

Richter magnitude scale

The **Richter magnitude scale**, also known as the **local magnitude (M_L) scale**, assigns a single number to quantify the amount of [seismic energy](#) released by an [earthquake](#). It is a base-10 [logarithmic scale](#) obtained by calculating the logarithm of the combined horizontal [amplitude](#) (shaking amplitude) of the largest displacement from zero on a particular type of [seismometer](#) (Wood–Anderson torsion). So, for example, an earthquake that measures 5.0 on the Richter scale has a shaking amplitude 10 times larger than one that measures 4.0. The effective limit of measurement for local magnitude M_L is about 6.8.

Magnitudes are still widely stated on the Richter scale in the mass media, although usually moment magnitudes—numerically about the same—are actually given; the Richter scale has been superseded by the [moment magnitude scale](#), which is calibrated to give generally similar values for medium-sized earthquakes (magnitudes between 3 and 7). Unlike the Richter scale, the moment magnitude scale is built on sound seismological principles, and does not saturate in the high-magnitude range.

The [energy](#) release of an earthquake, which closely correlates to its destructive power, scales with the $\frac{3}{2}$ power of the shaking amplitude. Thus, a difference in magnitude of 1.0 is equivalent to a factor of 31.6 ($= (10^{1.0})^{(3/2)}$) in the energy released; a difference in magnitude of 2.0 is equivalent to a factor of 1000 ($= (10^{2.0})^{(3/2)}$) in the energy released.^[1]

Development

Developed in [1935](#) by [Charles Richter](#) in partnership with [Beno Gutenberg](#), both of the [California Institute of Technology](#), the scale was firstly intended to be used only in a particular study area in [California](#), and on seismograms recorded on a particular instrument, the Wood-Anderson torsion [seismometer](#). Richter originally reported values to the nearest quarter of a unit, but values were later reported with one decimal place. His motivation for creating the local magnitude scale was to separate the vastly larger number of smaller earthquakes from the few larger earthquakes observed in California at the time.

His inspiration was the [apparent magnitude](#) scale used in astronomy to describe the brightness of stars and other celestial objects. Richter arbitrarily chose a magnitude 0 event to be an earthquake that would show a maximum combined horizontal displacement of 1 μm (0.00004in) on a seismograph recorded using a Wood-Anderson torsion seismometer 100 km (62 mi) from the earthquake epicenter. This choice was intended to prevent negative magnitudes from being assigned. However, the Richter scale has no actual lower limit, and sensitive modern seismographs now routinely record quakes with negative magnitudes.

Because M_L is derived from measurements taken from a single, band-limited seismograph, its values saturate when the earthquake is larger than 6.8, and do not increase for more powerful earthquakes.^[2] To overcome this shortcoming, Gutenberg and Richter later developed a magnitude scales based on [surface waves](#), [surface wave magnitude](#) M_s , and another based on [body waves](#), [body wave magnitude](#) m_b .^[3] M_s and m_b can still saturate when the earthquake is big enough.

These older magnitude scales have been superseded by the implementation of methods for estimating the [seismic moment](#), creating the [moment magnitude scale](#), although the former are still widely used because they can be calculated quickly.

Richter magnitudes

The Richter magnitude of an earthquake is determined from the [logarithm](#) of the [amplitude](#) of waves recorded by seismographs (adjustments are included to compensate for the variation in the distance between the various seismographs and the epicenter of the earthquake). The original formula is:^[4]

$$M_L = \log_{10} A - \log_{10} A_0(\delta),$$

where A is the maximum excursion of the Wood-Anderson seismograph, the empirical function A_0 depends only on the [epicentral distance](#) of the station, δ . In

practice, readings from all observing stations are averaged after adjustment with station-specific corrections to obtain the M_L value.

Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude; in terms of energy, each whole number increase corresponds to an increase of about 31.6 times the amount of energy released, and each increase of 0.2 corresponds to a doubling of the energy released.

Events with magnitudes of about 4.6 or greater are strong enough to be recorded by any of the seismographs in the world, given that the seismograph's sensors are not located in an earthquake's [shadow](#).

The following describes the typical effects of earthquakes of various magnitudes near the epicenter. The values are typical only and should be taken with extreme caution, since intensity and thus ground effects depend not only on the magnitude, but also on the distance to the epicenter, the depth of the earthquake's focus beneath the epicenter, and geological conditions (certain terrains can amplify seismic signals).

