

Interpreting Earthquake Magnitude Data

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With the recent large earthquakes in Peru and Indonesia, and some of the confusion about what the reported numbers mean, the authors thought that a brief primer into earthquake magnitudes might be helpful for some practitioners.

Most news reports and earthquake databases report at least the “magnitude” of the event, along with epicenter location and sometimes duration. Magnitude is, however, a source of confusion among both the lay public and professionals. The first magnitude scale, developed by Richter, was limited to California earthquakes, originated at depths less than 18 km within 600km of the seismograph location, and measured using a “Wood-Anderson” seismograph. However, most earthquakes along the Pacific Rim, away from California’s strike-slip fault system, are much deeper than 18km and different seismographs from around the world are now used to locate the epicenters and fine-tune the “final” magnitude and epicenter. Thus, the original Richter scale, which many people still think is what all magnitudes are reported in, is rarely applicable. In fact, Richter scale magnitude, also known as M_L or “local” magnitude, is not usually used. More common are four other measures of magnitude: body wave, surface wave, moment and energy-based. The basic equations for each follow:

$$M_L = \log(A) - \log A_0 \text{ (original Richter magnitude)}$$

$$M_b = \log(A/T) + Q \text{ (body wave magnitude)}$$

$$M_s = \log(A/T) + 1.66 \log(D) + 3.30 \text{ (surface wave magnitude)}$$

$$M_w = 2/3 \log(M_0) - 10.7 \text{ (moment magnitude)}$$

$$M_e = 2/3 \log(E) - 2.9 \text{ (energy-based magnitude)}$$

Where: \log = base 10

A, T = amplitude & period of ground motion (microns & seconds)

A_0 = a distance correction factor, a function of D

D, H = distance to epicenter & depth (degrees & kms)

Q = a correction factor obtained as a function D & H

$M_0 = G \times a \times d$

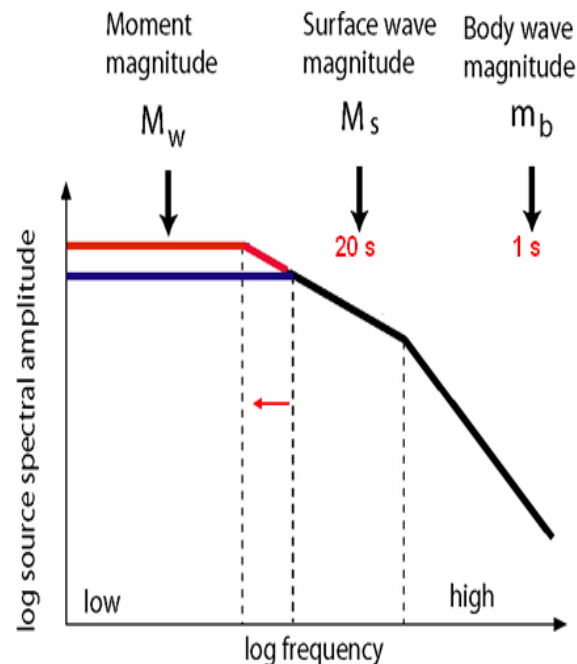
G = shear modulus of the faulted rock (dynes/cm²)

a = area of the fault or rupture surface (cm²)

d = average displacement on the rupture surface (cm)

E = energy radiated by the earthquake (in ergs)

M_w and M_s are perhaps the most commonly used measures and are designed for application to low- and high-frequency data, respectively. M_b is also used and generally applied to very high frequency data.



Unfortunately, each method of calculating magnitude can give very different results. The following demonstrates this for some important earthquakes.

