What is the Definition of an Earthquake?

An earthquake is the sudden, sometimes violent movement of the earth's surface from the release of energy in the earth's crust.

2. What Causes Most Earthquakes?

The crust of the earth when it is subject to tectonic forces, bends slightly. But, because the crust is rigid, when the stress or pressure exceeds the strength of the rocks, the crust breaks and snaps into a new position. Vibrations called **seismic waves** are generated and travel both through the earth and along its surface. These seismic waves cause the movement we call earthquakes.

3. Where Are Earthquakes Likely to Occur?

Within areas of the crust are fractures, known as **faults**, along which two crustal blocks have slipped or moved against each other. One block may move up while the other moves down, or one may move horizontally in one direction and the other in the opposite direction. Geologists and **seismologists** (scientists who study earthquakes and the processes that create them) have found that earthquakes occur repeatedly at **faults**, which are zones of weakness in the earth's crust.

4. How Many Earthquakes Happen Each Year?

There are over a million quakes annually, including those too small to be felt. The following table shows the average frequency of different magnitudes.

Description	Magnitude	Frequency per year
Great	8.0+	1
Major	7.0-7.9	18
Large (destructive)	6.0-6.9	120
Moderate (damaging)	5.0-5.9	1,000
Minor (damage slight)	4.0-4.9	6,000
Generally felt	3.0-3.9	49,000
Potentially perceptible	2.0-2.9	300,000
Imperceptible	less than 2.0	600,000+

5. How Many Earthquakes Happen Every Month? Day? Minute?

Using the previous table:

Per month.....Approximately 80,000

Per day.....Approximately 2,600

Per minute.....Approximately 2

And, per second, one earthquake is felt approximately every 30 seconds.

Of these only a relative few are capable of causing damage. Earthquakes are common natural events.

6. How Deep Do Earthquakes Occur in the World?

Earthquakes occur in the crust or upper mantle which ranges from the surface to about 800 kilometers deep (about 500 miles).

7. Where Do Most Earthquakes Occur in the World?

The surface of the earth is divided like a jigsaw puzzle into giant pieces called **tectonic or crustal plates.** These giant pieces move slowly over partially melted rock known as the **mantle.** As they move, they slide along each other, move into each other, move away from each other, or one slips under another. On these active plate boundaries about 95% of all the world's earthquakes occur. California, Alaska, Japan, South America, and the Philippines are all on plate boundaries. Only 5% are in areas of the plates far away from the boundaries. These are called **mid-plate or intra-plate** earthquakes and are, as yet, poorly understood.

8. Where do the Most Earthquakes Occur in the United States ?

Alaska has more earthquakes per year than the combined total of the rest of the United States. As many as 4,000 are recorded there every year. Alaska is on a plate boundary where one plate is sliding along another, a **subduction zone.**

9. Where Did the Largest Known Earthquake Occur?

A magnitude 9.5 earthquake in Chile in 1960 was the largest known earthquake and resulted in over 6,000 deaths. It triggered a **tsunami** or seismic wave (incorrectly known as a tidal wave) that killed people as far away as Hawaii and Japan. Chile is also on a **subduction zone.**

10. What Was the Largest Earthquake in the United States?

The great Alaska earthquake of March 27, 1964, is the largest earthquake in the United States. It had a **magnitude** of 9.2. 115 people died, with most of the deaths due to the **tsunami** it generated. Shaking was felt for an estimated 7 minutes, and raised or lowered the ground surface as much as 2 meters (6.5 feet) in some areas and 17 meters (approx. 56 feet) in others. The length of the ruptured fault was between 500 and 1,000 kilometers (310.5 and 621 miles). The amount of energy released was equal to 12,000 Hiroshima-type blasts, or 240 million tons of TNT.