Richter magnitudes	Description	Earthquake effects	Frequency of occurrence
Less than 2.0	Micro	Microearthquakes, not felt.	About 8,000 per day
2.0-2.9	Minor	Generally not felt, but recorded.	About 1,000 per day
3.0-3.9		Often felt, but rarely causes damage.	49,000 per year (est.)
4.0-4.9	Light	Noticeable shaking of indoor items, rattling noises. Significant damage unlikely.	6,200 per year (est.)
5.0-5.9	Moderate	Can cause major damage to poorly constructed buildings over small regions. At most slight damage to well-designed buildings.	800 per year
6.0-6.9	Strong	Can be destructive in areas up to about 160 kilometres (100 mi) across in populated areas.	120 per year
7.0-7.9	Major	Can cause serious damage over larger areas.	18 per year
8.0-8.9	Great	Can cause serious damage in areas several hundred miles across.	1 per year
9.0-9.9		Devastating in areas several thousand miles across.	1 per 20 years
10.0+	Epic	Never recorded; see below for equivalent seismic energy yield.	Extremely rare (Unknown)

(Based on U.S. Geological Survey documents.)^[5]

Great earthquakes occur once a year, on average. The largest recorded earthquake was the [Great Chilean Earthquake](#) of May 22, 1960 which had a magnitude (M_w) of 9.5.^[6]

The following table lists the approximate [energy](#) equivalents in terms of [TNT](#) explosive force^[7] – though note that the energy is that released *underground* (i.e. a small atomic bomb blast will not simply cause light shaking of indoor items) rather than the overground energy release. Most energy from an earthquake is not transmitted to and through the surface; instead, it dissipates into the crust and other subsurface structures.

Richter Approximate Magnitude	Appr. TNT for Seismic Energy Yield	Joule equivalent	Example
0.0	15.0g (0.529oz)	63.1 kJ	
0.5	84.4 g (2.98 oz)	355 kJ	Large hand grenade
1.0	474 g (1.05 lb)	2.00 MJ	Construction site blast
1.5	2.67 kg (5.88lb)	11.2 MJ	WWII conventional bombs
2.0	15.0 kg (33.1lb)	63.1 MJ	Late WWII conventional bombs
2.5	84.4 kg (186 lb)	355 MJ	WWII blockbuster bomb
3.0	474 kg (1050lb)	2.00 GJ	Massive Ordnance Air Blast bomb
3.5	2.67 metric tons	11.2 GJ	Chernobyl nuclear disaster , 1986
4.0	15.0 metric tons	63.1 GJ	Small atomic bomb
4.5	84.4 metric tons	355 GJ	
5.0	474 metric tons	2.00 TJ	Seismic yield of Nagasaki atomic bomb (Total yield including air yield 21 kT, 88 TJ) Lincolnshire earthquake (UK), 2008
5.5	2.67 kilotons	11.2 TJ	Little Skull Mtn. earthquake (NV, USA), 1992 Alum Rock earthquake (CA, USA), 2007 2008 Chino Hills earthquake (Los Angeles, USA)
6.0	15.0 kilotons	63.1 TJ	Double Spring Flat earthquake (NV, USA), 1994 Caracas (Venezuela), 1967 ; Rhodes (Greece), 2008
6.5	84.4 kilotons	355 TJ	Eureka Earthquake (Humboldt County CA, USA), 2010 Southeast of Taiwan (270km), 2010
6.7	168 kilotons	708 TJ	Northridge earthquake (CA, USA), 1994
6.9	336 kilotons	1.41 PJ	San Francisco Bay Area earthquake (CA, USA), 1989
7.0	474 kilotons	2.00 PJ	Java earthquake (Indonesia), 2009 ; 2010 Haiti Earthquake
7.1	670 kilotons	2.82 PJ	Energy released is equivalent to that of Tsar Bomba (50 megatons, 210 PJ), the largest thermonuclear weapon ever tested 1944 San Juan earthquake
7.5	2.67 megatons	11.2 PJ	Kashmir earthquake (Pakistan), 2005 Antofagasta earthquake (Chile), 2007
7.8	7.52 megatons	31.6 PJ	Tangshan earthquake (China), 1976 Hawke's Bay earthquake (New Zealand), 1931 April 2010 Sumatra earthquake (Indonesia)
8.0	15.0 megatons	63.1 PJ	San Francisco earthquake (CA, USA), 1906 Queen Charlotte earthquake (BC, Canada), 1949 México City earthquake (Mexico), 1985 Gujarat earthquake (India), 2001 Chincha Alta earthquake (Peru), 2007 Sichuan earthquake (China), 2008 ; 1894 San Juan earthquake
8.5	84.4 megatons	355 PJ	Toba eruption ^{<i>[citation needed]</i>} 75,000 years ago; the largest known volcanic event; Sumatra earthquake (Indonesia), 2007
8.8	238 megatons	1.00 EJ	Chile earthquake, 2010
9.0	474 megatons	2.00 EJ	Lisbon Earthquake (Lisbon, Portugal), All Saints Day, 1755
9.2	946 megatons	3.98 EJ	Anchorage earthquake (AK, USA), 1964
9.3	1.34 gigatons	5.62 EJ	Indian Ocean earthquake, 2004
9.5	2.67 gigatons	11.2 EJ	Valdivia earthquake (Chile), 1960
10.0	15.0 gigatons	63.1 EJ	Never recorded by humans
12.55	100 teratons	422 ZJ	Yucatán Peninsula impact (causing Chicxulub crater) 65 Ma ago (10 ⁸ megatons; over 4x10 ³⁰ ergs = 400 ZJ). ^{[8][9][10][11][12]}

THE RICHTER AND MERCALLI SCALES

The strength of an earthquake is usually measured on one of two scales, the Modified Mercalli Scale and the Richter Scale. The Mercalli Scale is a rather arbitrary set of definitions based upon what people in the area feel, and their observations of damage to buildings around them. The scale goes from 1 to 12, (I to XII) or using the descriptive titles of the levels, from Instrumental to Catastrophic.

