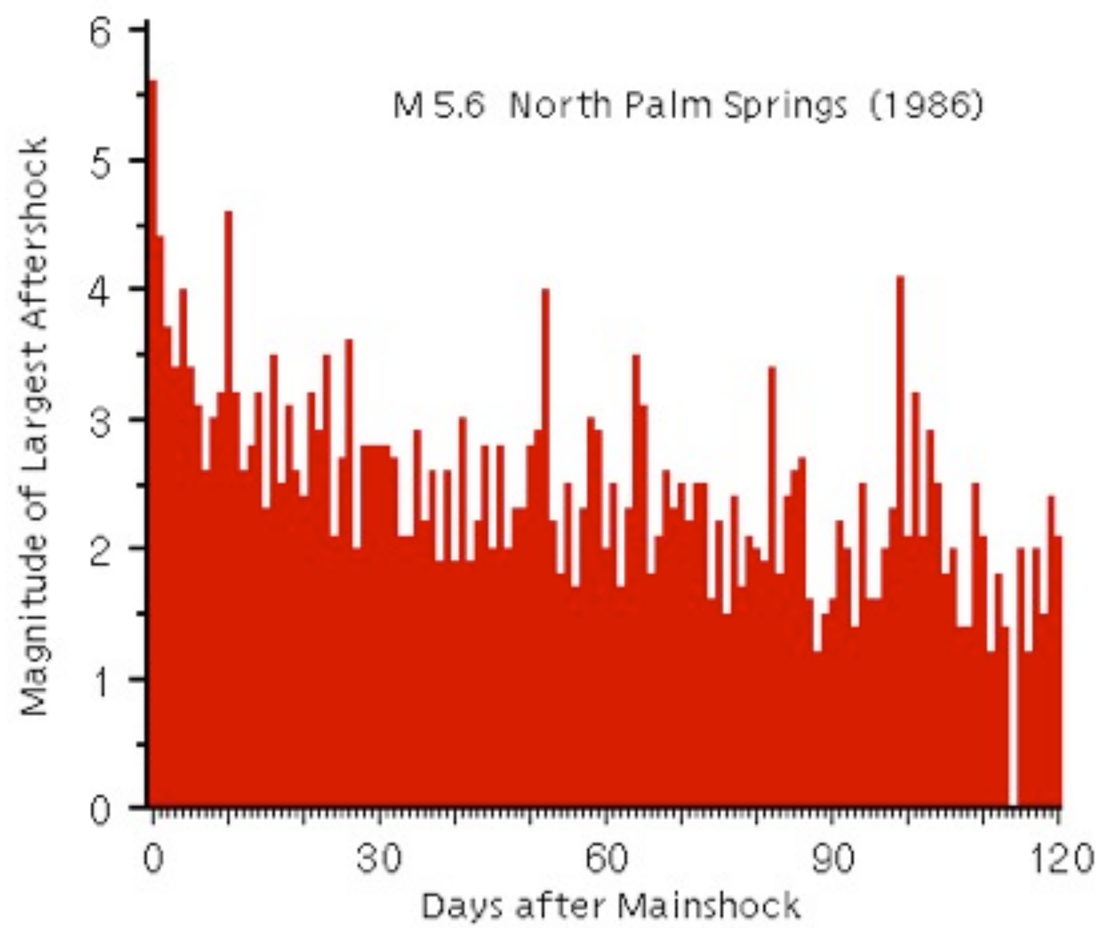
Bath's Law: the largest aftershock is 1 magnitude unit smaller than the mainshock