11. Where Was the Largest Earthquake in the Continental United States?

A series of four great earthquakes occurred in the central United States on December 16, 1811, and January 23, and February 7, 1812. All had estimated magnitudes greater than 7.5 on the Richter Scale, the largest happening on February 7, 1812. They are collectively known as the New Madrid earthquakes (after a small town in Missouri) and were felt as far away as Washington D.C., and Boston, Massachusetts. These events were felt over a region far greater than any other in the United States, an estimated 2 million square miles. There were fewer than 100 deaths, because of the small number of people living in the area. The earthquakes raised and lowered land levels several feet, created one large lake and several smaller lakes, and formed waterfalls on the Mississippi River. One small town was destroyed and there was extensive damage to structures and changes to land surfaces throughout the region. These earthquakes were far away from a plate boundary, and are the largest known to have happened in a mid-plate area.

12. It Seems that Large Earthquakes in the U.S. Are Responsible for Relatively Few Deaths. Is This True Around the World?

No. In other areas of the world smaller earthquakes are responsible for the deaths of many thousands of people. This is primarily because of buildings which are poorly designed and constructed for earthquake regions, and population density. The following table shows some of the major earthquakes around the world in the last twenty years, and the number of deaths associated with them.

Year	Date	Region	Deaths	Magnitude
1971	02-09	Southern California	65	6.5
1972	12-23	Managua, Nicaragua	5,000	6.2
1976	02- 04	Guatemala	22,000	7.9
1977	07-27	Tangshan, China	250,000+	7.6
1980	03- 04	Romania	2,000	7.2
1980	10- 10	Algeria	35,000	7.7
1981	11-23	Southern Italy	3,000	7.2
1982	06-11	Southern Iran	3,000	6.9
1983	12- 13	Yemen	28,000	6.0
1985	10- 30	Turkey	1,342	6.0
1989	09- 19	Mexico	10,000	7.0
1985	12- 07	Armenia	25,000	6.9
1989	10-17	Northern California	67	7.1
1990	06-20	Iran	40,000	7.7

13. What Was the Greatest Number of People Killed in One Earthquake?

An earthquake in China in 1556 killed approximately 830,000 people.

14. How Are Earthquakes Measured?

A **seismometer** is an instrument that senses the earth's motion; a **seismograph** combines a seismometer with recording equipment to obtain a permanent record of the motion. From this record scientists can calculate how much energy was released in an earthquake, which is one way to decide its magnitude. Calculations are made from several different seismograms, both close to and far from an earthquake source to determine its magnitude. Calculations from various seismic stations and seismographs should give the same magnitude, with only one magnitude for any given earthquake.

Richter Magnitude is the scale most people are familiar with, but scientists use other more accurate scales. Another nonscientific way of measuring earthquakes is by their intensity or degree of shaking. Intensity is descriptive, and is determined by inspection of damage and other effects, with the greatest intensity being close to the epicenter, and smaller intensities further away. The **Modified Mercalli Intensity Scale** uses Roman Numerals from I to XII to describe different earthquake effects is commonly used.

15. What Does the Richter Scale Look Like?

The **Richter Scale** is not an actual instrument. It is a measure of the amplitude of seismic waves and is related to the amount of energy released. This can be estimated from the recordings of an earthquake on a seismograph. The scale is **logarithmic**, which means that each whole number on the scale increases by 10. A magnitude 6.0 earthquake is 10 times greater than a 5.0, a 7.0 is 100 times greater, and a magnitude 8.0 is 1,000 times greater.

16. When was the First Instrument for Detecting Earthquakes Invented?

The earliest known earthquake detection instrument was invented in 132 A.D. by Zhang Heng, a Chinese philosopher. The instrument was a large (2 meters or 6.5 feet in diameter) bronze jar, with a central pendulum inside. Decorating the jar on the outside were a series of dragon heads connected to a pendulum, each with a ball in a hinged mouth. Directly beneath each dragon head, on the surface of the stand, was a bronze toad, head up, mouth open to receive a ball from the dragon's mouth.

During an earthquake, the ground motion would move the pendulum and cause one or more balls to fall from a dragon's mouth into a toad's mouth. The direction of the earthquake was indicated by which of the dragon heads had dropped a ball.