Modified Mercalli Scale			
Intensity	Verbal Description	Magnitude	Witness Observations
I	Instrumental	1 to 2	Detected only by seismographs
II	Feeble	2 to 3	Noticed only by sensitive people
III	Slight	3 to 4	Resembling vibrations caused by heavy traffic
IV	Moderate	4	Felt by people walking; rocking of free standing objects
V	Rather Strong	4 to 5	Sleepers awakened and bells ring
VI	Strong	5 to 6	Trees sway, some damage from overturning and falling object
VII	Very Strong	6	General alarm, cracking of walls
VIII	Destructive	6 to 7	Chimneys fall and there is some damage to buildings
IX	Ruinous	7	Ground begins to crack, houses begin to collapse and pipes break
X	Disasterous	7 to 8	Ground badly cracked and many buildings are destroyed. There are some landslides
XI	Very Disasterous	8	Few buildings remain standing; bridges and railways destroyed; water, gas, electricity and telephones out of action.
XII	Catastrophic	8 or greater	Total destruction; objects are thrown into the air, much heaving, shaking and distortion of the ground

Whilst this scale is fine if you happen to experience an earthquake in an inhabited area of a developed country, it is of no use whatsoever in the middle of a desert or in any other place without trees, houses and railways! Descriptions such as "Resembling vibrations caused by heavy traffic." depend very much upon the observer having felt heavy traffic in the past. Even then, what one person in a small town considers to be 'heavy' will most certainly differ from what a person living adjacent to a major urban road system would describe as 'heavy'.

Clearly this scale has advantages, but something else is required if we are to be able to compare the magnitude of earthquakes wherever they occur. The Intensity Scale differs from the **Richter Magnitude Scale** in that the effects of any one earthquake vary greatly from place to place, so there may be many **Intensity** values (e.g.: **IV**, **VII**) measured for the same earthquake. Each earthquake, on the other hand, should have only one **Magnitude**, although the various methods of calculating it may give slightly different values (e.g.: **4.5**, **4.6**).

The Richter Scale is designed to allow easier comparison of earthquake magnitudes, regardless of the location.

C.F. Richter was a geologist living and working in California, U.S.A, an area subjected to hundreds of 'quakes every year. He took the existing Mercalli scale and tried to add a 'scientific' scale based

on accurate measurements that could be recorded by seismographs (instruments used to measure vibration) regardless of their global location.

By measuring the speed, or acceleration, of the ground when it suddenly moves, he devised a scale that reflects the 'magnitude' of the shock.

The Richter scale for earthquake measurements is logarithmic. This means that each whole number step represents a ten-fold increase in measured amplitude. Thus, a magnitude 7 earthquake is 10 times larger than a 6, 100 times larger than a magnitude 5 and 1000 times as large as a 4 magnitude.

This is an open ended scale since it is based on measurements not descriptions.

An earthquake detected only by very sensitive people registers as 3.5 on his scale, whilst the worst earthquake ever recorded reached 8.9 on the 'Richter Scale'.

When trying to understand the forces of an earthquake it can help to concentrate just upon the up and down movements. Gravity is a force pulling things down towards the earth. This accelerates objects at 9.8 m/s^2 . To make something, such as a tin can, jump up into the air requires a shock wave to hit it from underneath travelling *faster* than 9.8m/s^2 . This roughly corresponds to 11 (Very disastrous) on the Mercalli Scale, and 8.1 or above on the Richter Scale. In everyday terms, the tin can must be hit by a force that is greater than that which you would experience if you drove your car into a solid wall at 35 khp (22 mph).

Richter Scale

Richter Scale	Approximate Acceleration	Approximate Mercalli equivalent
<3.5	< 1 cm/s^2	I
3.5	2.5 cm/s^2	II
4.2		III
4.5	10 cm/s^2	IV
4.8	25 cm/s^2	V
5.4	50 cm/s^2	VI
6.1	100 cm/s^2	VII
6.5	250 cm/s^2	VIII
6.9		IX
7.3	500 cm/s^2	X
8.1	750 cm/s^2	XI
> 8.1	980 cm/s^2	XII

Surface wave magnitude

The **surface wave magnitude (M_s) scale** is one of the [magnitude scales](#) used in [seismology](#) to describe the size of an [earthquake](#). It is based on measurements in [Rayleigh surface waves](#) that travel primarily along the uppermost layers of the earth. It is currently used in [People's Republic of China](#) as a national standard (**GB 17740-1999**) for categorising earthquakes.^[1] Surface wave magnitude was initially developed in 1950s by the same researchers who developed the [local magnitude scale](#) M_L in order to improve resolution on larger earthquakes.^[2]

The successful development of the local-magnitude scale encouraged [Gutenberg](#) and [Richter](#) to develop magnitude scales based on teleseismic observations of earthquakes. Two scales were developed, one based on surface waves, M_s , and one on body waves, m_b .

