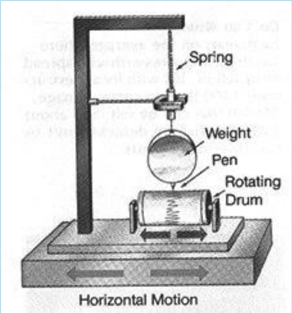
EARTHQUAKE MEASUREMENTS

The vibrations produced by earthquakes are detected, recorded, and measured by instruments call seismographs[1]. The zig-zag line made by a seismograph, called a "seismogram," reflects the changing intensity of the vibrations by responding to the motion of the ground surface beneath the instrument. From the data expressed in seismograms, scientists can determine the time, the epicenter, the focal depth, and the type of faulting of an earthquake and can estimate how much energy was released.

Seismograph/Seismometer

Earthquake recording instrument, seismograph has a base that sets firmly in the ground, and a heavy weight that hangs free[2]. When an earthquake causes the ground to shake, the base of the seismograph shakes too, but the hanging weight does not. Instead the spring or string that it is hanging from absorbs all the movement. The difference in position between the shaking part of the seismograph and the motionless part is what is recorded.

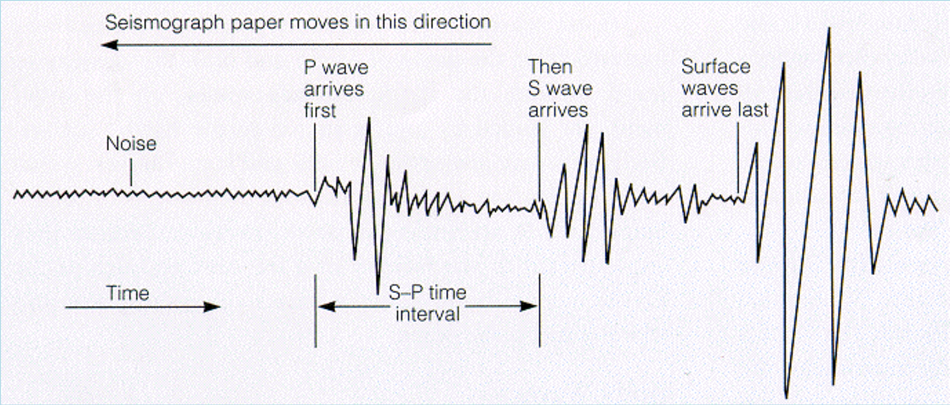


Seismograph

Measuring Size of Earthquakes

The size of an earthquake depends on the size of the fault and the amount of slip on the fault, but that's not something scientists can simply measure with a measuring tape since faults are many kilometers deep beneath the earth's surface. They use the seismogram recordings made on the seismographs at the surface of the earth to determine how large the earthquake was. A short wiggly line that doesn't wiggle very much means a small earthquake, and a long wiggly line that wiggles a lot means a large earthquake[2]. The length of the wiggle depends on the size of the fault, and the size of the wiggle depends on the amount of slip.

The severity of an earthquake can be expressed in terms of both intensity and magnitude[3].



Example of a seismogram

Source: http://darkwing.uoregon.edu/~drt/Classes/201_99/Rice/Seismology.html

However, the two terms are quite different, and they are often confused. Magnitude is related to the amount of seismic energy released at the hypocenter of the earthquake whereas intensity is based on the observed effects of ground shaking on people, buildings, and natural features. The intensity of shaking from an earthquake varies depending on where you are during the earthquake.

Magnitude

The magnitude is a number that characterizes the relative size of an earthquake. Magnitude is based on measurement of the maximum motion recorded by a seismograph[4]. Several scales have been defined, but the most commonly used are (1) local magnitude (ML), commonly referred to as "Richter magnitude," (2) surface-wave magnitude (Ms), (3) body-wave magnitude (Mb), and (4) moment magnitude (Mw). Scales 1-3 have limited range and applicability and do not satisfactorily measure the size of the largest earthquakes. The moment magnitude (Mw) scale, based on the concept of seismic moment, is uniformly applicable to all sizes of earthquakes but is more difficult to compute than the other types. All magnitude scales should yield approximately the same value for any given earthquake.

Intensity Scale

It manifests the degree of damage, which gets diminished as we go away from the main shock source zone and the reverse is also true[5]. There are several earthquake intensity scales, which can be referred from the relevant pages.

- European
  http://en.wikipedia.org/wiki/European_Macroseismic_Scale

- USA (MM)
  http://en.wikipedia.org/wiki/Mercalli_intensity_scale

- Japan (JMA)
  http://en.wikipedia.org/wiki/Japan_Meteorological_Agency_seismic_intensity_scale

The Richter scale[3]

The Richter magnitude scale was developed in 1935 by Charles F. Richter of the California Institute of Technology as a mathematical device to compare the size of earthquakes. The magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs. Adjustments are included in the magnitude formula to compensate for the variation in the distance between the various seismographs and the epicenter of the earthquakes. On the Richter Scale, magnitude is expressed in whole numbers and decimal fractions. For example, a magnitude of 5.3 might be computed for a moderate earthquake, and a strong earthquake might be rated as magnitude 6.3. Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude; as an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

Richter Magnitude and its example[5]