This instrument was sensitive enough to perceive shaking too small to be felt, as it detected an earthquake over 600 kilometers (372 miles) away, news of which arrived several weeks later.

Earthquake detectors are mentioned later in oriental manuscripts, but in the west earthquake detection instruments did not emerge until centuries later.

17. What is the Difference Between an Earthquake Prediction And a Forecast?

An earthquake prediction involves assigning a specific date, location, and magnitude for an earthquake. A forecast assigns a series of probabilities and a range of years and magnitudes to a region. There is no way to accurately predict earthquakes, but forecasts have been calculated for different areas of the United States. The earthquake in northern California on October 17, 1989 was not predicted, but did fall within the magnitude range, time span, and region forecast by U.S. Geological Survey staff.

18. Does Animal Behavior Change Before Earthquakes?

Changes in animal behavior before earthquakes have been observed and documented in different parts of the world, most recently in the northern California earthquake of October 17, 1989. It has been recorded that a fish in a high school biology lab in California would flip on its side before some earthquakes.

Dogs, cats, snakes, and horses has also been known to behave strangely before earthquakes. Since behavior is not earthquake specific, change in animal behavior can therefore result from other events, and it is impossible to determine beforehand what factor has caused the change. Also, the behavior is not consistent. Sometimes earthquakes occur with no previous behavior change.

19. Does the Ground Really Open Up and Swallow People?

This is an earthquake myth. Cracks and fissures appearing in the ground are a common effect of earthquakes. Most of these are narrow and shallow. In very large earthquakes changes in the level of the land can result in larger cracks that can cause a lot of damage to buildings, but people and buildings do not get swallowed by the ground.

20. Do Earthquakes Cause Volcanoes?

No, there are different earth processes responsible for volcanoes. Earthquakes may occur in an area before, during, and after a volcanic eruption, but they are the result of the active forces connected with the eruption, and not the cause of volcanic activity.

21. Are Earthquakes Weather Related?

In the 4th Century B.C., Aristotle proposed that earthquakes were caused by winds trapped in subterranean caves. Small tremors were thought to have been caused by air pushing on the cavern roofs, and large ones by the air breaking the surface. This theory lead to a belief in earthquake weather, that because a large amount of air was trapped underground, the weather would be hot and calm before an earthquake.

A later theory stated that earthquakes occurred in calm, cloudy conditions, and were usually preceded by strong winds, fireballs, and meteors. There is no connection between weather and earthquakes. They are the result of geologic processes within the earth and can happen in any weather and at any time during the year.

22. What Are Earthquake Scientists Called?

Seismologists: seismos-from the Greek meaning earthquakes, and ologist-meaning a person who studies (something). A seismologist is a person who studies earthquakes and the mechanics of the earth.

23. How Much Energy is Released in an Earthquake?

Earthquakes release a tremendous amount of energy, which is why they can be so destructive. The table below shows magnitudes with the approximate amount of TNT needed to release the same amount of energy.

Magnitude	Approximate TNT Energy
4.0	6 tons
5.0	199 tons
6.0	6,270 tons
7.0	199,000 tons
8.0	6,270,000 tons
9.0	99,000,000 tons