Peru, August 18, 2007

$M_L = 7.0$ (Peruvian Geophysical Institute), $M_w = 8.0$ (USGS)

Indian Ocean, December 26, 2004

$M = 8.2$ (reported as "Richter" magnitude without further reference)

$M_w = 9.1$ to 9.3 (USGS reports as 9.1, CalTech as 9.2, others as 9.3)

Alaska, March 27, 1964

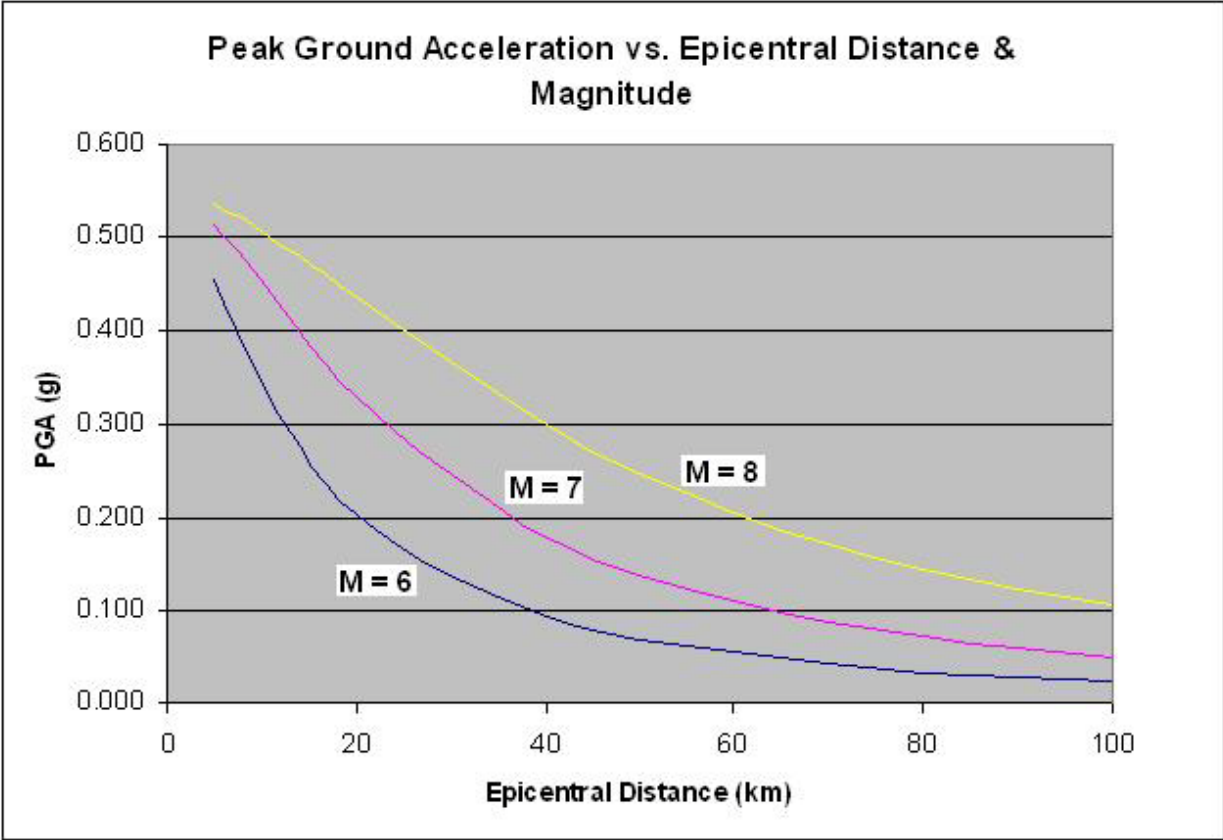
$M_s = 8.3$, $M_w = 9.2$

Chile, May 22, 1960

$M_s = 8.5$, $M_w = 9.5$

Of course, this creates some confusion amongst the public when different agencies are reporting significantly different magnitudes. More importantly, this becomes problematic when engineers do seismic risk studies and produce design or peak ground accelerations for dams, plant structures and other facilities. Ground acceleration is directly related to earthquake magnitude, as well as other factors such as distance to epicenter and local soil conditions. Thus, the method used to calculate the magnitude is a critical piece of information when comparing different

data sources. Unfortunately, not all seismic databases properly track and report this information but simply report the magnitude. Since commonly used magnitude calculations can produce a full order of magnitude difference, knowing which method was used is an important – though often overlooked – part of any earthquake risk analysis.



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