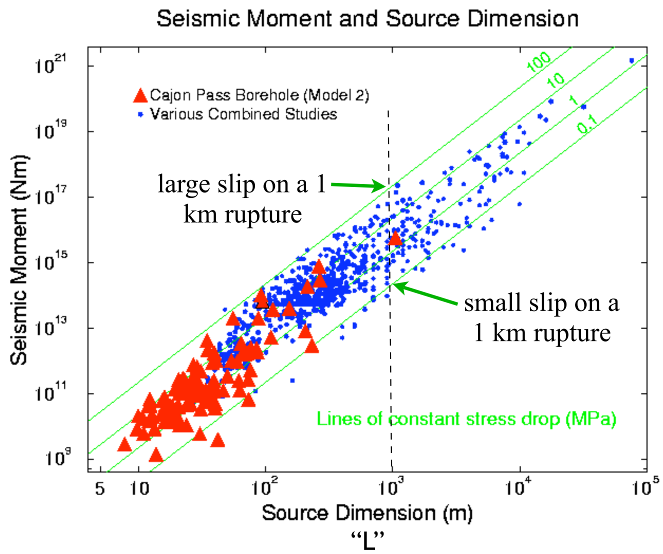
Shear stress drop $\Delta\tau$ seems insensitive to magnitude



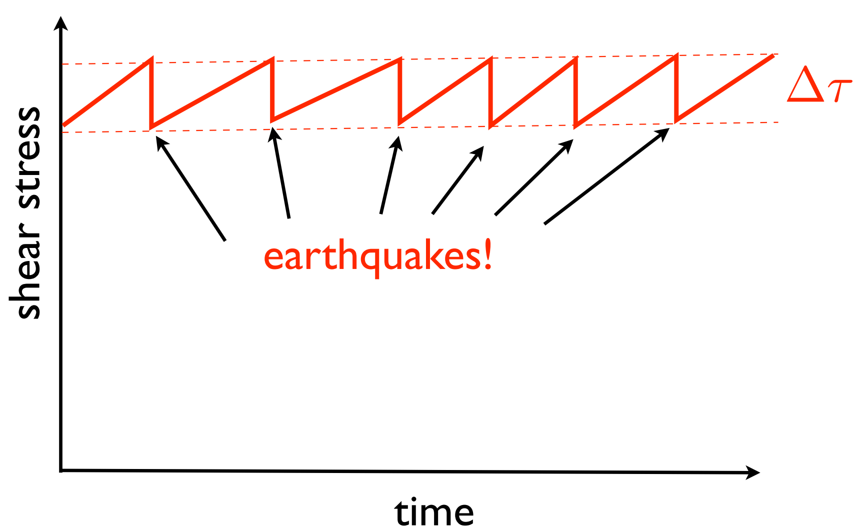
typical $\Delta\tau$ is 1 to 10 MPa

$\Delta\tau$ is proportional to (slip/L)

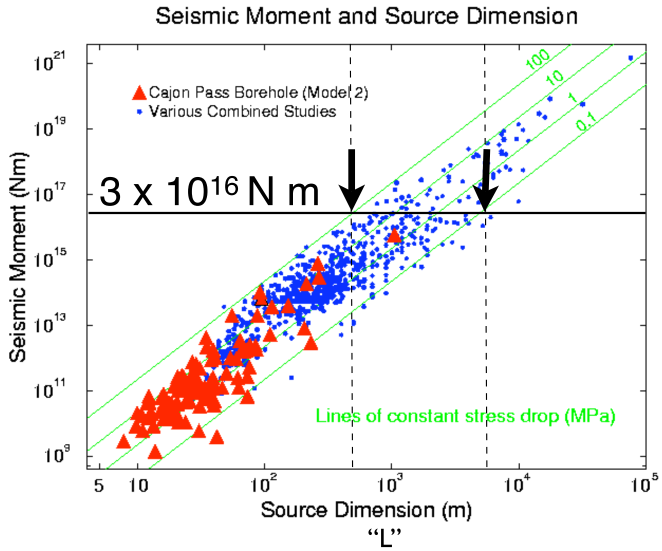
typical $\Delta\tau$ is 1 to 10 MPa

in a large earthquake, this stress drop occurs over a larger area

$\Delta\tau$ can be spatially variable



A range of slip values is possible for a given rupture size - this controls $\Delta\tau$