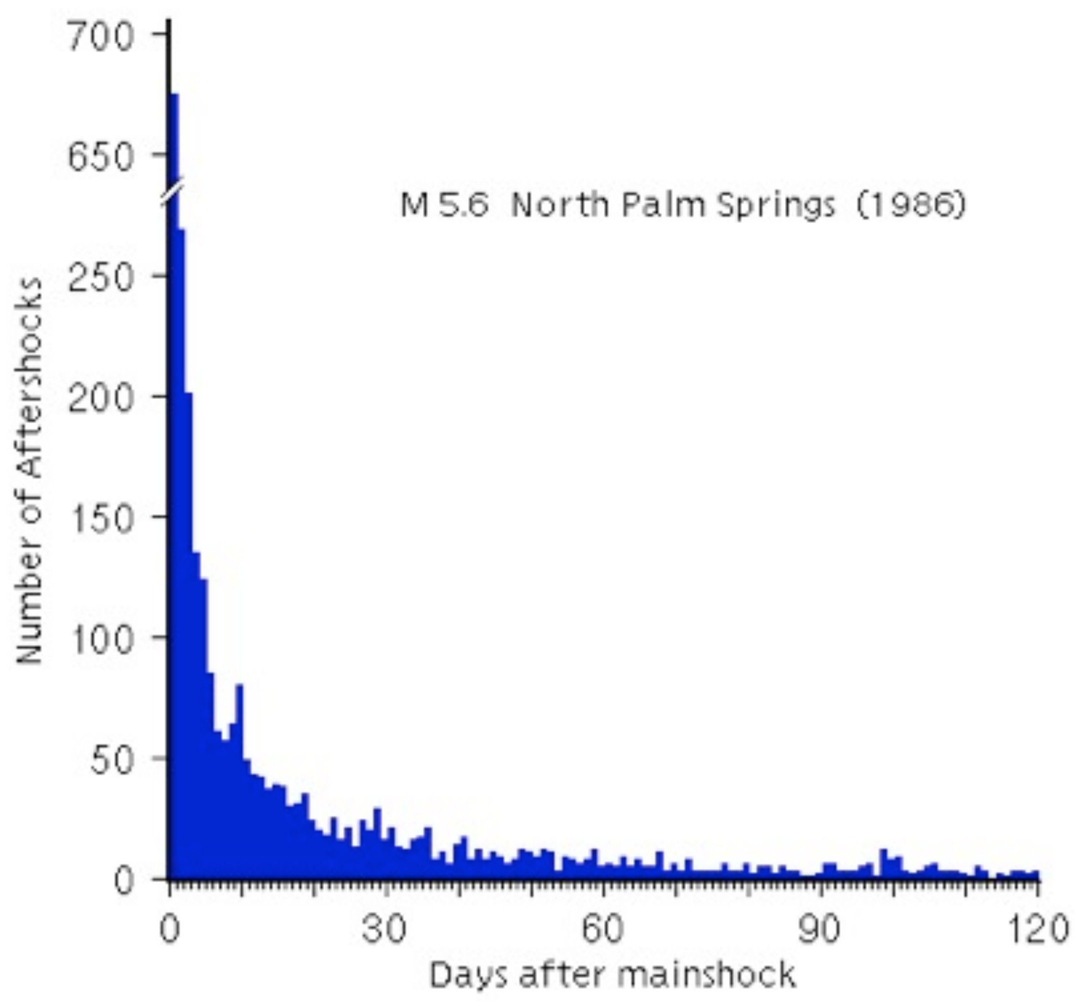


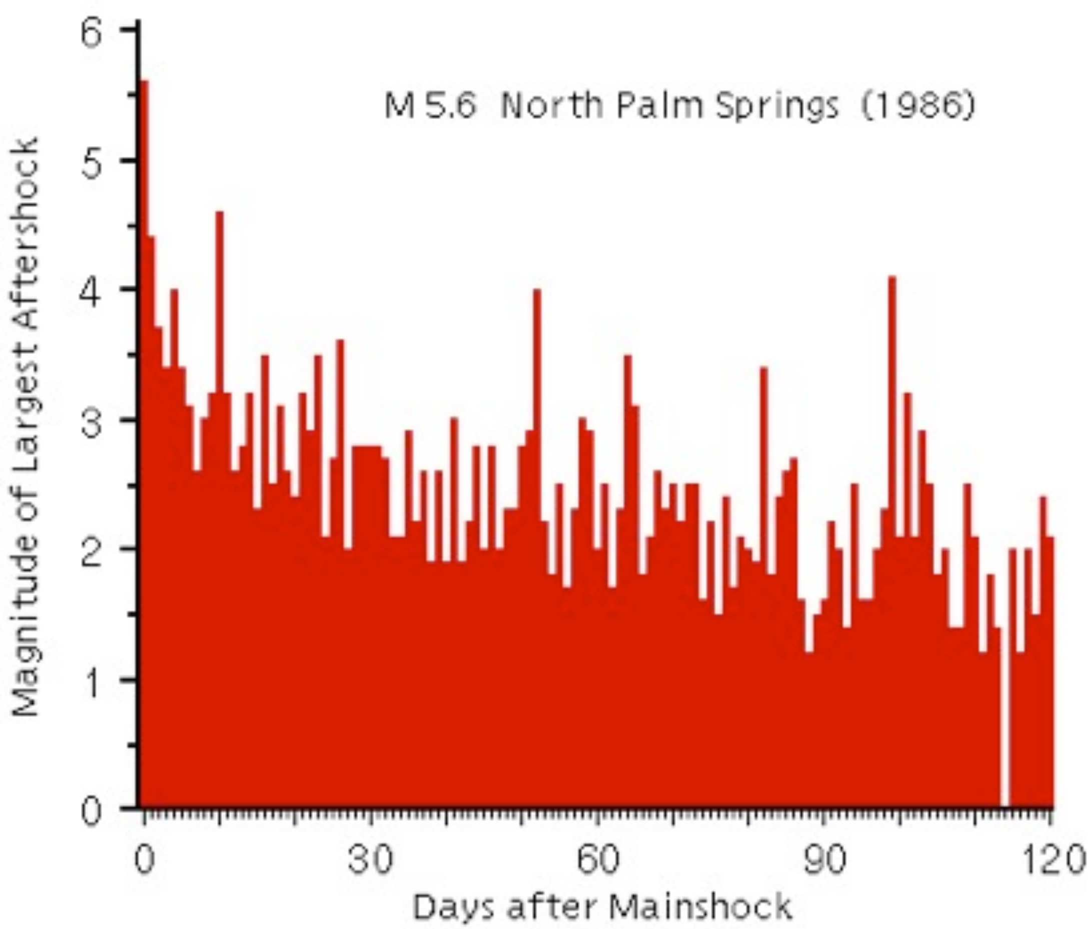
Does not work for every quake but seems to be true on average

Does it work for this one?

Combining GR statistics with Omori's Law gives probability of aftershocks with particular magnitudes, during specific time intervals after a big quake

I predict that you will see this in a future homework assignment





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