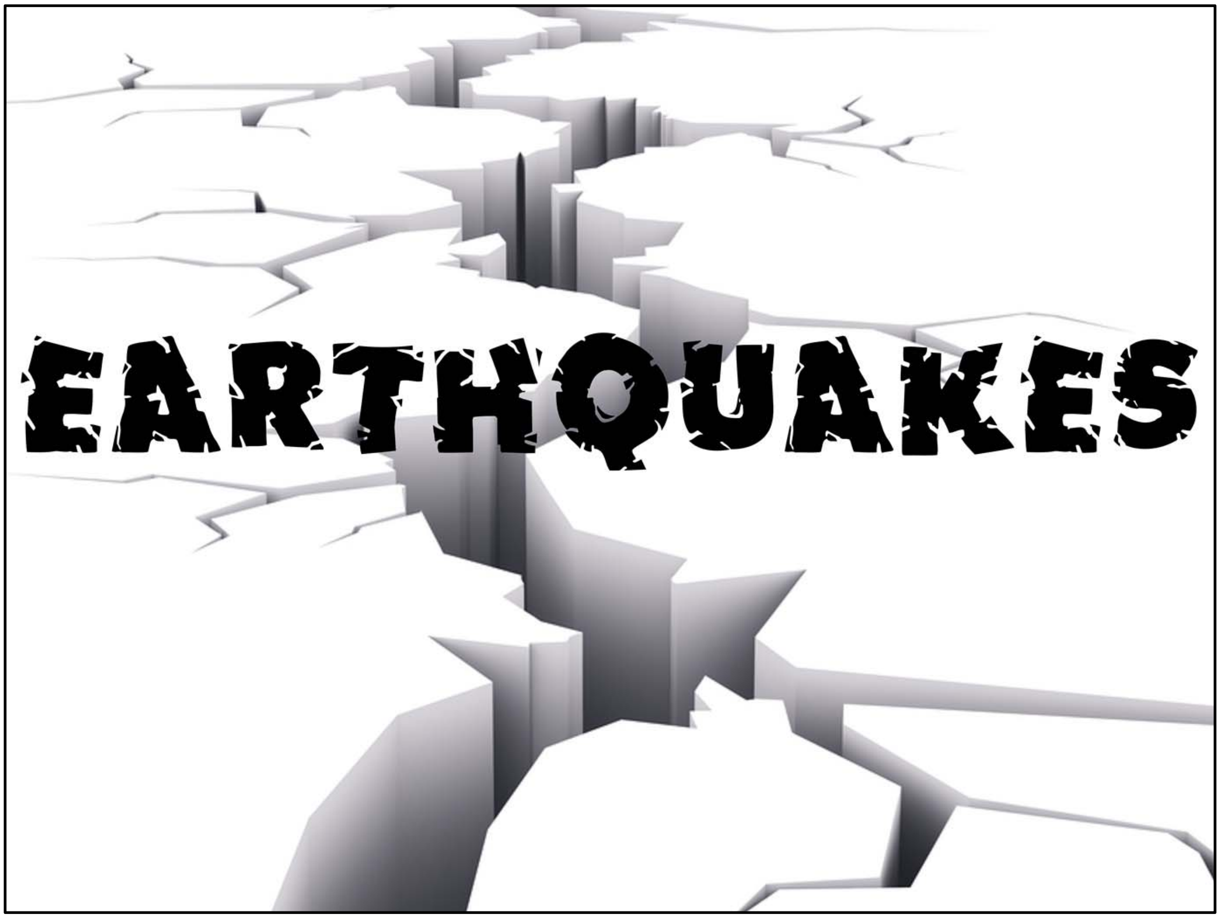
# Module 7: Plate Tectonics and Earth's Structure