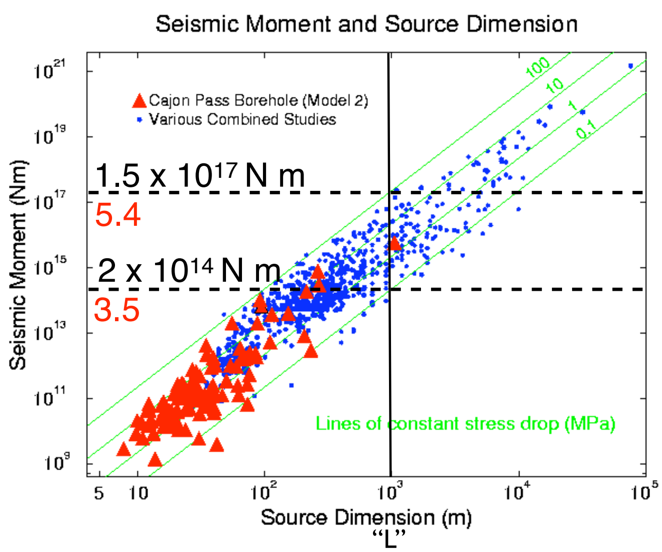
what is the range of dimensions and average slip values for a M5 earthquake?

$\log M_o = 1.5(M_w + 6.0333)$

$M_w = \log M_o/1.5 - 6.0333$

$M_o = AsG$

A range of magnitudes are possible for a given rupture size



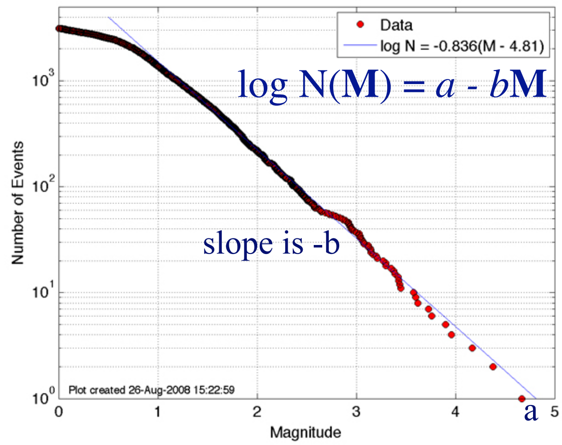
what is the range magnitudes for an earthquake rupture that is about 1 km long?

$\log M_o = 1.5(M_w + 6.0333)$

$M_w = \log M_o/1.5 - 6.0333$

$M_o = AsG$

Gutenberg-Richter Plots: Magnitude vs. how frequent

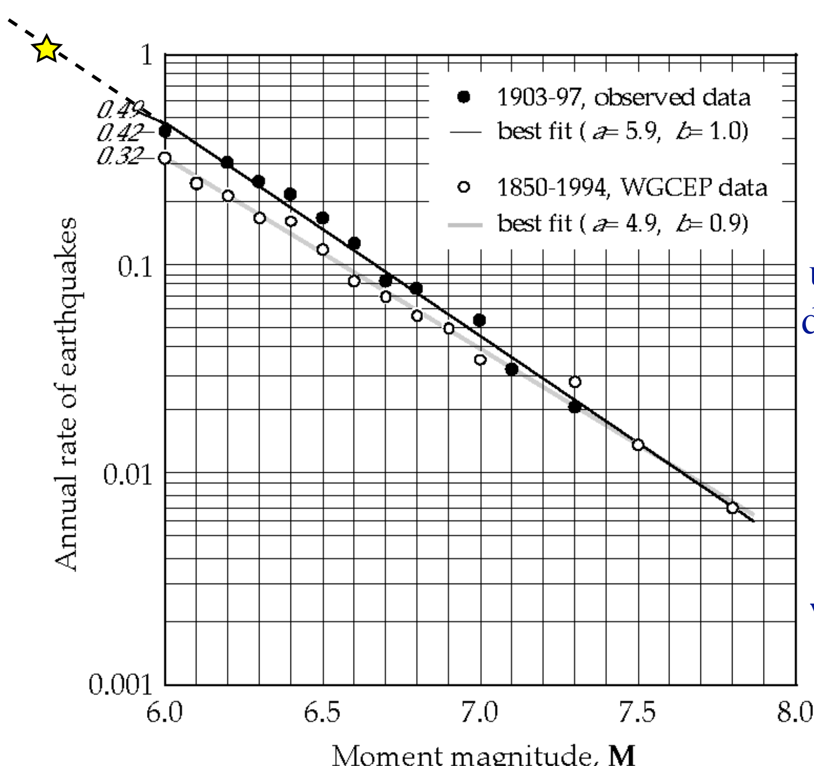


2008 earthquake swarm in Reno NV
from the Nevada Seismo Lab

N(M) is number of earthquakes of magnitude M or LARGER

log is the base 10 log (not ln)