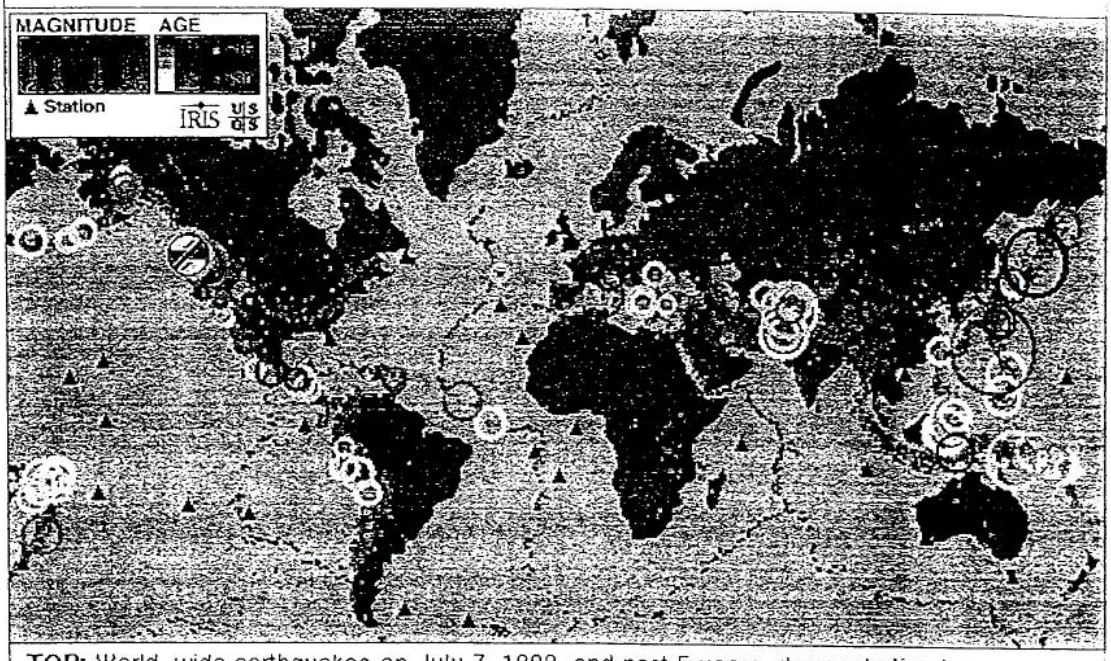
24. Do All Large Magnitude Earthquakes Result in Great Amounts of Death and Destruction?

No. The destructive forces of an earthquake depends on many factors. Large earthquakes commonly occur in remote areas of the world, with no buildings or people, and are not destructive. In addition to magnitude, some of the factors that determine damage and deaths are: population densities, the density and types of building construction, local geologic conditions, distance from the epicenter, earthquake depth, how long the shaking continues, and the degree of earthquake preparedness in the region.

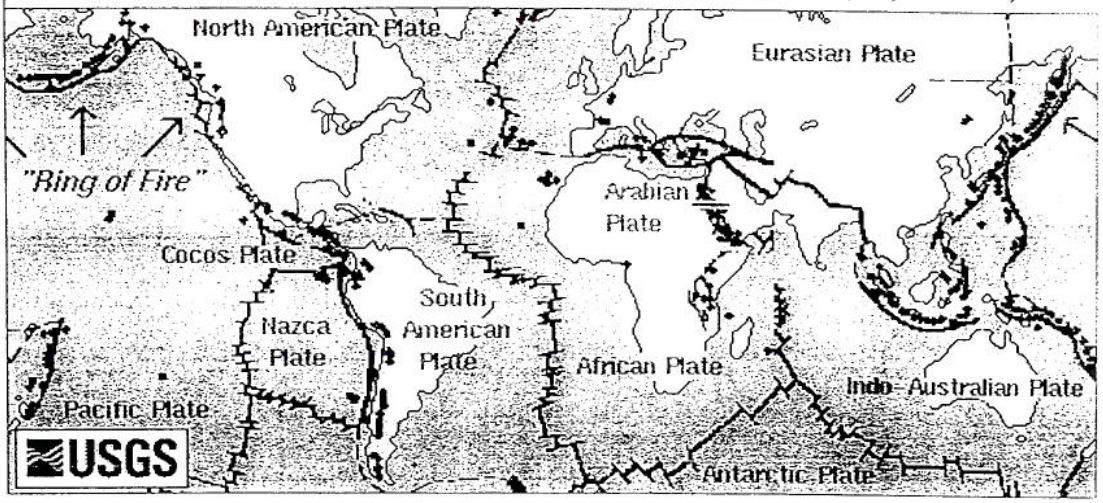
25. Can Earthquakes Be Prevented?