Surface waves with a period near 20 s generally produce the largest amplitudes on a standard long-period seismograph, and so the amplitude of these waves is used to determine M_s , using an equation similar to that used for M_L .

– William L. Ellsworth, *The San Andreas Fault System, California (USGS Professional Paper 1515), 1990-1991*

Recorded magnitudes of earthquakes during that time, commonly [attributed to Richter](#), could be either M_s or M_L .

Definition

The formula to calculate surface wave magnitude is:

$$M = \lg\left(\frac{A}{T}\right)_{\max} + \sigma(\Delta)$$

where A is the maximum [particle displacement](#) in surface waves ([vector sum](#) of the two horizontal displacements) in μm , T is the corresponding [period](#) in s, Δ is the [epicentral distance](#) in $^\circ$, and

$$\sigma(\Delta) = 1.66 \lg(\Delta) + 3.5$$

According to GB 17740-1999, the two horizontal displacements must be measured at the same time or within 1/8 of a period; if the two displacements have different periods, weighed sum must be used:

$$T = \frac{T_N A_N + T_E A_E}{A_N + A_E}$$

where A_N is the north-south displacement in μm , A_E is the east-west displacement in μm , T_N is the period corresponding to A_N in s, and T_E is the period corresp. to A_E in s.

Other studies

Vladimír Topyáš and Reinhard Mittag proposed to relate surface wave magnitude to [local magnitude scale](#) M_L , using^[5]

$$M_s = -3.2 + 1.45M_L$$

Other formulas include three revised formulae proposed by CHEN Junjie et al.:

$$M_s = \log\left(\frac{A_{max}}{T}\right) + 1.54 \log \Delta + 3.53$$

$$M_s = \log\left(\frac{A_{max}}{T}\right) + 1.73 \log \Delta + 3.27$$

and

$$M_s = \log\left(\frac{A_{max}}{T}\right) - 6.2 \log \Delta + 20.6$$

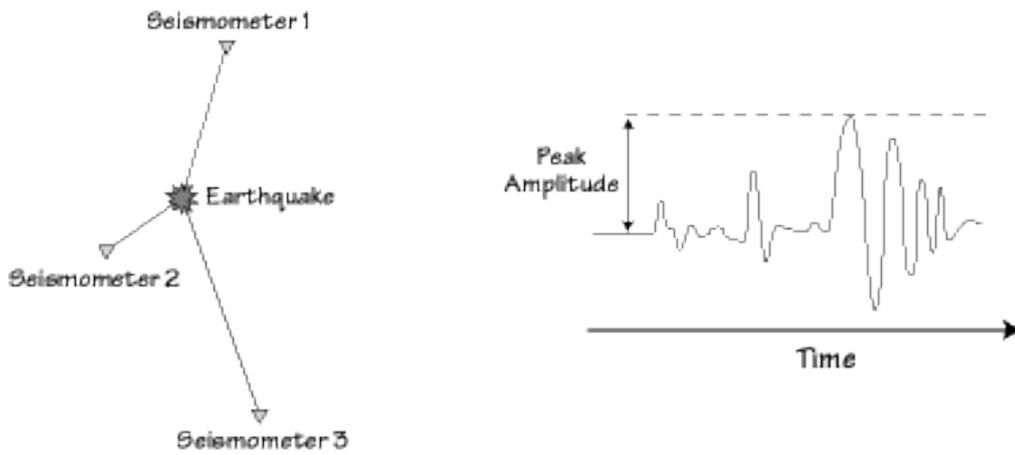
SLU EAS-A193 Class Notes

EARTHQUAKE SIZE

Earthquake Magnitude

The magnitude is the most often cited measure of an earthquake's size, but it is not the only measure, and in fact, there are different types of earthquake magnitude. Early estimates of earthquake size were based on non-instrumental measures of the earthquakes effects. For example, we could use values such as the number of fatalities or injuries, the maximum value of shaking intensity, or the area of intense shaking. The problem with these measures is that they don't correlate well. The damage and devastation produced by an earthquake will depend on its location, depth, proximity to populated regions, as well as its "true" size. Even for earthquakes close enough to population centers values such as maximum intensity and the area experiencing a particular level of shaking did not correlate well.

With the invention and deployment of seismometers it became possible to accurately locate earthquakes and measure the ground motion produced by seismic waves.