b is about 1 for tectonic earthquakes, about 2 for volcano-related seismicity.
If data are for one year and b = 1,
then a is the magnitude that happens on average once per year.



larger, less frequent quakes.

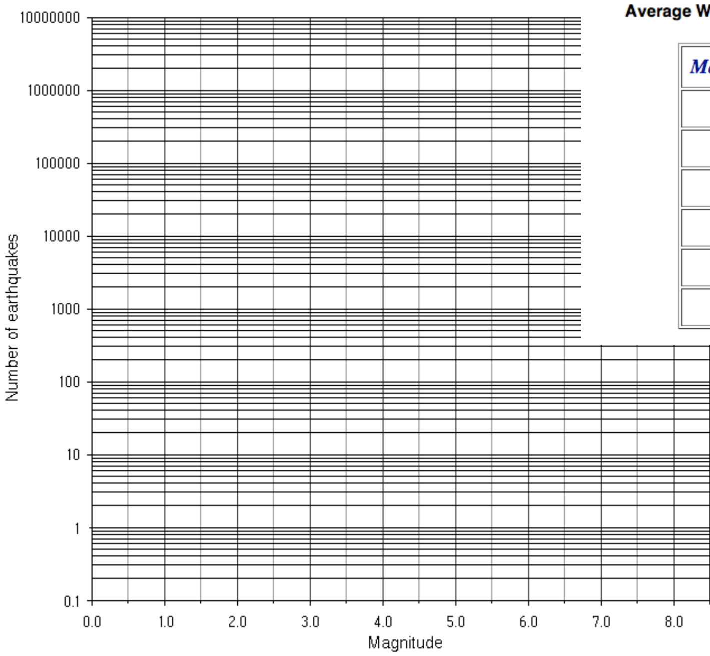
use years of data and plot annual rate instead of number of quakes.

where is a?

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

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

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 a?
What is b?

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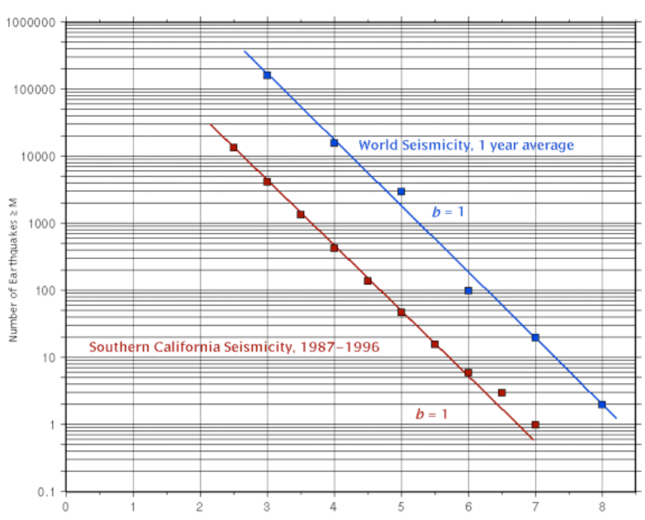

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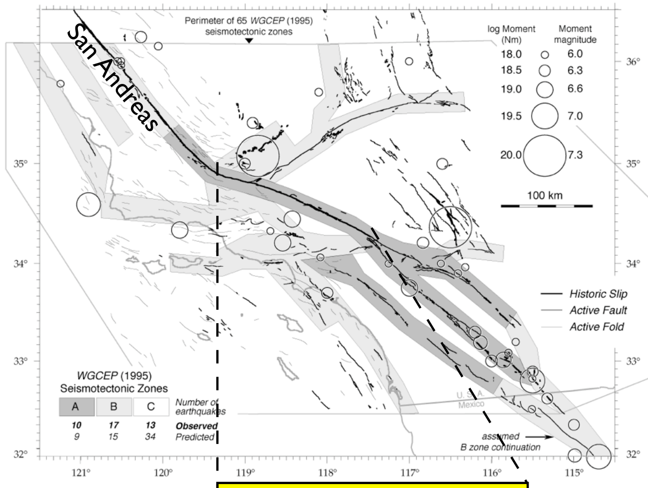
Using Gutenberg-Richter seismicity statistics for forecasting