## Topic 4 Content : Earthquakes Presentation Notes



Earthquakes

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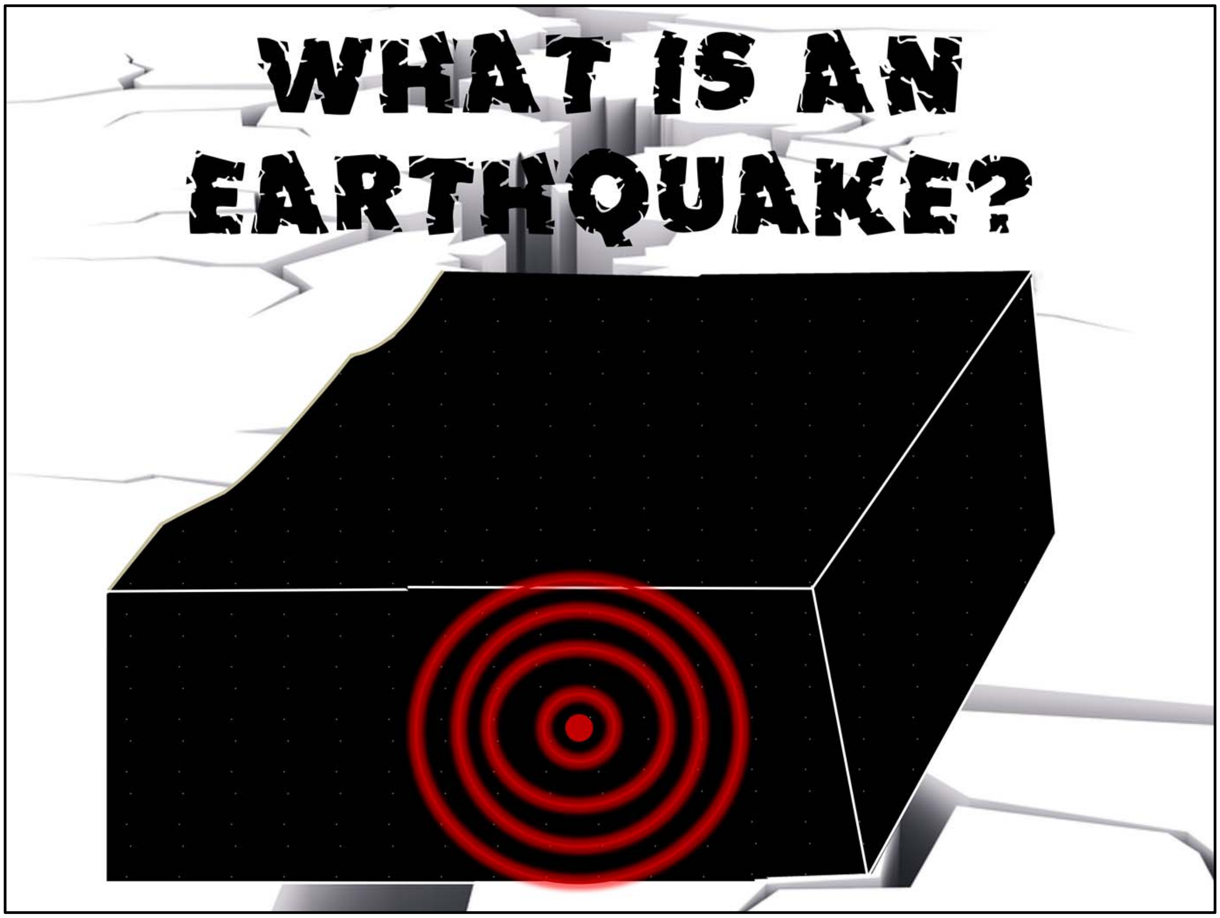
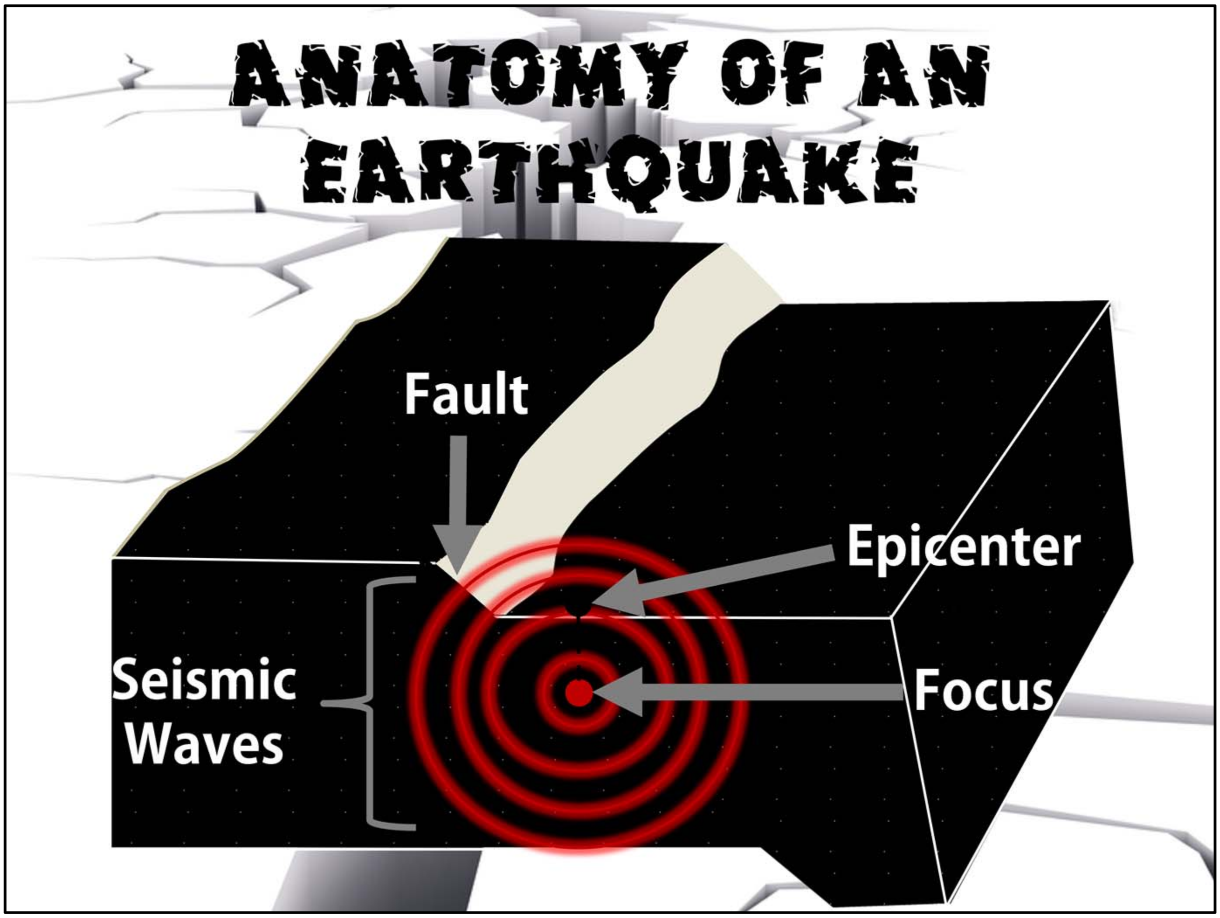


Earthquakes are vibrations within the Earth produced by the rapid release of energy from rocks that break under extreme stress. Earthquakes are also triggered by volcanic eruptions. Here you can see a large cross-section of land. What you cannot see is the stress is building up in the rock as one side of the land is being forced a past the other side. Eventually, the rock will break and send energy rippling through the ground. When that energy reaches the surface, trembling occurs. It is that trembling and shaking that is known as an earthquake.



During an earthquake, seismic waves of energy radiate in all directions from the point of the earthquake’s origin underneath Earth’s crust. The point of origin is called the focus of the earthquake. The point on the Earth’s crust directly above the focus is the earthquake’s epicenter. The epicenter is determined by measuring the arrival of the waves of energy from the focus.

