Moment magnitude earthquake scale

Notes from the history channel TV show "10.0" (2011) 120 min

30 X times more energy for each number up the scale.

Magnitude 10 == 300 x 50 Megaton of energy
6 billion people in the world currently.

Speed of travel of earthquake waves in the curst of earth is about 7,000 MPH for super shear waves (like breaking the sound barrier) travel at 10,000 to 12,300 MPH so as to give a big quick 1-2 punch on a structures. Both slow and fast wave arrive close together at a distance point giving the effect of grater destruction for a bigger range than was previously thought possible.

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The **moment magnitude scale** (abbreviated as **MMS**; denoted as $\mathbf{M_W}$) is used by seismologists to measure the size of earthquakes in terms of the energy released.[1] The magnitude is based on the moment of the earthquake, which is equal to the rigidity of the Earth multiplied by the average amount of slip on the fault and the size of the area that slipped.[2] The scale was developed in the 1970s to succeed the 1930s-era Richter magnitude scale (M_L). Even though the formulae are different, the new scale retains the familiar continuum of magnitude values defined by the older one. The MMS is now the scale used to estimate magnitudes for all modern large earthquakes by the United States Geological Survey.[3]

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[edit] Definition

The symbol for the moment magnitude scale is M_w, with the subscript w meaning mechanical work accomplished. The moment magnitude M_w is a dimensionless number defined by

where M_0 is the magnitude of the seismic moment in dyne centimeters (10^{-7} Nm).[1] The constant values in the equation are chosen to achieve consistency with the magnitude values produced by earlier scales, most importantly the Local Moment (or "Richter") scale.

As with the Richter scale, an increase of 1 step on this logarithmic scale corresponds to a $10^{1.5} \approx 32$ times increase in the amount of energy released, and an increase of 2 steps corresponds to a $10^3 = 1000$ times increase in energy.

[edit] Comparative energy released by two earthquakes

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A closely related formula, obtained by solving the previous equation for M_0, allows one to assess the proportional difference $f_{\Delta E}$ in energy release between earthquakes of two different moment magnitudes, say m_1 and m_2:

[edit] Radiated seismic energy

Potential energy is stored in the crust in the form of built-up stress. During an earthquake, this stored energy is transformed and results in

- cracks and deformation in rocks
- heat,
- radiated seismic energy E_s.

The seismic moment M_0 is a measure of the total amount of energy that is transformed during an earthquake. Only a small fraction of the seismic moment M_0 is converted into radiated seismic energy E_s, which is what seismographs register. Using the estimate

Choy and Boatwright defined in 1995 the *energy magnitude* [4]

[edit] Nuclear explosions

The energy released by nuclear weapons is traditionally expressed in terms of the energy stored in a kiloton or megaton of the conventional explosive trinitrotoluene (TNT).

A rule of thumb equivalence from seismology used in the study of nuclear proliferation asserts that a one kiloton nuclear explosion creates a seismic signal with a magnitude of approximately 4.0.[5] This in turn leads to the equation [6]

where m_{TNT} is the mass of the explosive TNT that is quoted for comparison (relative to megatons Mt).

Such comparison figures are not very meaningful. As with earthquakes, during an underground explosion of a nuclear weapon, only a small fraction of the total amount of energy transformed ends up being radiated as seismic waves. Therefore, a seismic efficiency has to be chosen for a bomb that is quoted as a comparison. Using the conventional specific energy of TNT (4.184 MJ/kg), the above formula implies the assumption that about 0.5% of the bomb's energy is converted into radiated seismic energy E_s.[7] For real underground nuclear tests, the actual seismic efficiency achieved varies significantly and depends on the site and design parameters of the test.

[edit] Comparison with Richter scale

Main article: Richter magnitude scale

In 1935, Charles Richter and Beno Gutenberg developed the local magnitude (M_{L}) scale (popularly known as the Richter scale) with the goal of quantifying medium-sized earthquakes (between magnitude 3.0 and 7.0) in Southern California. This scale was based on the ground motion measured by a particular type of seismometer at a distance of 100 kilometres (62 mi) from the earthquake. Because of this, there is an upper limit on the highest measurable magnitude; all large earthquakes will have a local magnitude of around 7. The local magnitude's estimate of earthquake size is also unreliable for measurements taken at a distance of more than about 350 miles (600 km) from the earthquake's epicenter.[3]

The moment magnitude (M_{w}) scale was introduced in 1979 by Caltech seismologists Thomas C. Hanks and Hiroo Kanamori to address these shortcomings while maintaining consistency. Thus, for medium-sized earthquakes, the moment magnitude values should be similar to Richter values. That is, a magnitude 5.0 earthquake will be about a 5.0 on both scales. This scale was based on the physical properties of the earthquake, specifically the seismic moment (M_0). Unlike other scales, the moment magnitude scale does not saturate at the upper end; there is no upper limit to the possible measurable magnitudes. However, this has the side-effect that the scales diverge for smaller earthquakes.[1]

Moment magnitude is now the most common measure for medium to large earthquake magnitudes,[8] but breaks down for smaller quakes. For example, the United States

Geological Survey does not use this scale for earthquakes with a magnitude of less than 3.5, which is the great majority of quakes. For these smaller quakes, other magnitude scales are used. All magnitudes are calibrated to the M_L scale of Richter and Gutenberg.