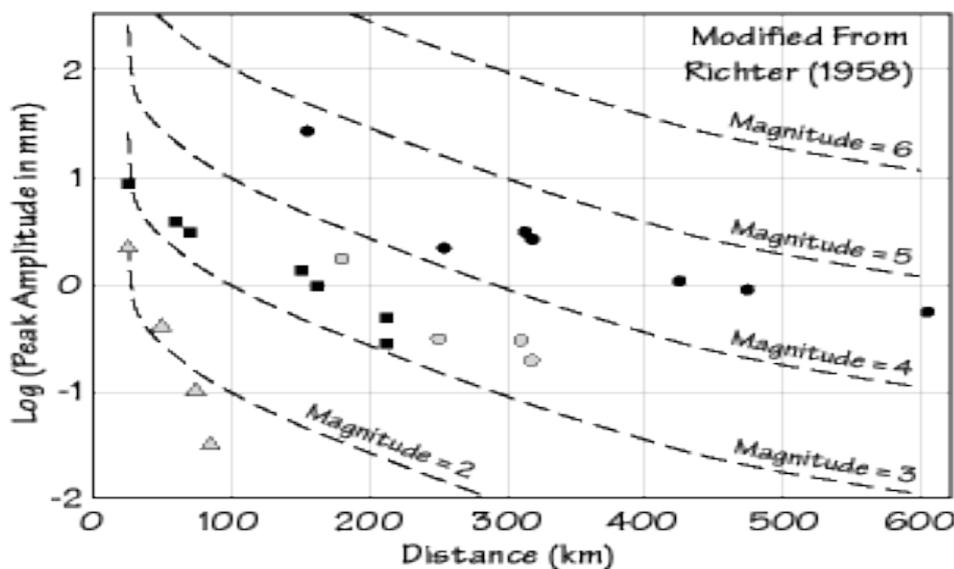
The development and deployment of seismometers lead to many changes in earthquake studies, magnitude was the first quantitative measure of earthquake size based on seismograms. The maximum or "peak" ground motion is defined as the largest absolute value of ground motion recorded on a seismogram. In the example above the surface wave has the largest deflection, so it determines the peak amplitude.

It was natural for these instrumental measures to be used to compare earthquakes, and one of the first ways of quantifying earthquakes using seismograms was the magnitude.

Richter's Magnitude Scale

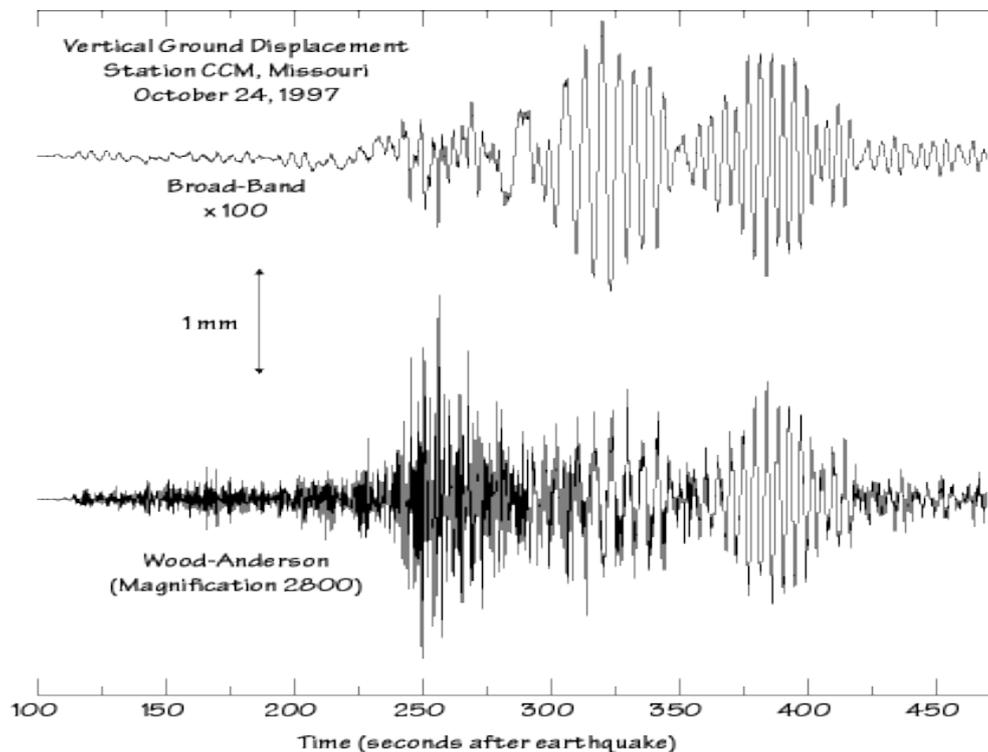
In 1931 a Japanese seismologist named Kiyoo Wadati constructed a chart of maximum ground motion versus distance for a number of earthquakes and noted that the plots for different earthquakes formed parallel, curved lines (the larger earthquakes produced larger amplitudes). The fact that earthquakes of different size generated curves that were roughly parallel suggested that a single number could quantify the relative size of different earthquakes.