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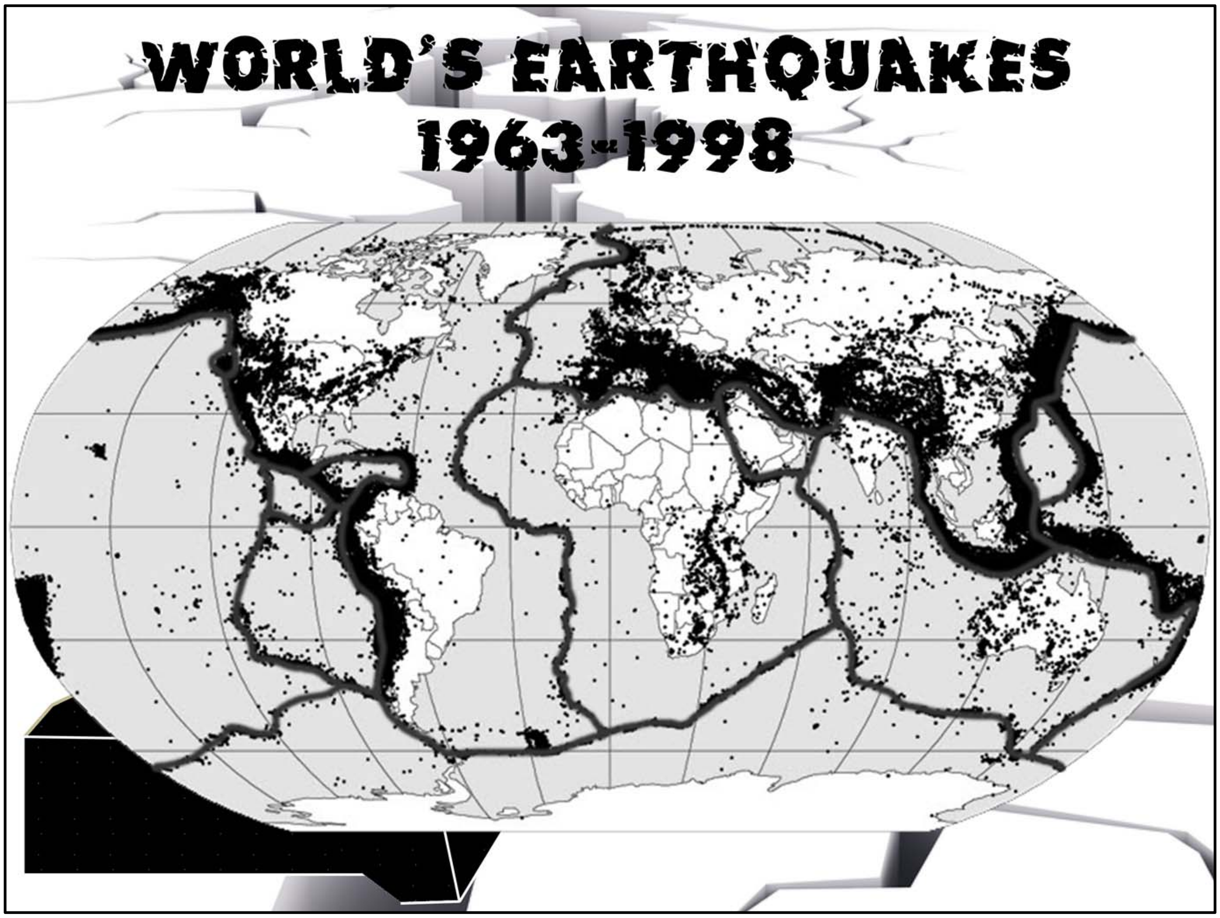
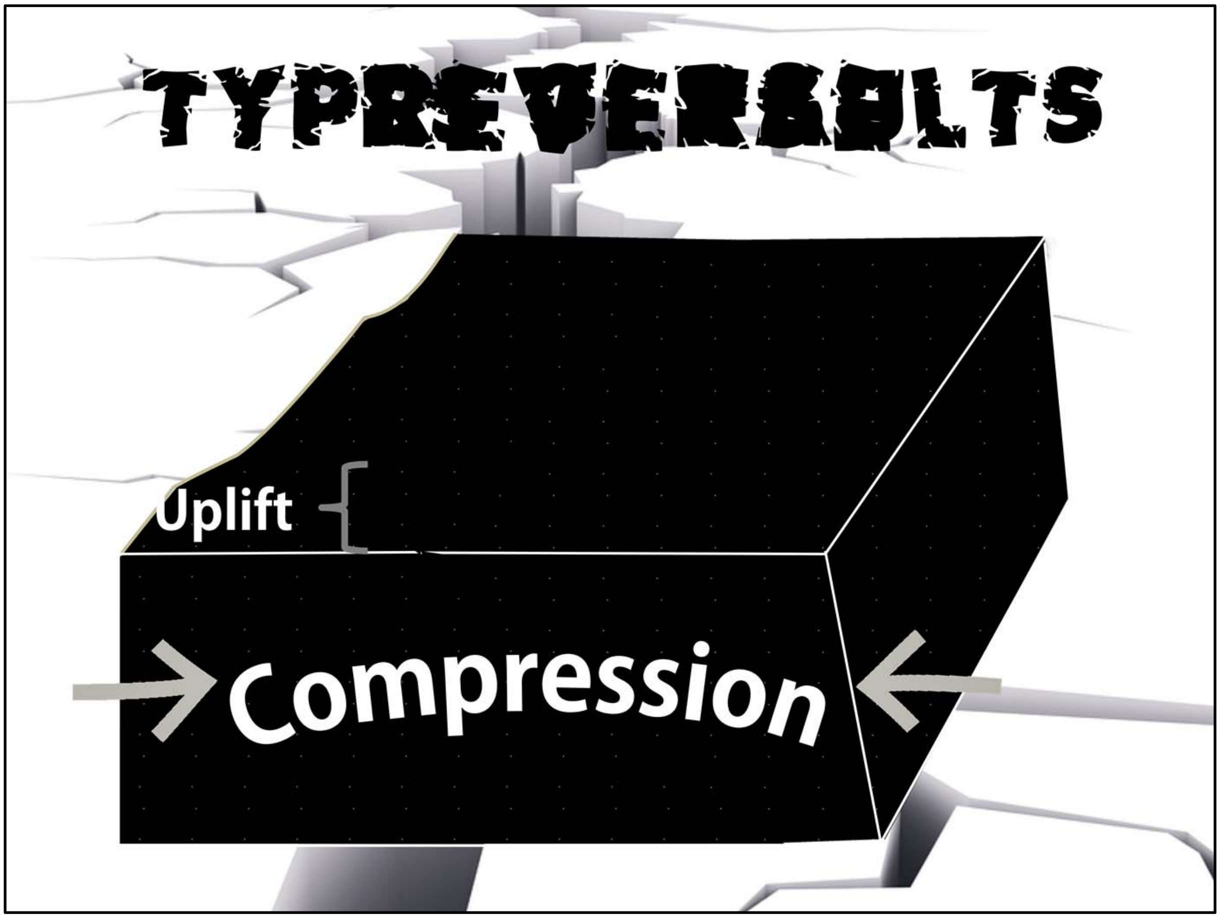
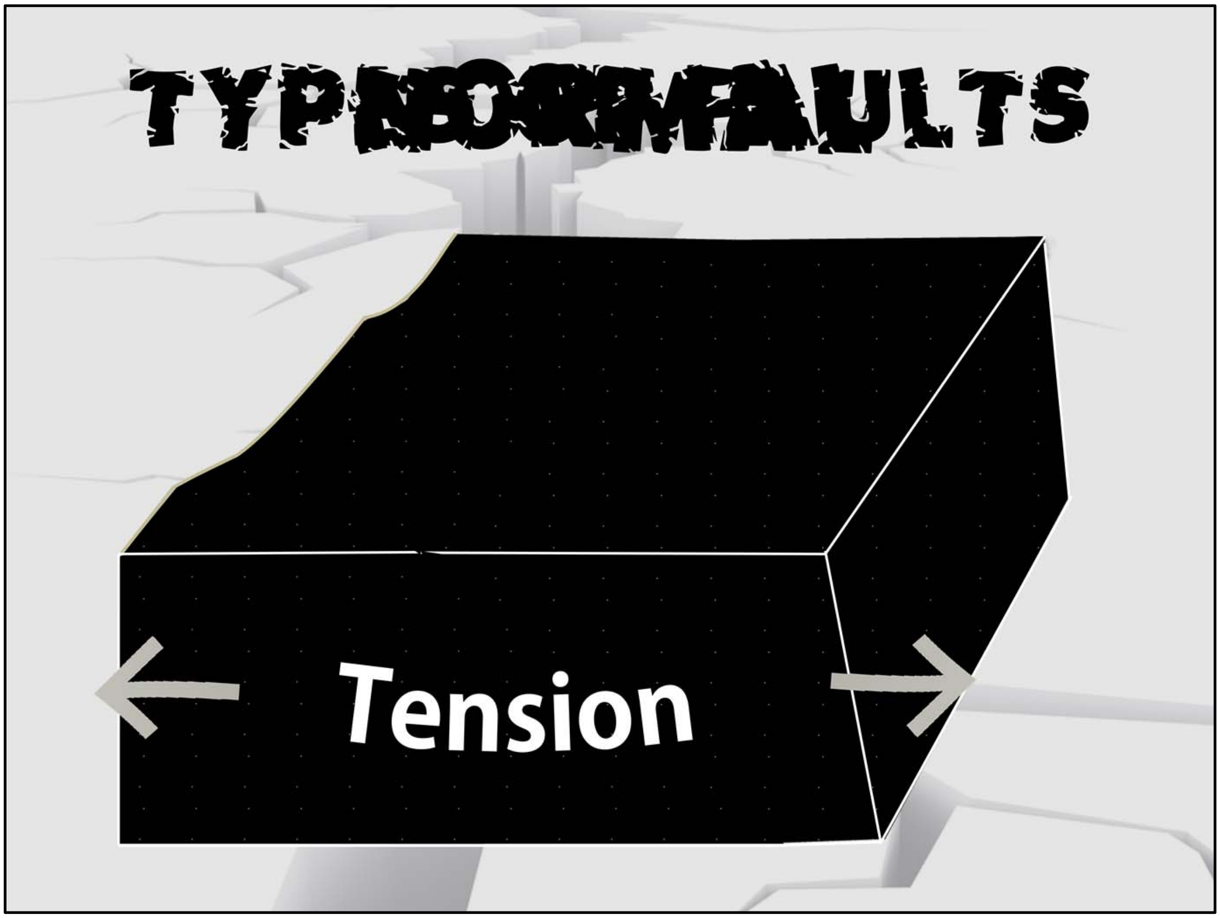