Magnitude scales differ from earthquake intensity, which is the perceptible moving, shaking, and local damages experienced during a quake. The shaking intensity at a given spot depends on many factors, such as soil types, soil sublayers, depth, type of displacement, and range from the epicenter (not counting the complications of building engineering and architectural factors). Rather, they are used to estimate only the total energy released by the quake.

The following table compares magnitudes towards the upper end of the Richter Scale for major Californian earthquakes.[1]

Date		M_L	M_w
1933-03-11	2	6.3	6.2
1940-05-19	30	6.4	7.0
1941-07-01	0.9	5.9	6.0
1942-10-21	9	6.5	6.6
1946-03-15	1	6.3	6.0
1947-04-10	7	6.2	6.5
1948-12-04	1	6.5	6.0
1952-07-21	200	7.2	7.5
1954-03-19	4	6.2	6.4

[edit] See also

Richter magnitude scale

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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.[1]

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 reports a fundamental property of the earthquake derived from instrument data, rather than reporting instrument data which is not always comparable across earthquakes, and does not saturate in the high-magnitude range. Since the Moment Magnitude scale generally yields very similar results to the Richter scale, magnitudes of earthquakes reported in the mass media are usually reported without indicating which scale is being used.

The energy release of an earthquake, which closely correlates to its destructive power, scales with the $^{3}/_{2}$ 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.[2]

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[edit] 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 (0.00004 in) 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.[1] 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.

[edit] 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]

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	Description	Earthquake effects	Frequency of

magnitudes			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	Approximate TNT for Seismic Energy Yield	Joule equivalent	Example
0.0	15.0 g (0.529 oz)	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 (5.88 lb)	11.2 MJ	World War II conventional bombs
2.0	15.0 kg (33.1 lb)	63.1 MJ	Late World War II conventional bombs
2.5	84.4 kg (186 lb)	355 MJ	World War II blockbuster bomb
3.0	474 kg (1050 lb)	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 2010 Central Canada earthquake[8][9]
5.5	2.67 kilotons	11.2 TJ	Little Skull Mtn. earthquake (Nevada, USA), 1992 Alum Rock earthquake (California, USA), 2007 2008 Chino Hills earthquake (Los Angeles, USA)
6.0	15.0 kilotons	63.1 TJ	Double Spring Flat earthquake (Nevada, USA), 1994
6.5	84.4 kilotons	355 TJ	Caracas (Venezuela), 1967 Rhodes (Greece), 2008 Eureka Earthquake (Humboldt County, California, USA), 2010 Southeast of Taiwan (270 km), 2010
6.6	? kilotons	? TJ	San Fernando earthquake (California, USA), 1971
6.7	168 kilotons	708 TJ	Northridge earthquake (California, USA), 1994
6.9	336 kilotons	1.41 PJ	San Francisco Bay Area earthquake (California, USA), 1989
7.0	474 kilotons	2.00 PJ	Java earthquake (Indonesia), 2009 2010 Haiti earthquake
7.1	670 kilotons	2.82 PJ	1944 San Juan earthquake 2010 Canterbury earthquake (New Zealand)
7.2	938 kilotons	3.94 PJ	1977 Vrancea earthquake (Romania) 2010 Baja California 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 1990 Luzon earthquake (Philippines) April 2010 Sumatra earthquake (Indonesia)
8.0	15.0 megatons	63.1 PJ	Mino-Owari earthquake (Japan), 1891 San Juan earthquake (Argentina), 1894 San Francisco earthquake (California, USA), 1906 Queen Charlotte Islands earthquake (British Columbia, Canada), 1949 México City earthquake (Mexico), 1985 Gujarat earthquake (India), 2001 Chincha Alta earthquake (Peru), 2007 Sichuan earthquake (China), 2008
8.5	84.4 megatons	355 PJ	Energy released is larger than that of the Tsar Bomba (50 megatons, 210 PJ), the largest thermonuclear weapon ever tested Toba eruption 75,000 years ago; among the largest known volcanic events.[10] 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
9.1–9.3	1.34 gigatons	5.62 EJ	Indian Ocean earthquake, 2004
9.2	946 megatons	3.98 EJ	Anchorage earthquake (Alaska, USA), 1964
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 (creating Chicxulub crater) 65 Ma ago (10^8 megatons; over $4x10^{30}$ ergs = 400 ZJ).[11][12][13][14][15]
32.0	1×10^{21} yottatons	4.2×10^{30} YJ	Approximate magnitude of the starquake on the magnetar SGR 1806-20, registered on December 27, 2004.[16]

http://en.wikipedia.org/wiki/Richter_magnitude_scale