in each zone

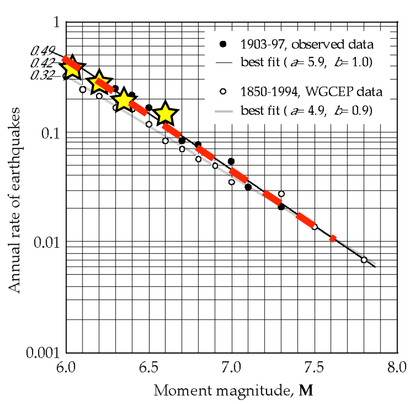
Moment rate is slip rate x area x G

The total (annual) moment for a G-R distribution of quakes must add up to this (unless the fault is creeping)

U.S. Geological Survey

in each zone

Moment rate is slip rate x area x G
we can estimate this from GPS and paleoseismology studies (offset features etc.)

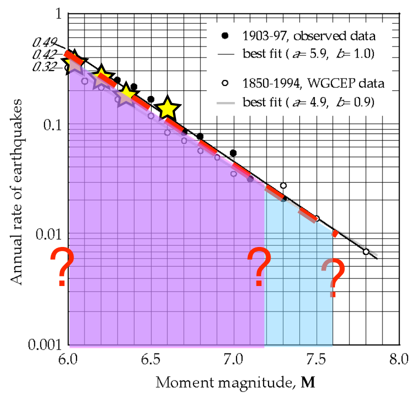


The total moment for a G-R distribution of quakes must add up to this (unless the fault is creeping)

with the G-R relation you can fill in the blanks and come up with frequencies for rare big quakes and for quakes that are too small to detect with availanle seismometer networks.

$$\dot{M}_o = \int (10^{M_w + 6.033}) r dM_w$$

$$\dot{M}_o = \int (10^{M_w+6.033}) r dM_w$$



What are the integration limits?

$$\dot{M}_o = \int (10^{M_w+6.033}) r dM_w$$

we know the rate "r" (how many earthquakes per year) from the Gutenberg-Richter equation:

log N(**M**) = *a* - *b***M**

$N(M) = 10^{a-bM}$

but unfortunately this is the number of earthquakes >= M (not just = M)

as you go from Mw to Mw-1, the total number of earthquakes increases by a factor of 10

as you go from Mw to Mw-1, the total energy release of earthquakes decreases by a factor of about 32

$$\frac{\Delta \dot{M}_o}{\Delta M_w} \longrightarrow 0$$

contributions to the summed moment from small quakes, though there are more of them, get smaller and smaller. So minimum M is not too important.