Earthquakes occur along faults, which are fractures or breaks in the Earth's crust. These fractures form when the stress on the rock is greater than the strength of the rock. Faults are associated with the boundaries of tectonic plates, so earthquakes most often occur along plate boundaries. This image shows the location of each earthquake from 1963 until 1998. The lines indicate the approximate location of all of the plate boundaries. As you can see from the image, the majority of earthquakes occur on these boundaries. There are cases when earthquakes occur off of the boundaries. Do not forget that the world looked much different in the past. Many of these earthquakes are occurring on ancient fault lines. These fault lines may have formed when all of the continental land was once together.



There are three basic fault types and each one is caused by a different type of stress. A reverse fault is a fracture that forms from the stress of compression. These faults are common at convergent plate boundaries. When an earthquake occurs along this type of fault, one side of the fault will rise when compared to the other side. This is also known as uplift.



Normal faults have the opposite motion of reverse faults. These faults are common at divergent plate boundaries and occur due to the force of tension. When an earthquake occurs along this type of fault, one side of the fault will lower when compared to the other side.

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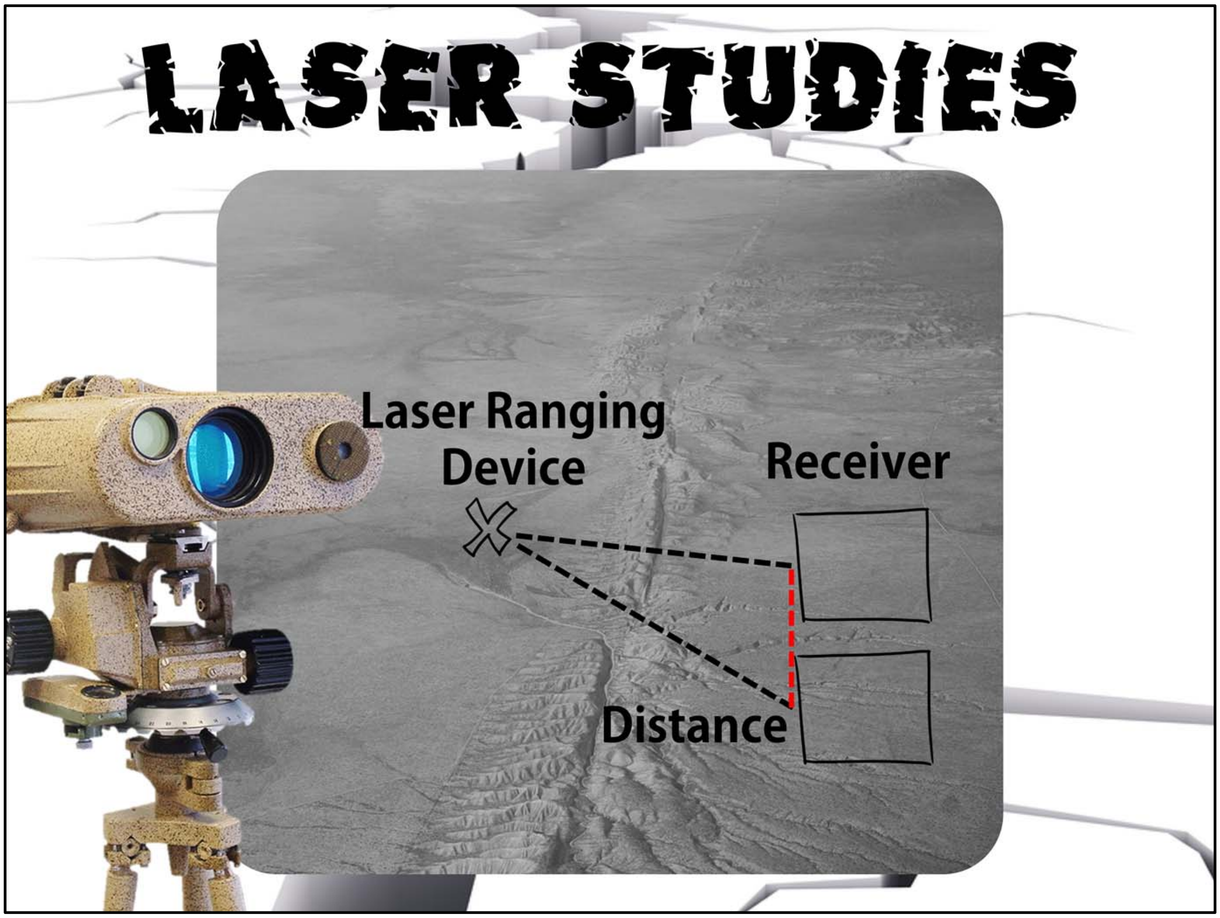
Strike-slip faults have only horizontal motion. These faults are common at transform plate boundaries and occur due to the force of shearing. When an earthquake occurs along this type of fault, one side of the fault will slide past the other side. The most notorious strike-slip fault is found in California. The San Andreas Fault extends over 800 miles. That means that the majority of California could feel an earthquake as this fault shifts. Parts of the San Andreas Fault are visible on the surface of Earth as a visible scar.