There is no known way to prevent earthquakes, but it is possible to lessen the impact. The amount of devastation from an earthquake can be greatly diminished by building structures using earthquake resistant design, making the interiors of buildings safe from falling objects, and educating people about earthquake safety.

Earthquakes, Active Volcanoes, and Plate Tectonics



TOP: World-wide earthquakes on July 7, 1999, and past 5 years, demonstrating how earthquakes define boundaries of tectonic plates. Data from NEIC. Chart from IRIS Consortium, USGS, U.Colorado, Reel Illusions, Inc., and U.Washington. Chart modified for web use. Purple triangles are seismic stations, green/yellow "ball" is 5.1 event of July 3, 1999. **BOTTOM:** World-wide active volcanoes (red circles), tectonic plates, and the "Ring of Fire". Chart modified from Tilling, Heliker, and Wright, 1987, and Hamilton, 1976. -- *Topinka, USGS/CVO, 1999*



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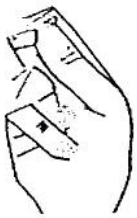
Earthquakes: Seismic Waves

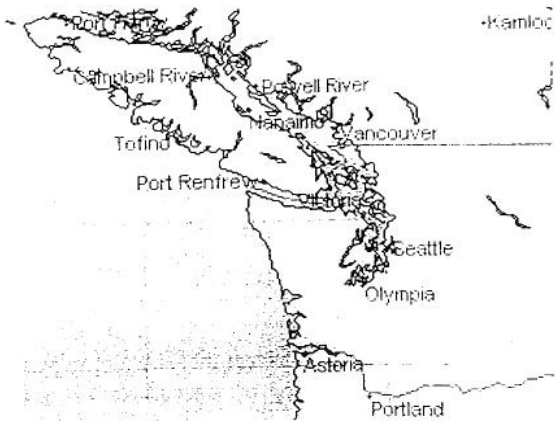


Snapping fingers!

Make Your Own Earthquake With a Snap of Your Fingers

Can you snap your fingers? Try it now and observe what is happening.

When you snap your fingers, imagine that each finger is a big chunk of rock deep inside the earth's surface. Like your fingers, one rock mass is forced against another. Think of the increasing amount force you place on your fingers as pressure caused by movements of the Earth's crust. Now, think of the movement of your fingers to create the snap as the sudden movement of the earth, an **earthquake**. Think too, that the sound of the snap itself as being the seismic energy travelling from the location of the quake. If you can think this way, you are well on your way to understanding earthquakes and the energy they release in huge waves that shake, rattle and roll the earth's surface.



Blue primary waves followed by red secondary waves move outward in concentric circles from the epicenter of an earthquake off British Columbia and Washington State.

Seismic Waves

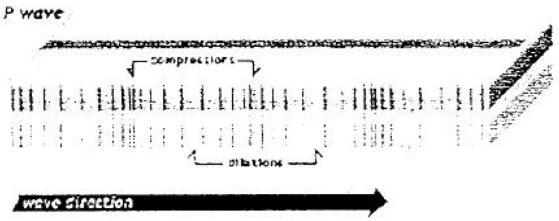
Deep inside the earth, rocks are constantly being pressured to move. This pressure builds and builds until the strain is so great the rocks can no longer bear the tension. Suddenly, there is a movement that releases all the energy some of which has been building up over years. This released energy travels through rocks in the form of vibrations called **seismic waves**. The waves travel outward from the spot where rocks of the earth's crust snapped under the strain. This spot is called the **hypocenter**. The spot on the earth's surface right above the hypocenter is called the **epicenter**. Earthquakes are felt the strongest at the epicenter.

Energy released at the hypocenters of earthquakes travel as three different types of waves. You can think of these waves by picturing the ripples

created when a stone is thrown into a puddle or lake. The first set of waves are called P-waves or primary waves. The second ones are called S-waves or secondary waves. The third waves are called L-waves or Love wave, named after the scientist who first discovered it.