In 1935 Charles Richter constructed a similar diagram of peak ground motion versus distance and used it to create the first earthquake magnitude scale (a logarithmic relationship between earthquake size and observed peak ground motion). He based his scale on an analogy with the stellar brightness scale commonly used in astronomy which is also similar to the pH scale used to measure acidity (pH is a logarithmic measure of the Hydrogen ion concentration in a solution).



Sample of the data used by Richter to construct the magnitude scale for southern California. The symbols represent observed peak ground motions for earthquakes recorded during January of 1932 (different symbols represent different earthquakes). The dashed lines represent the reference curve for the decrease in peak-motion amplitude with increasing distance from the earthquake. A magnitude 3.0 earthquake is defined as the size event that generates a maximum ground motion of 1 millimeter (mm) at 100 km distance.

To complete the construction of the magnitude scale, Richter had to establish a reference value and identify the rate at which the peak amplitudes decrease with distance from an earthquake. He established a reference value for earthquake magnitude when he defined the magnitude as the base-ten logarithm of the maximum ground motion (in micrometers) recorded on a Wood-Anderson short-period seismometer one hundred kilometers from the earthquake. Richter was pragmatic in his definition, and chose a value for a magnitude zero that insured that most of the earthquakes routinely recorded would have positive magnitudes. Also, the Wood-Anderson short-period instrument that Richter chose for his reference records seismic waves with a period of about 0.8 seconds, roughly the vibration periods that we feel and that damage our buildings and other structures.



Example seismogram recorded on a Wood-Anderson short period seismogram. The top waveform shows the broad-band displacement, the lower trace shows the corresponding ground motion that would register on a Wood-Anderson seismograph.

Richter also developed a distance correction to account for the variation in maximum ground motion with distance from an earthquake (the dashed curves shown in the above diagram show his relationship for southern California). The precise rate that the peak ground motions decrease with distance depends on the regional geology and thus the magnitude scale for different regions is slightly dependent on the "distance correction curve".

Thus originally, Richter's scale was specifically designed for application in southern California. Richter's method became widely used because it was simple, required only the location of the earthquake (to get the distance) and a quick measure of the peak ground motion, was more reliable than older measures such as intensity. It became widely used, well established, and forms the basis for many of the measures that we continue to use today. Generally the magnitude is computed from seismographs from as many seismic recording stations as are available and the average value is used as our estimate of an earthquake's size.

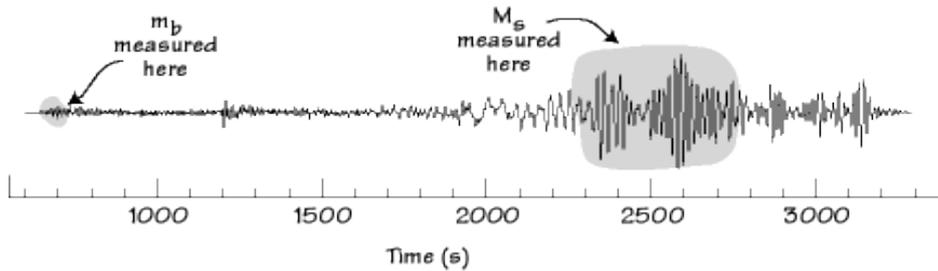
We call the Richter's original magnitude scale M_L (for "local magnitude"), but the press usually reports all magnitudes as Richter magnitudes.

Teleseismic Magnitude Scales

To study earthquakes outside southern California, Richter extended the concepts of his local magnitude scale for global application. In the 1930's through the 1950's together with Beno Gutenberg, Richter constructed magnitude scales to compare the size of earthquakes outside of California. Ideally they wanted a magnitude scale that gave the same value if the earthquake is recorded locally or from a great distance. That way you could compare the seismicity of earthquakes in different parts of Earth. But the extension of methods to

estimate the local magnitude is complicated because the type of wave generating the largest vibrations and the period of the largest vibrations recorded at different distances from an earthquake varies. Near the earthquake the largest wave is a short-period S-wave, at greater distances longer-period surface waves become dominant.

To exploit the best recorded signal (the largest) magnitude scales were developed for "teleseismic" (distant) observations using P waves or Rayleigh waves. Eventually the teleseismic P-wave scale became known as "body-wave magnitude" and the Rayleigh wave based measure came to be called "surface-wave magnitude". The surface-wave magnitude is usually measured from 20s period Rayleigh waves, which are very well transmitted along Earth's surface and thus usually well observed.