How do geologists study the movement along a fault line? First, geologists can analyze where the different sides of the faults once connected. You can see from the image of the San Andreas Fault that the path of a river has been altered by the movement of the fault. The river that should run straight now changes direction right at the fault line. How much does this fault move each year? To determine this information, geologists use laser ranging devices. When placed on each side of the fault, the laser ranging device can accurately measure how much the fault moves. This is another way geologists use remote sensing, or obtaining information from a distance.



How does a laser ranging device work? Geologists place the laser device on one side of the fault and aim it at a receiver on the opposite side of the fault. As the fault moves, distance between the laser ranging device and the receiver will change relative to one another. This distance will let scientists know the movement of the fault over time. The red line indicates the distance the receiver moved over time.

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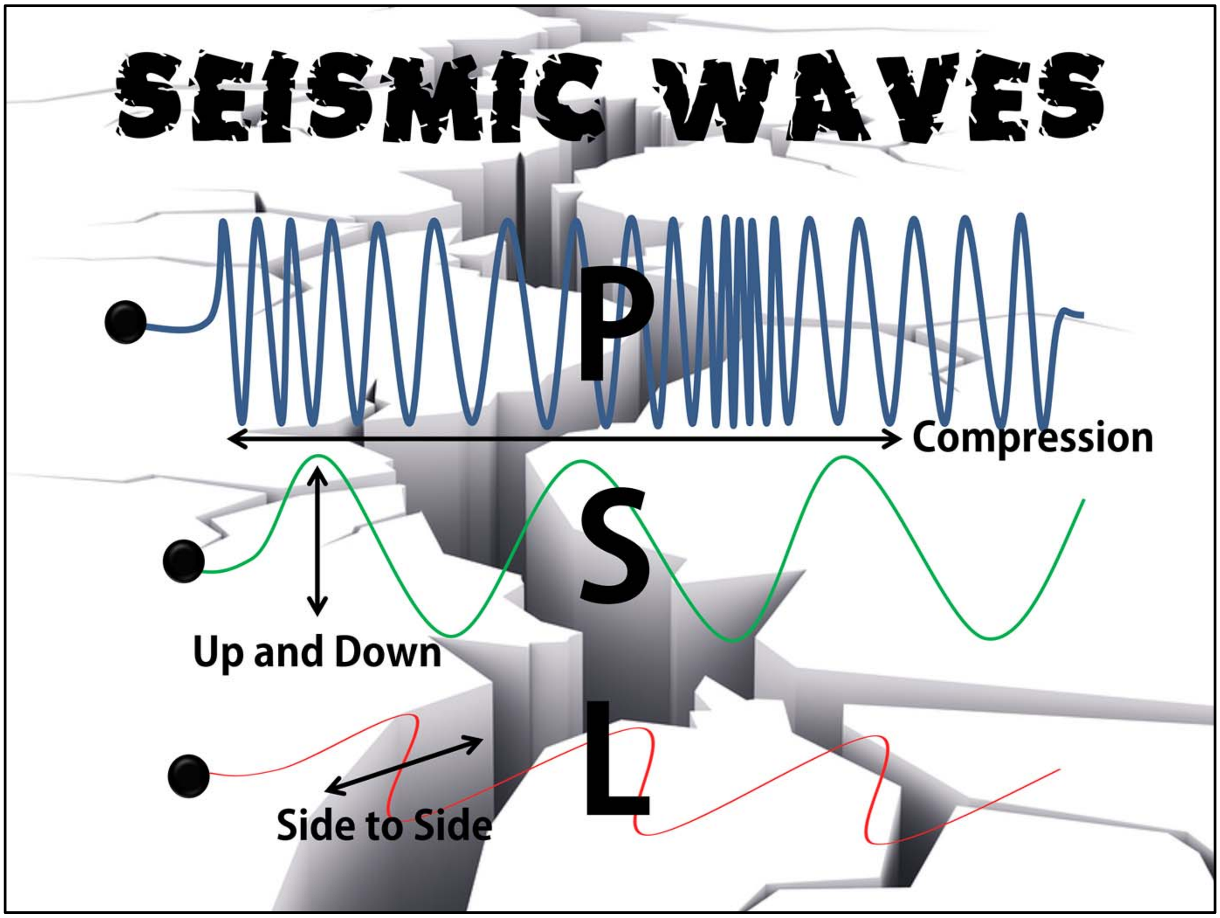

Earthquakes cause two types of wave energy that radiate outward from the earthquakes' focus. These waves are called seismic waves. The body waves travel through Earth's interior. Primary waves, also called P waves, push and pull rocks in the direction the wave is traveling. The push and pull energy of this seismic wave can be observed by the movement of the black dot. Secondary waves, or S waves, shake the particles in the rock at right angles in the direction the wave is traveling. Again, the black dot shows how the energy of this wave would move up and down. P waves can travel through solids, liquids, or gases. S waves can only travel through solids. P waves travel faster than S waves, so they are monitored first. The epicenter of an earthquake is determined by measuring the difference in arrival time of P and S waves. Surface waves, also called L waves, travel along Earth's surface and cause the majority of physical damage that earthquakes leave behind. The side to side energy that these waves possess is shown by the movement of the black dot.