The energy of all three types of waves is passed from one rock particle to another in the same way one dominoes hits another and then another in a line of falling dominoes. These seismic waves cause back-and-forth, side-to-side, and up-and-down motions in the earth. These motions are what people sense during a earthquake. These motions also cause the movement of objects we often see in video images of areas hit by an quake.

Primary Waves (P-waves)

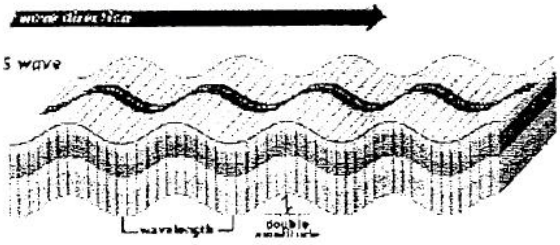


Primary waves are compression waves. They push and pull the rocks os the earth's surface.

Primary waves travel the fastest, at an average speed of 4.5 kilometres per second. They can move through solid rock and fluids, like water or the liquid core layers of the earth. P-waves are the first waves to reach the Earth's surface after an earthquake.

Primary waves push and pull on the rocks through which they are travelling. This creates a back and forth movement on the Earth's surface. This is just like sound waves pushing and pulling the air. Have you ever heard a big clap of thunder and heard the windows rattle at the same time? The windows rattle because the sound waves were pushing and pulling on the window glass much like P-waves push and pull on rock. Sometimes animals can hear the P-waves of an earthquake. Usually, we only feel the bump and rattle of these waves.

Secondary Waves (S-Waves)

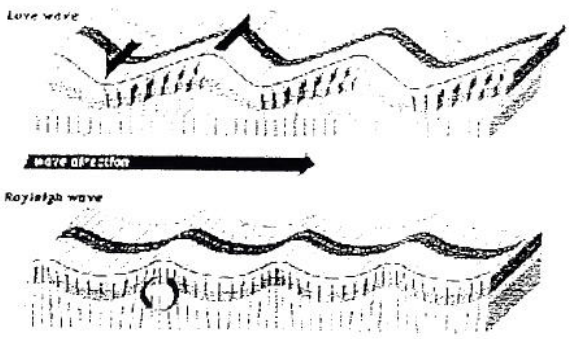


Secondary moves move through solid rock only. These shear waves move the earth's surface

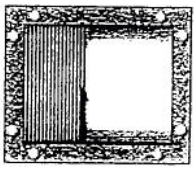
Secondary waves travel slower than primary waves. Their average speed is 2.4 kilometres per second. Also called shear waves, S-waves create a side to side motion in the rocks through which they are travelling. Unlike the other earthquake waves, S-waves cannot travel through water or the liquid rock of the Earth's core layer. S- waves will rock building side-to-side.

Togther, P-waves and S-waves are called body

side to side.



Love waves move along the surface of the earth and cause it to move up and down like something bobbing on the surface of the ocean.



This is an image of a seismograph, an instrument used to record the energy released by an earthquake. When the needle is moved by the motion of the earth, it leaves a wavy line.

seismic waves because they travel inside the body of the earth to the surface. Together, they cause tall buildings to sway one way and then another.

Love Waves (L-waves)

Love waves, named after the British scientist who first discovered them, only move along the surface of the earth. There speeds vary depending on the material, rock or soil, forming the surface. These waves cause the surface to move from side-to-side. These are the waves that cause the most damage to buildings and other structures created by man during an earthquake.

A part of Love waves is an **R-wave** or Rayleigh wave. Rayleigh waves move the surface of the earth around in a circle, forward and down then back and up. This is the same as the motion in an ocean wave. Both Rayleigh and Love waves get smaller, deeper in the ground.

Seismology

The energy released by an earthquake is created when rocks beneath the earth break. **Seismology** is the study of earthquakes and these seismic waves. A **seismologist** is a scientist who studies earthquakes and seismic waves. A **seismograph** is an instrument that measures earthquakes. A **seismogram** is the recording itself.