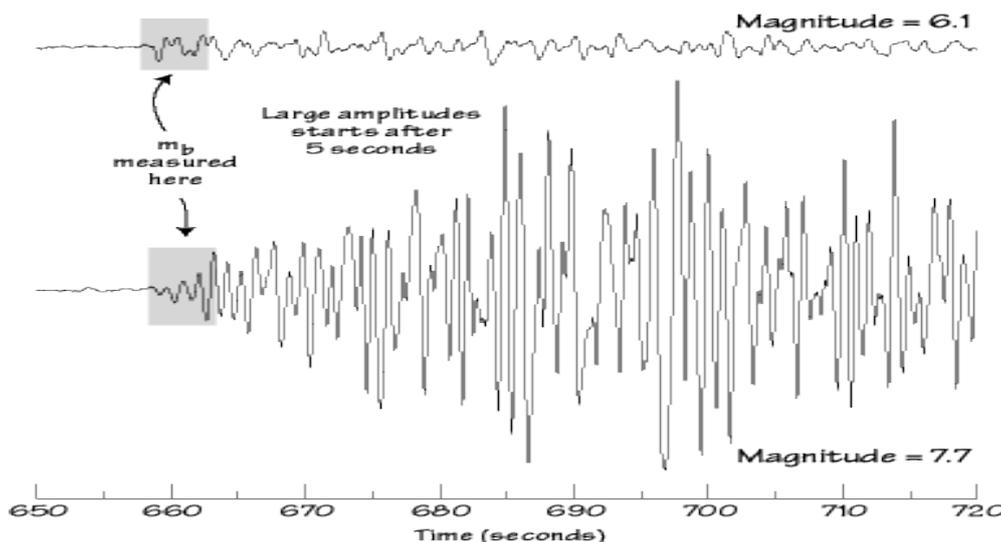
Gutenberg and Richter developed

two magnitudes for application to distant earthquakes: mb is measured using the first five seconds of a teleseismic (distant) P-wave and Ms is derived from the maximum amplitude Rayleigh wave.

Problems with Magnitude Scales

There are several problems associated with using magnitude to quantify earthquakes, and all are a direct consequence of trying to summarize a process as complex as an earthquake in a single number. First, since the distance corrections depend on geology each region must have a slightly different definition of local magnitude. Also, since at different distances we rely on different waves to measure the magnitude, the estimates of earthquake size don't always precisely agree. Also, deep earthquakes do not generate surface waves as well as shallow earthquakes and magnitude estimates based on surface waves are biased low for deep earthquakes.

Also, measures of earthquake size based on the maximum ground shaking do not account for another important characteristic of large earthquakes - they shake the ground longer. Consider the example shown in the diagram below. The two seismograms are the P-waves generated by magnitude 6.1 and 7.7 earthquakes from Kamchatka. The body-wave magnitude for these two earthquakes is much closer because the rule for estimating body-wave magnitude is to use the maximum amplitude in the first five seconds of shaking. As you can see, the difference in early shaking between the two earthquakes is much less than the shaking a little bit later which indicates the larger difference in size.



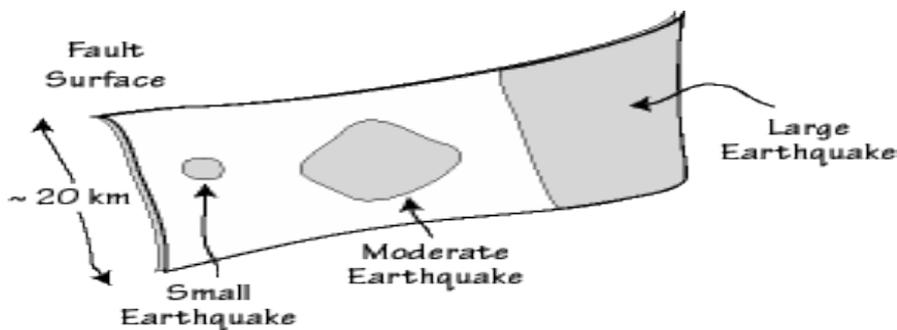
Teleseismic (distant) P-waves generated by two earthquakes in Kamchatka and recorded at station CCM, Cathedral Caves, MO, US. The signals

that would be recorded on a on a short-period seismometer are shown using the same scale. The time is referenced to the onset of rupture for each earthquake.

Even after 5 seconds the amplitude ratio of these P waves does not accurately represent the difference in size of these two earthquakes. The magnitude 6.1 event probably ruptured for only a few seconds, the magnitude 7.7 ruptured for closer to a minute.

Earthquake Dimensions - Rupture Size and Offset

Another measure of earthquake size is the area of the fault that slipped during the earthquake. During large earthquakes the part of the fault that ruptures may be hundreds of kilometers long and 10s of kilometers deep. Smaller earthquake rupture smaller portions of the fault. Thus the area of the rupture is an indicator of the earthquake size.



The size of the area that slips during an earthquake is increases with earthquake size. The shaded regions on the fault surface are the areas that rupture during different size events. The largest earthquakes generally rupture the entire depth of the fault, which is controlled by temperature. The temperature increases with depth to a point where the rocks become plastic and no longer store the elastic strain energy necessary to fail suddenly.

