Making sense of risk
Disaster preparedness
Asia Pacific

EARTHQUAKE
Background information

Earthquakes are the vibrations that result when rocks under stress break along an underground surface, called a fault plane. The 'focus' or 'hypocentre' of an earthquake is the point of origin deep underground and the 'epicenter' is the point on the Earth's surface directly above the earthquake's focus.[i]

How are earthquakes located?

The word 'Seismos', Greek for 'shaking' or 'shock', is applied to the science of earthquakes and the equipment used in their measurement. In the past, earthquake activity was detected using a seismograph, which relied on a mechanical system to record seismic energy and record it on paper; today, seismometers detect seismic activity and convert it to a digital image.[i]

Seismometers located at specific geographic locations are monitored by earthquake monitoring systems. These systems also use 'crustal velocity models' to approximate the speed of seismic waves travelling between the earthquake and the seismometers. The location of an earthquake's focus or hypocenter (that is, its latitude, longitude and depth below the surface) is then determined by a combination of the arrival times of the waves at seismometers in different locations, the location of the seismometers, and the speed of the seismic waves.[i]

Magnitude and intensity

Magnitude and intensity are two measures of an earthquake's characteristics. Magnitude is a measure of the energy released at the source of the earthquake; intensity is the effect that the shaking has on people, structures and the natural environment.

The *magnitude* of an earthquake was traditionally measured on the Richter scale, which is a mathematical formula rather than a physical device; today, it is measured from seismic moment, which is proportional to the fault area multiplied by the average displacement in the fault. This new measure of magnitude, known as the Moment Magnitude scale, is now commonly used for medium to large earthquakes, which are not measured very accurately by the Richter scale (especially if the seismometers are located far from the epicenter).

The Modified Mercalli scale (MM) uses Roman numerals from I to XII to signify the *intensity* of an earthquake (that is, how much the ground shakes at a specific location). This method can be problematic in sparsely-populated areas since it relies solely on the assessment of damage to man-made structures and eyewitness accounts.[ii] The magnitude of an earthquake can be inferred from the MM intensity, as indicated in the table below.

Magnitude	Typical maximum MM intensity
1.0-3.0	I
3.0-3.9	II-III
4.0-4.9	IV-V
5.0-5.9	VI-VII
6.0-6.9	VII-IX
7.0 and above	VIII and above

Magnitude vs intensity comparison.[iii]

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For every unit increase in magnitude, the energy released increases 30-fold.[i] For example, a magnitude 6.0 earthquake releases approximately 30 times more energy than a magnitude 5.0 earthquake, and a magnitude 7.0 earthquake releases 30 x 30 (90) times more energy than a magnitude 5.0 earthquake.

The energy released by a magnitude 8.6 earthquake is comparable to the energy that would be released by 10,000 World War II atomic bombs.[i] Most earthquakes, however, are of smaller magnitude and cause little or no damage.

Revising historical earthquake records

An international effort, led by the International Seismological Centre, to review earthquake records has resulted in a 'downgrade' of the magnitudes of many historical earthquakes. Approximately 20,000 earthquakes worldwide were reassessed in terms of their magnitude and location in order to extend and improve the global seismic events database.[i]

As part of this worldwide initiative, in 2016 Geoscience Australia undertook the revision of several Australian earthquakes (see Table 1.).

In one example, the 1941 earthquake in Meeberrie, Western Australia, which was initially recorded as a magnitude 7.2 earthquake (based largely on personal accounts of those who experienced it) has been revised to a magnitude 6.3. This is particularly interesting, because although this earthquake is not large when compared with other events elsewhere, it was felt as far north as Port Headland, as far south as Albany and Norseman, and even caused minor damage in Perth, some 500 kilometers from the epicenter.[i]

Geoscience Australia's Atlas of Seismic Maps of Australia summarises the revised magnitudes and provides regional estimates of earthquake vulnerability. This in turn informs the Building Code of Australia, which then specifies the appropriate construction of buildings in earthquake-prone areas.

In New Zealand, a new national system for managing earthquake-prone buildings (EPB) and focusing on occupants' safety was introduced in July 2017. It identifies three seismic risk zones and requires that EPB be identified and strengthened or removed within a specified time frame.[iv]

Magnitude post 2016 revisions	Magnitude pre-2016 revisions	Location	Date
6.6	6.5	Tennant Creek, NT	1988
6.5	6.9	Meckering, WA	1968
6.4	5.6	Simpson Desert, NT	1941
6.3	6.4	Tennant Creek, NT	1988
6.3	7.2	Meeberrie, WA	1941
6.2	6.3	Collier Bay, WA	1997
6.2	6.3	Tennant Creek, NT	1988
6.1	6.2	Cadoux, WA	1979

Table 1. Modified from: Australian Government Geoscience Australia, Earthquake

Where do they occur?