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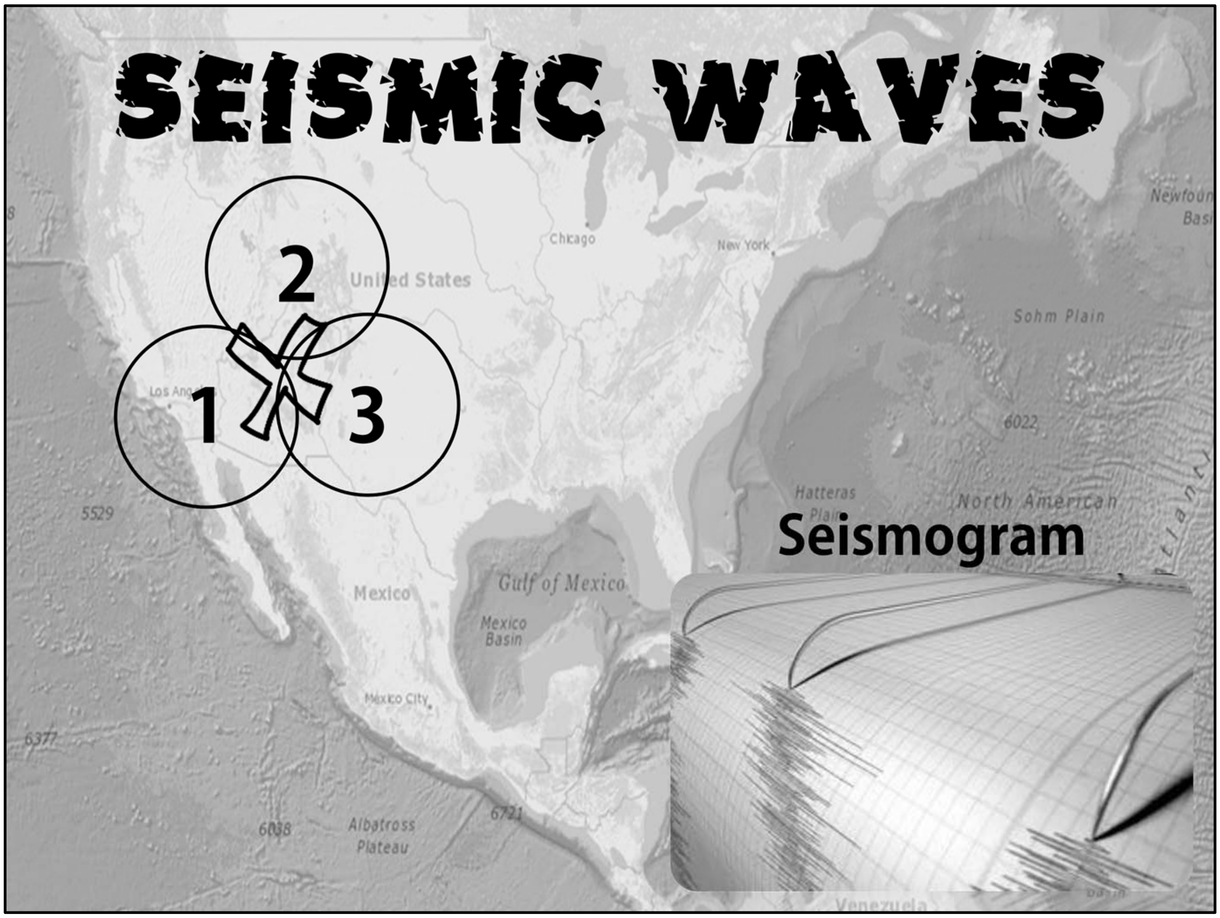