Usually we estimate fault rupture areas using the location of aftershocks, but we may also estimate the area of rupture from seismograms if the observations are of high quality.

Another measure of an earthquake size is the dimension of the offset produced during an earthquake - that is, how far did the two sides move? Small earthquakes have slips that are less than a centimeter, large earthquakes move the rocks about 10-20 meters.

Seismic Moment and Moment Magnitude

Seismic moment is a quantity that combines the area of the rupture and the amount of fault offset with a measure of the strength of the rocks - the shear modulus μ .

$$\text{Seismic Moment} = \mu \times (\text{Rupture Area}) \times (\text{Fault Offset})$$

Usually we measure the moment directly from seismograms, since the size of the very long-period waves generated by an earthquake is proportional to the seismic moment. The physical units of seismic moment are force x distance, or dyne-cm.

For scientific studies, the moment is the measure we use since it has fewer limitations than the magnitudes, which often reach a maximum value (we call that magnitude saturation).

To compare seismic moment with magnitude, M_w , we use a formula constructed by Hiroo Kanamori of the California Institute of Seismology:

$$M_w = 2 / 3 * \log(\text{Seismic Moment}) - 10.73$$

where the units of the moment are in dyne-cm.

Magnitude Summary

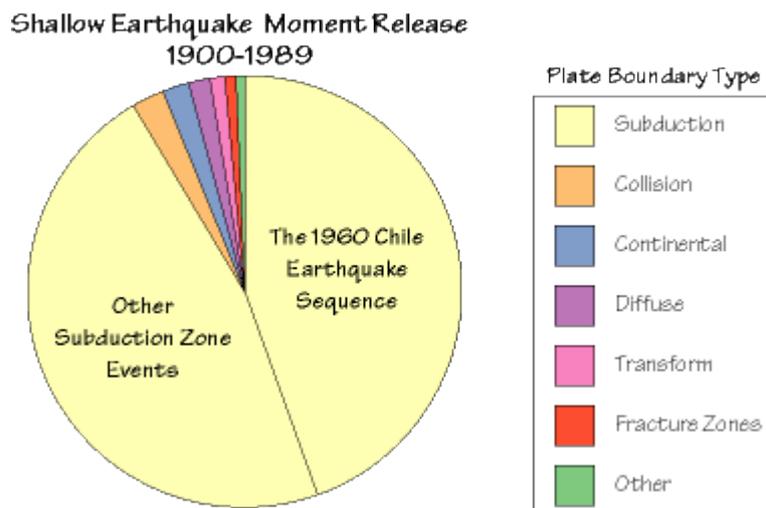
The symbols used to represent the different magnitudes are

Magnitude	Symbol	Wave	Period
Local (Richter)	ML	S or Surface Wave*	0.8 s
Body-Wave	mb	P	1 s
Surface-Wave	Ms	Rayleigh	20 s
Moment	Mw	Rupture Area, Slip	> 100 s

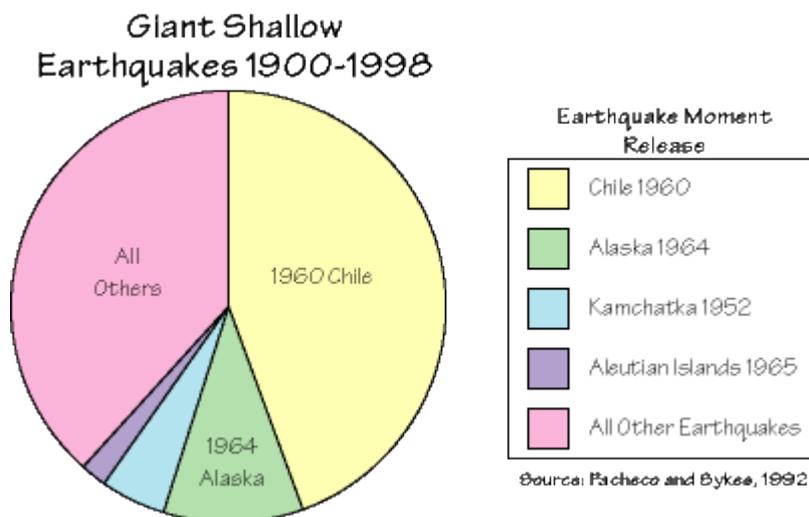
*at the distances appropriate for local magnitude, either the S-wave or the surface waves generally produce the largest vibrations.

Giant Earthquakes

The seismic moment and moment magnitude give us the tool we need to compare the size of the largest quakes. We find that the "moment release" in shallow earthquakes throughout the entire century is dominated by several large subduction zone earthquake sequences. First, let's compare the amount of energy released in the different plate settings:



or we can just compare the largest four earthquakes (those with magnitudes greater than 9) with all the other shallow earthquakes.



MMI	VI	VII	VIII	IX	X	XI	XII
PGA (g)	0.12	0.21	0.36	0.53	0.71	0.86	1.15