Earthquakes generally occur where two tectonic plates collide, or collide and slide past each other. Large events are especially common around the Pacific 'rim' – at the edge of the Pacific plate – in New Zealand, Japan, the Solomon Islands, Papua New Guinea and the Americas, and where the Indo-Australian plate collides with the Eurasian plate, in Indonesia. The focus of these earthquakes may be up to 700 kilometres deep.

Shallow earthquakes can also occur where tectonic plates pull apart, and, less commonly, in the relatively stable intraplate regions distant from the plate edges.

Australia's earthquakes (the largest, in Tennant Creek, Northern Territory in 1988, measured 6.6 magnitude; see Table 1) are caused by the collision of the Indo-Australian plate with the Eurasian, Philippine and Pacific plates as it pushes north. The 1968 earthquake in Meckering, Western Australia (see Table 1), while not the largest, caused extensive damage because it occurred in a more populous area.

Western Australia experiences earthquakes of more than 4.0 magnitude relatively frequently; one occurs approximately every five years in the Meckering area.[i]

New Zealand experiences up to 15,000 tremors every year, the most powerful to date being the 8.2 magnitude Wairarapa earthquake in 1855, during which about 5,000 square kilometres of land was shifted vertically.[v]

The New Zealand GNS Science body predicts that a major earthquake is likely to occur along the Alpine fault of the South Island within the next 50 years.

Earthquake effects

The extent, or amplitude, of the shaking in an earthquake is dependent on the magnitude, the distance from the epicenter, the depth of the focus, the topography, and other local ground conditions.

Earthquakes of less than 3.5 magnitude rarely cause damage, but the damage caused and injuries suffered relate to the population density and presence of man-made structures. A magnitude 4.0 tremor can topple chimneys, for example, and the magnitude 5.6 earthquake in Newcastle, New South Wales in Australia, caused fatalities.

The effects of earthquakes are not confined to shaking and damage to buildings or roads. They can also cause landslides and soil liquefaction. Liquefaction happens in water-saturated unconsolidated soils when seismic waves turn the solid soil into a viscous liquid.[vi] Sandy, silty and poorly-drained soils are the most susceptible. The liquefied soil is able to flow, potentially causing buildings to topple, and it may even erupt at the surface.

In the 7.5-magnitude Tangshan earthquake of 1976, an estimated 2,400 square kilometers experienced liquefaction, while the liquefaction of the lake sediment beneath Mexico City contributed to the serious damage sustained in its 1985 earthquake.[iv]

In earthquake-prone areas, buildings anchored to bedrock or consolidated soils are less likely to sustain damage if soil liquefaction occurs.

An earthquake which occurs beneath the seabed can cause a tsunami, or destructive sea waves which can travel long distances and cause extensive damage.

The damage to power lines and gas mains caused by earthquakes can result in fires.

At what intensity is an earthquake felt, and at what intensity does it cause damage?

I. Not felt except by a very few under especially favorable conditions.

II. Felt only by a few persons at rest, especially on upper floors of buildings.

III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.

IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.

VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.

VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.

VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.

IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.

XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Abbreviated Modified Mercalli intensity scale[vii]

Quick facts

- → A magnitude 7.0 earthquake releases 90 times more energy than a magnitude 5.0 earthquake.
- → Seismic waves travel very fast. They can reach the other side of the earth – a distance of 13,000km – in less than 20 minutes.
- → Liquefaction of water-saturated soil beneath buildings during an earthquake can cause them to topple.
- → Australia experiences an average of 100 earthquakes of magnitude 3.0 and more every year, and a potentially damaging earthquake of 6.0 or more approximately every eight years.
- → Australia has not experienced a magnitude 7 earthquake since record keeping began (in the late 1800's.)
- → Australia's Seismic Hazard Maps are available from https://tinyurl.com/y8xrrbwu.
- → New Zealand experiences over 15,000 earthquakes annually, only 100-150 of which are large enough to be felt.[v]
- → New Zealand's real-time hazards can be accessed through Geonet (http://www.geonet.org.nz/).[viii]

Want more information?

[i] Australian Government Geoscience Australia, Earthquake

[ii] University of Kansas, Measuring earthquake magnitude and intensity

[iii] USGS, Earthquakes Hazards Program, Magnitude/intensity comparison

[iv] Ministry of Business, Innovation and Employment, Building performance, Managing Earthquake-prone buildings

[v] GNS Science, Where were New Zealand's largest earthquakes?

[vi] Rafferty, P, Encyclopaedia Britannica, Soil liquefaction

[vii] USGS, The Severity of an Earthquake

[viii] GeoNet Geological hazard information for New Zealand

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