as $\dot{M}_o \longrightarrow -\infty$

$$\dot{M}_o = \int (10^{M_w + 6.033}) r dM_w$$

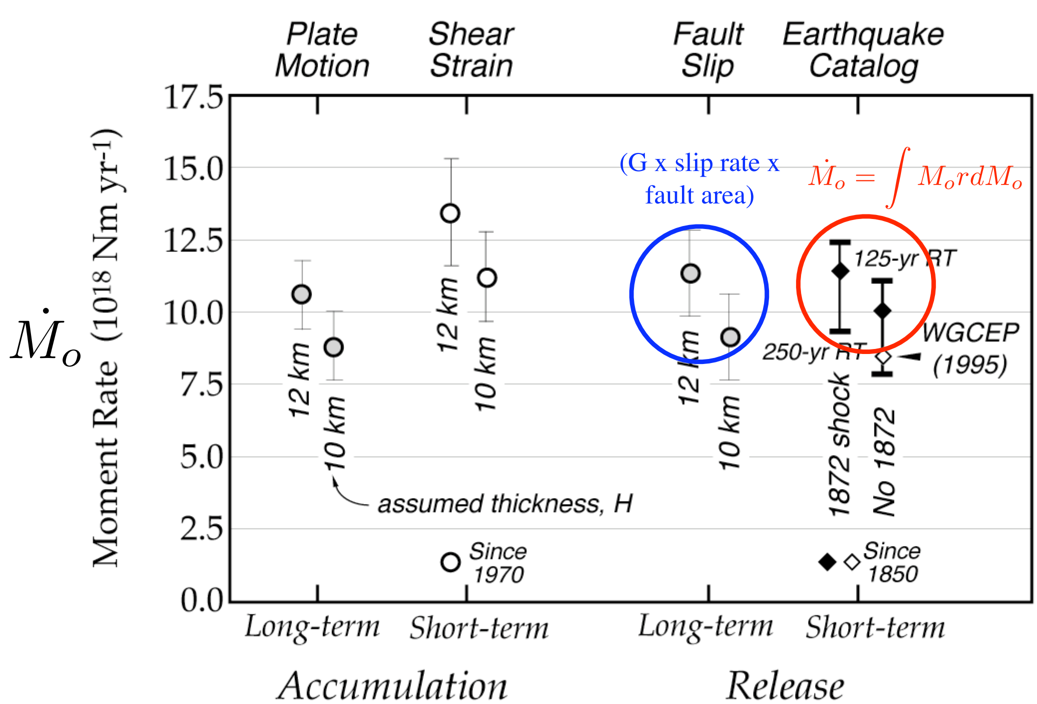
as you go from Mw to Mw+1, the total number of earthquakes decreases by a factor of 10

as you go from Mw to Mw+1, the total energy release of earthquakes increases by a factor of about 32

contributions to the summed moment from large quakes, though there are very few of them, get bigger and bigger. So maximum M is very important.

$$\frac{\Delta \dot{M}_o}{\Delta M_w} \longrightarrow \infty$$

as $\dot{M}_o \longrightarrow \infty$



Ross S. Stein and Thomas C. Hanks
U.S. Geological Survey

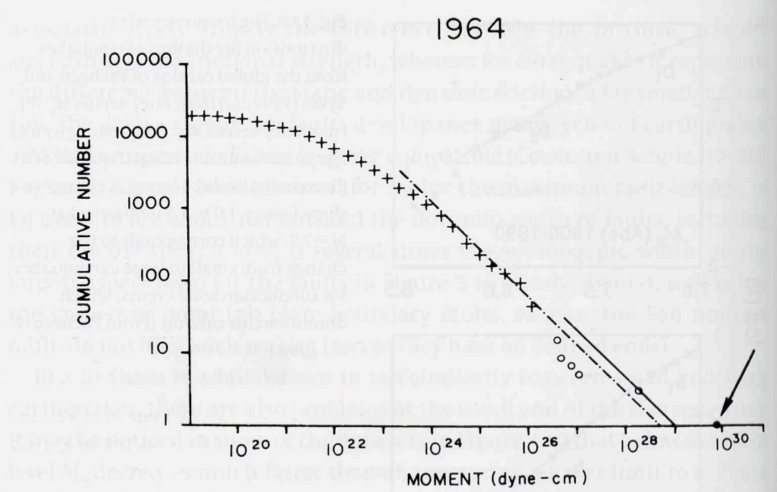
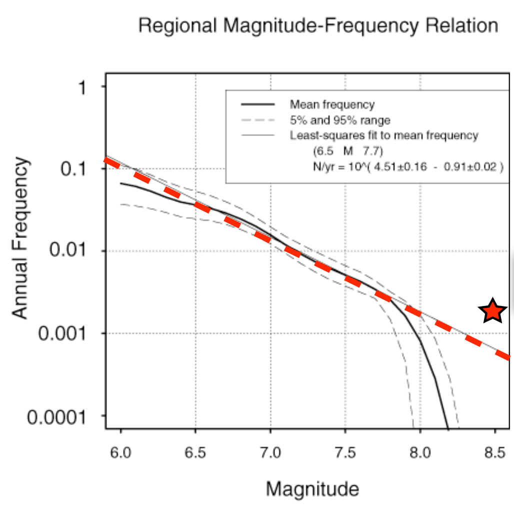