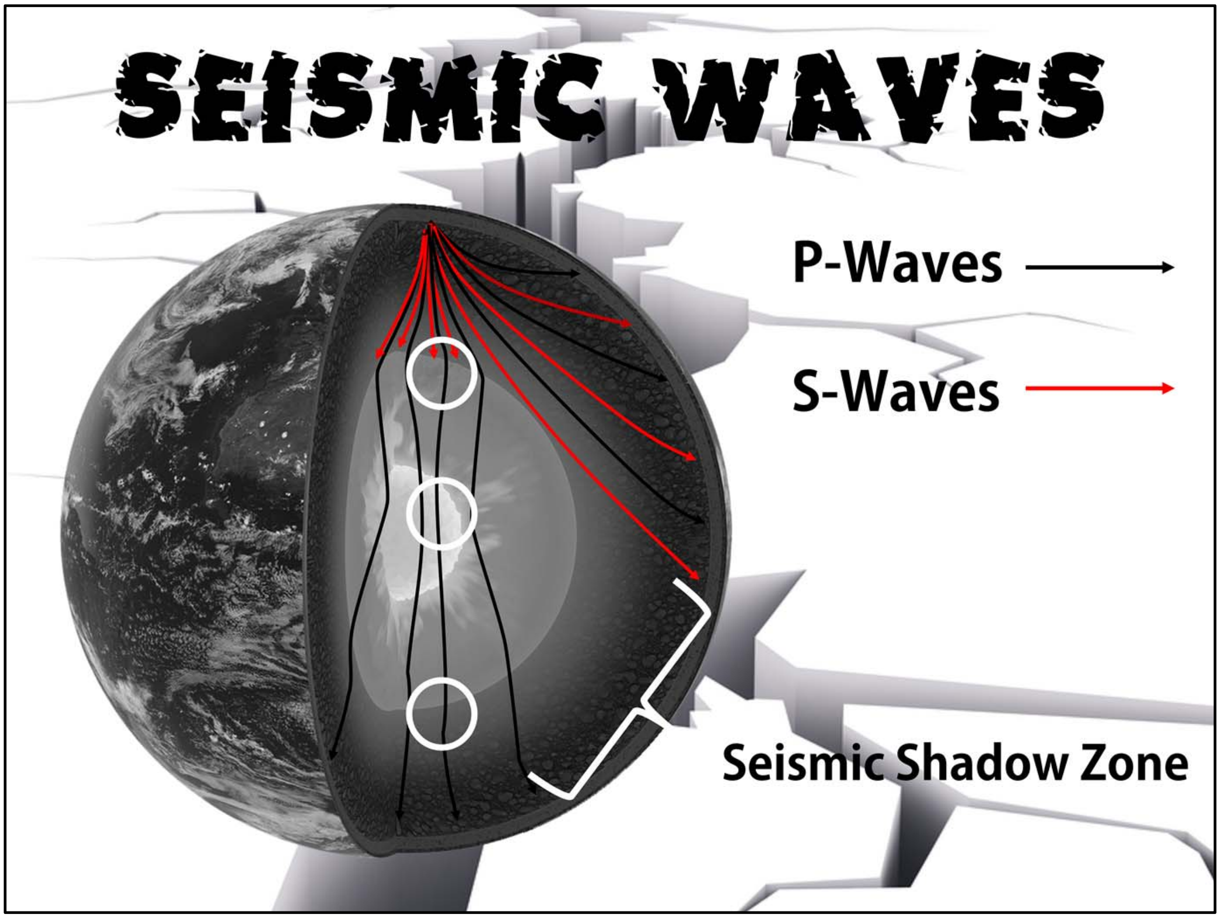
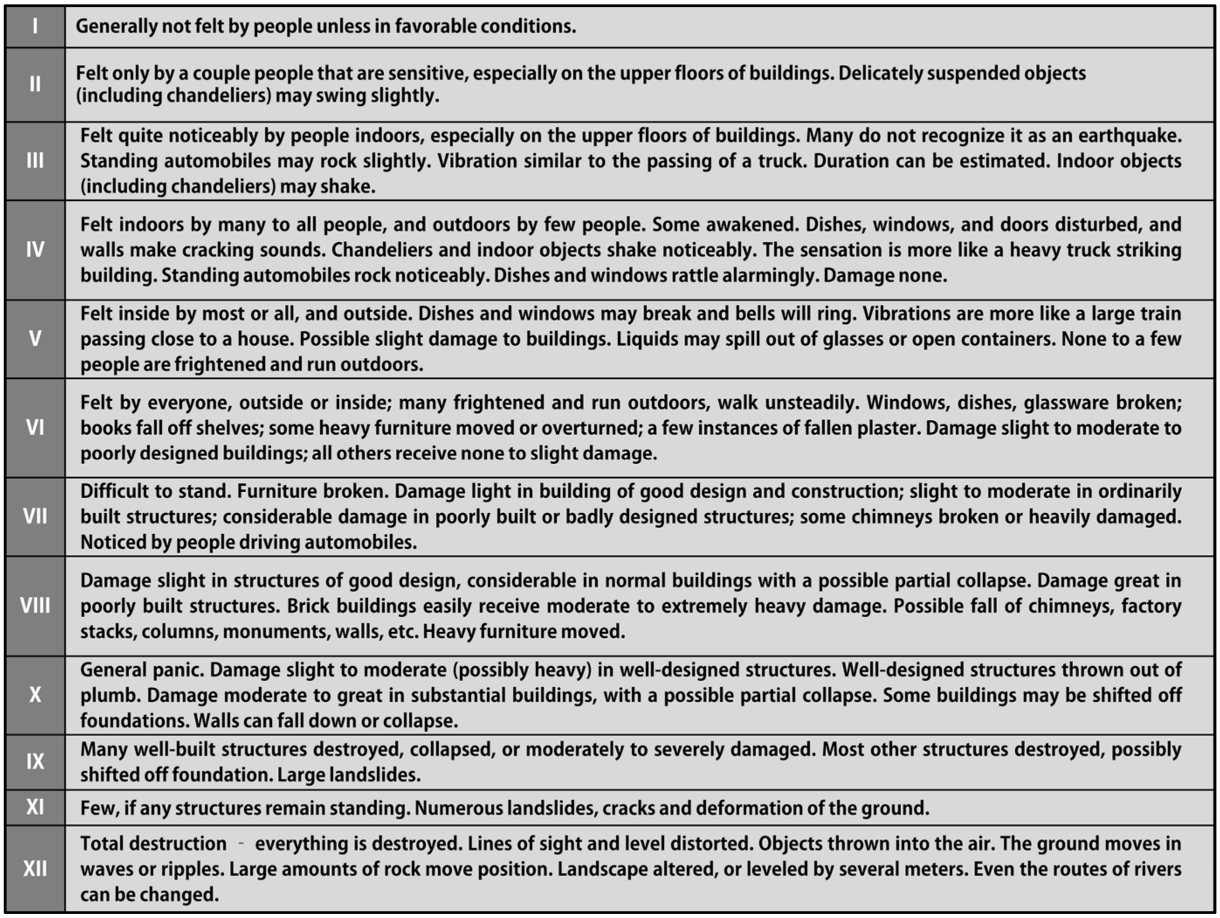


