Calculating An Earthquake’s Magnitude—Why does it change?

There seems to be no end of confusion surrounding the question, “Why do seismologists change the magnitude of an earthquake? Magnitudes aren’t simply pulled out of a hat, yet the resultant downgrading or, in the case of larger earthquakes, upgrading of an earthquake’s magnitude is understandably often misinterpreted. Are seismologists hiding something? (27 sec)

The Global Seismographic Network, along with thousands of other seismograph stations worldwide, record seismic waves released by an earthquake. Data from each earthquake are recorded in real-time, and either transmitted immediately by telecommunications to a data management facility or stored for future analysis. Much of the stored data is accessible to anyone who requests it. The National Earthquake Information Center operates a 24-hour service that issues reports in near-real time for magnitudes greater than 3.0 in the U.S., or magnitude 5.0 anywhere else in the world.

 These are just a fraction of the millions of smaller earthquakes detected and located by seismic networks each year.

Obtaining an accurate preliminary magnitude can be difficult due not only to the complex processes that occur deep within the Earth, but because there are over a dozen techniques of calculating the magnitude. Some methods give approximate values within seconds of the earthquake. Others require more complete data sets and extensive analysis.

Computers use the preliminary amplitude and arrival times for P, S, and surface waves from multiple seismograph stations, to derive an *initial* magnitude and location, called the epicenter. Since the amplitude of a seismogram is largest near the earthquake, corrections must be calculated for distance from the hypocenter, where the fault actually broke. Seismograms measured close to the epicenter can be a complicated superposition of P, S, and surface waves, whereas distant highly sensitive seismometers are able to record a more-predictable signature due to the P and S body waves that traveled through the mantle, and the slower surface waves that travel near the earth’s surface.

Calculating an earthquake’s magnitude also requires measuring other characteristics of the earthquake, such as its orientation, frequency, duration, with additional adjustments made for specifically what kind of soil and local geology the station sits on, and how the waves traveled through the earth Also factored in are the characteristics of the seismograph that measures and records the seismogram including whether it records 3 components, or directions of movement, and what type of waves it is calibrated to record.

Each method of determining magnitude has its own limitations. Two examples are the Richter and Moment Magnitude scales.

The Richter magnitude, recorded on a certain type of seismograph that was common in early 20th century when this scale was developed, relates the maximum amplitude of the seismic waves, plotted against distance, which is calculated by S minus P arrival times. Connecting the two gives the Richter magnitude. This scale is good for local smaller earthquakes *below* magnitude five which produce most of their energy as short-period, high frequency waves, but is not as effective for larger earthquakes.

The Moment Magnitude is based on the lowest frequency data recorded on modern seismometers and can be related to the distance the fault moved, the area of the moving fault, and the rigidity, or strength, of the rocks on both sides of the fault. It thus measures the size of an earthquake in terms of the total energy it released. The larger the earthquake, the more energy is released at lower frequencies that are associated with damaging surface waves. The Moment Magnitude works well for long-period, low-frequency, large distant earthquakes. It is the most common measure for earthquakes greater than magnitude five.

The 1989 Loma Prieta, California earthquake had an original Richter magnitude of 7.1. In areas where structures were built on unconsolidated sediment, the intensity was severe. Several years later, it was downgraded to a Moment Magnitude of 6.9 on the basis of more-detailed studies of the various *types* of shock waves generated, combined with the extent of slippage along the San Andreas Fault and new methodologies. Far from "downgrading" the *power* of past earthquakes, the moment magnitude concept simply includes in its calculations the results of years of research findings about how earthquakes behave. Revised estimates of magnitude do not mean that the quakes were any less destructive.

To complicate the initial magnitude picture, large earthquakes are not simple local fault breaks, but often are a cascading sequence of breaks along a long fault rupture.

The Tohoku earthquake was initially reported as magnitude 7.9 . However, that was just the onset of a 500-km-long rupture that was to continue ripping for 3 minutes. It was quickly upgraded to 8.8, then to 8.9, and then finally to 9.0 Mw. Five years later, when all the data were in, it was finally classified as Magnitude 9.1, the fourth largest earthquake ever recorded.

The reason it took so long is because the larger the earthquake, the more complex are the seismic waves recorded from the earthquake. In addition, surface waves can be more prominent farther away from an earthquake in contrast to body waves that tend to die off, or attenuate, at greater distances from the hypocenter.

Determining an earthquake's exact magnitude once took weeks, but now seismologists, using sophisticated computers can crunch the data in minutes to hours for small quakes, and hours to days or weeks for Great earthquakes.

Remember, if you see different magnitudes reported for the same earthquake, it is also important to note that sometimes what appears to be a smaller magnitude may be a different magnitude scale.

# In closing, part of the confusion about magnitude lies in the fact that every earthquake has one magnitude but many different intensities.

# [*onscreen text:* See “*Earthquake Intensity—What controls the shaking you feel?”* https://youtu.be/BP7gKXLjqxk