Fig. 4.13. Distribution of small earthquakes within the rupture zone of the 1964 Alaska earthquake, normalized to the recurrence time of that earthquake. The 1964 earthquake is indicated by an arrow. Notice that it is about 1½ orders of magnitude larger than the extrapolation of the small earthquakes 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

in areas 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

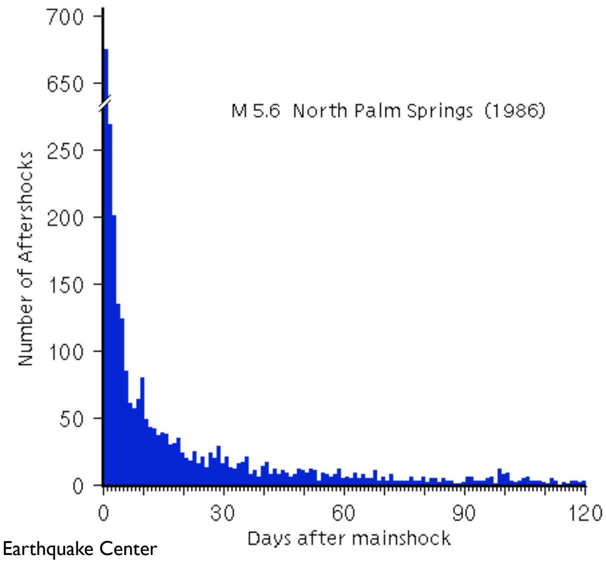
example: Cascadia subduction zone M9+ earthquakes

Integrating moment of earthquakes will produce too little moment if you are not aware of the characteristic earthquakes

Aftershocks

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

p is approximately 1 (can vary)
c is about 0.05 (keeps the denominator above zero)
k is the number of aftershocks on day one



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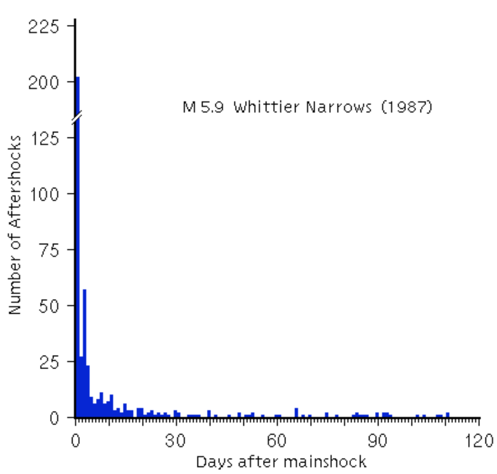
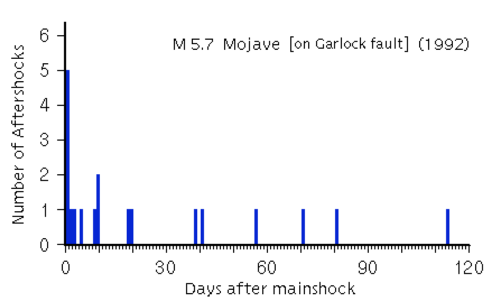
YMMV

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

p is approximately 1 (can vary)
c is about 0.05 (keeps the denominator above zero)
k is the number of aftershocks on day one





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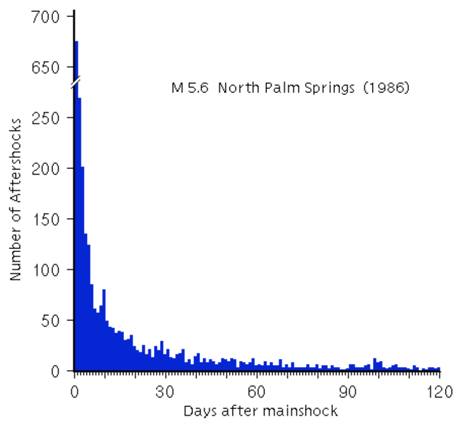
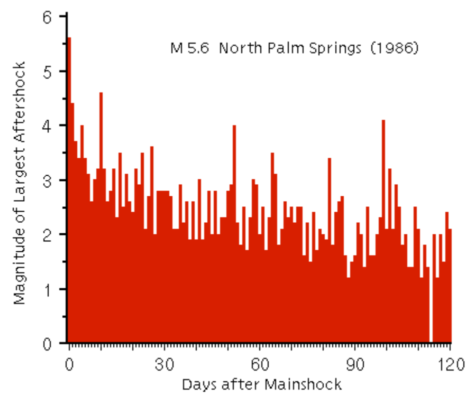
Combining GR statistics with Omori's Law gives probability of aftershocks with particular magnitudes after a big quake





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