Richter Approximate Magnitude	Approximate TNT for Seismic Energy Yield	Joule equivalent	Example
0.0	1 kg (2.2 lb)	4.2 MJ	
0.5	5.6 kg (12.4 lb)	23.5 MJ	Large Hand grenade

1.0	32 kg (70 lb)	134.4 MJ	Construction site blast
1.5	178 kg (392 lb)	747.6 MJ	WWII conventional bombs
2.0	1 metric ton	4.2 GJ	Late WWII conventional bombs
2.5	5.6 metric tons	23.5 GJ	WWII blockbuster bomb
3.0	32 metric tons	134.4 GJ	Massive Ordnance Air Blast bomb
3.5	178 metric tons	747.6 GJ	Chernobyl nuclear disaster, 1986
4.0	1 kiloton	4.2 TJ	Small atomic bomb
4.5	5.6 kilotons	23.5 TJ	
5.0	32 kilotons	134.4 TJ	Nagasaki atomic bomb (actual seismic yield was negligible since it detonated in the atmosphere. The Hiroshima atomic bomb was 15 kilotons) Lincolnshire earthquake (UK), 2008
5.4	150 kilotons	625 TJ	2008 Chino Hills earthquake (Los Angeles, United States)
5.5	178 kilotons	747.6 TJ	ittle Skull Mtn. earthquake (NV, USA), 1992 Alum Rock earthquake (CA, USA), 2007
6.0	1 megaton	4.2 PJ	Double Spring Flat earthquake (NV, USA), 1994
6.5	5.6 megatons	23.5 PJ	Rhodes (Greece), 2008
6.7	16.2 megatons	67.9 PJ	Northridge earthquake (CA, USA), 1994
6.9	26.8 megatons	112.2 PJ	San Francisco Bay Area earthquake (CA, USA), 1989
7.0	32 megatons	134.4 PJ	
7.1	50 megatons	210 PJ	Energy released is equivalent to that of Tsar Bomba, the largest thermonuclear weapon ever tested.
7.5	178 megatons	747.6 PJ	Kashmir earthquake (Pakistan), 2005 Antofagasta earthquake (Chile), 2007
7.8	600 megatons	2.4 EJ	Tangshan earthquake (China), 1976`
8.0	1 gigaton	4.2 EJ	Toba eruption 75,000 years ago; which, according to the Toba catastrophe theory, affected modern human evolution San Francisco earthquake (CA, USA), 1906 Queen Charlotte earthquake (BC, Canada), 1949

			México City earthquake (Mexico), 1985 Gujarat earthquake (India), 2001
8.5	5.6 gigatons	23.5 EJ	Sumatra earthquake (Indonesia), 2007
9.0	32 gigatons	134.4 EJ	Lisbon Earthquake (Lisbon, Portugal), All Saints Day, 1755
9.2	90.7 gigatons	379.7 EJ	Anchorage earthquake (AK, USA), 1964
9.3	114 gigatons	477 EJ	Indian Ocean earthquake, 2004 (40 ZJ in this case)
9.5	178 gigatons	747.6 EJ	Valdivia earthquake (Chile), 1960 (251 ZJ in this case)
10.0	1 teraton	4.2 ZJ	Never recorded.

Richter Magnitudes and Earthquake effects[5]

Richter Magnitudes	Description	Earthquake Effects	Frequency of Occurrence
< 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	Minor	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	Great	Devastating in areas several thousand miles across.	1 per 20 years
10.0+	Epic	Never recorded	Extremely rare

			(Unknown)

The Moment Magnitude Scale[6]

Unfortunately, many scales, such as the Richter scale, do not provide accurate estimates for large magnitude earthquakes. Today the moment magnitude scale, abbreviated MW, is preferred because it works over a wider range of earthquake sizes and is applicable globally. The moment magnitude scale is based on the total moment release of the earthquake. Moment is a product of the distance a fault moved and the force required to move it. It is derived from modeling recordings of the earthquake at multiple stations. Moment magnitude estimates are about the same as Richter magnitudes for small to large earthquakes. But only the moment magnitude scale is capable of measuring M8 (read ‘magnitude 8’) and greater events accurately.

Modified Mercalli Intensity Scale

Another way to measure the strength of an earthquake is to use the Mercalli scale. Invented by Giuseppe Mercalli in 1902, this scale uses the observations of the people who experienced the earthquake to estimate its intensity[6]. This scale, composed of 12 increasing levels of intensity that range from imperceptible shaking to catastrophic destruction, is designated by Roman numerals[3]. It does not have a mathematical basis; instead it is an arbitrary ranking based on observed effects. The Modified Mercalli Intensity value assigned to a specific site after an earthquake has a more meaningful measure of severity to the nonscientist than the magnitude because intensity refers to the effects actually experienced at that place.

References

[1] http://pubs.usgs.gov/gip/earthq1/measure.html
[2] http://earthquake.usgs.gov/learn/kids/eqscience.php
[3] http://pubs.usgs.gov/gip/earthq4/severitygip.html
[4] http://earthquake.usgs.gov/learn/glossary/?term=magnitude
[5] http://www.saarc-sadkn.org/about_earthquake.aspx
[6] http://www.geo.mtu.edu/UPSeis/intensity.html