Even though earthquakes are not strong enough to be felt everywhere on Earth, the entire Earth does receive the energy from an earthquake. Humans may not always feel these vibrations unless they are close to the earthquake’s epicenter, but sensitive monitoring equipment called seismometers record the waves on a seismogram. Seismograms record the time, duration, and velocity of P and S waves. Data from seismometers around the world is pieced together to determine the epicenter of an earthquake. When scientists compare the data from three seismograms, they can pinpoint the exact location of an earthquake’s epicenter and its magnitude. This process is called triangulation. Imagine an earthquake takes place in the southwestern United States. A seismometer in California picks up the seismic waves first. Next, a seismometer in Colorado senses the waves. Finally, the waves are felted and recorded in Texas by a third seismometer. Where exactly is the epicenter of this earthquake? If you draw a circle on a map around three different seismometers where the radius of each is the distance from that station to the earthquake, the intersection of those three circles is the epicenter.

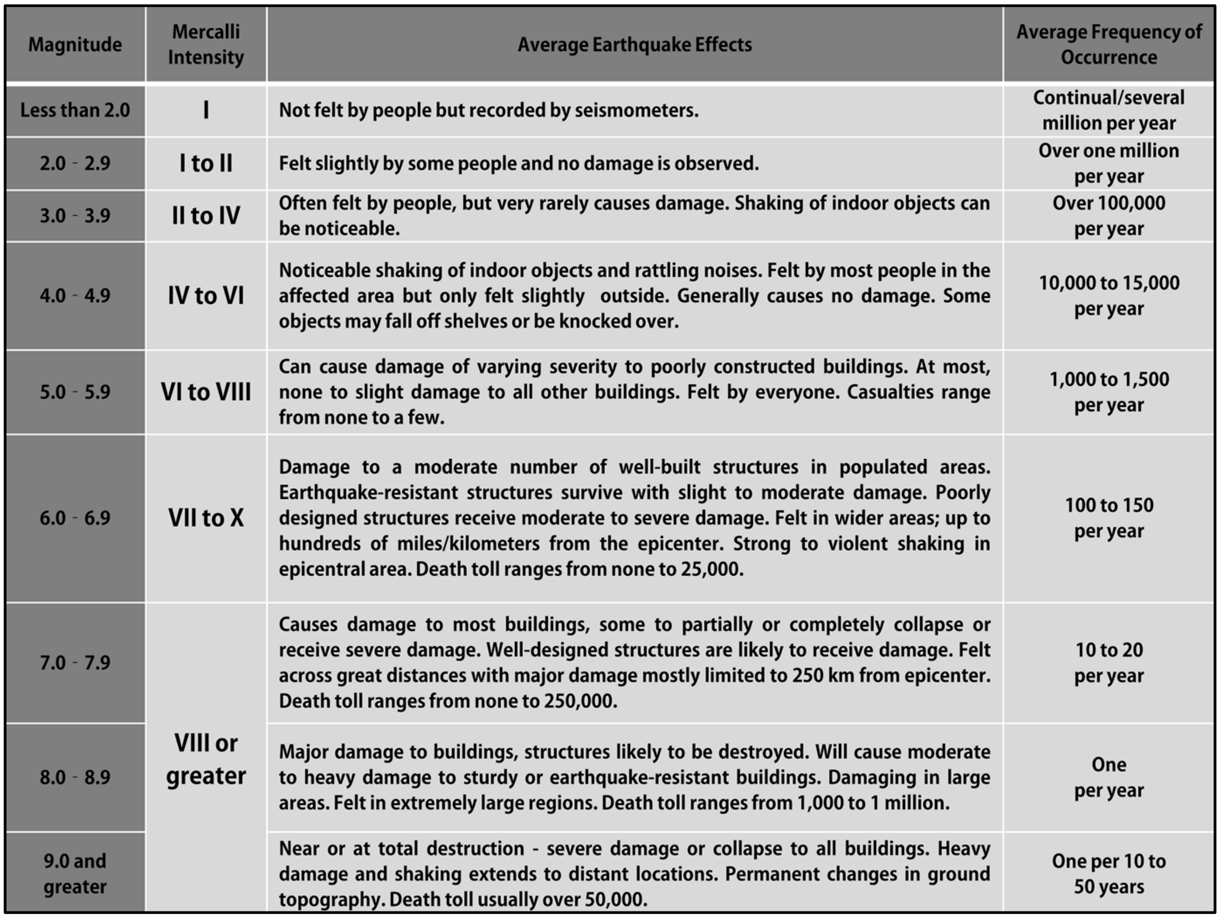


Studying seismic waves helped scientists determine the structure of the inner Earth. As seismic waves from an earthquake travel through Earth, they refract when reaching different densities of materials. This changes the arrival time of the seismic waves at other locations around the world. There is even one area of the world that will not receive any seismic waves. The area that receives no seismic waves is known as the seismic shadow zone. You can see in the image that S waves do not travel through liquid. These waves do not travel through the liquid outer core. The P waves are bent, or refracted, as they travel through the different layers. This means that each layer must contain a different density and composition.



| | |
|---|---|
| I | Generally not felt by people unless in favorable conditions. |
| II | Felt only by a couple people that are sensitive, especially on the upper floors of buildings. Delicately suspended objects (including chandeliers) may swing slightly. |
| III | Felt quite noticeably by people indoors, especially on the upper floors of buildings. Many do not recognize it as an earthquake. Standing automobiles may rock slightly. Vibration similar to the passing of a truck. Duration can be estimated. Indoor objects (including chandeliers) may shake. |
| IV | Felt indoors by many to all people, and outdoors by few people. Some awakened. Dishes, windows, and doors disturbed, and walls make cracking sounds. Chandeliers and indoor objects shake noticeably. The sensation is more like a heavy truck striking building. Standing automobiles rock noticeably. Dishes and windows rattle alarmingly. Damage none. |
| V | Felt inside by most or all, and outside. Dishes and windows may break and bells will ring. Vibrations are more like a large train passing close to a house. Possible slight damage to buildings. Liquids may spill out of glasses or open containers. None to a few people are frightened and run outdoors. |
| VI | Felt by everyone, outside or inside; many frightened and run outdoors, walk unsteadily. Windows, dishes, glassware broken; books fall off shelves; some heavy furniture moved or overturned; a few instances of fallen plaster. Damage slight to moderate to poorly designed buildings; all others receive none to slight damage. |
| VII | Difficult to stand. Furniture broken. Damage light in building of good design and construction; slight to moderate in ordinarily built structures; considerable damage in poorly built or badly designed structures; some chimneys broken or heavily damaged. Noticed by people driving automobiles. |
| VIII | Damage slight in structures of good design, considerable in normal buildings with a possible partial collapse. Damage great in poorly built structures. Brick buildings easily receive moderate to extremely heavy damage. Possible fall of chimneys, factory stacks, columns, monuments, walls, etc. Heavy furniture moved. |
| X | General panic. Damage slight to moderate (possibly heavy) in well-designed structures. Well-designed structures thrown out of plumb. Damage moderate to great in substantial buildings, with a possible partial collapse. Some buildings may be shifted off foundations. Walls can fall down or collapse. |
| IX | Many well-built structures destroyed, collapsed, or moderately to severely damaged. Most other structures destroyed, possibly shifted off foundation. Large landslides. |
| XI | Few, if any structures remain standing. Numerous landslides, cracks and deformation of the ground. |
| XII | Total destruction - everything is destroyed. Lines of sight and level distorted. Objects thrown into the air. The ground moves in waves or ripples. Large amounts of rock move position. Landscape altered, or leveled by several meters. Even the routes of rivers can be changed. |

The strength of an earthquake is measured in two different ways, earthquake intensity and earthquake magnitude.  Earthquake intensity is measured by the amount of shaking and the resulting damage at a specific place.  This scale is based on observable damage and the observations and experiences of the people who experienced the earthquake. The Modified Mercalli Intensity Scale is used to measure earthquake intensity by assessing the resulting damage. A relatively weak earthquake in a populated area can rank high on the Modified Mercalli Intensity Scale, while a strong earthquake in a remote area may rank lower than expected.  Take a moment to view the different classifications and their descriptions of the Modified Mercalli Intensity Scale.



| Magnitude | Mercalli Intensity | Average Earthquake Effects | Average Frequency of Occurrence |
|---|---|---|---|
| Less than 2.0 | I | Not felt by people but recorded by seismometers. | Continual/several million per year |
| 2.0 - 2.9 | I to II | Felt slightly by some people and no damage is observed. | Over one million per year |
| 3.0 - 3.9 | II to IV | Often felt by people, but very rarely causes damage. Shaking of indoor objects can be noticeable. | Over 100,000 per year |
| 4.0 - 4.9 | IV to VI | Noticeable shaking of indoor objects and rattling noises. Felt by most people in the affected area but only felt slightly outside. Generally causes no damage. Some objects may fall off shelves or be knocked over. | 10,000 to 15,000 per year |
| 5.0 - 5.9 | VI to VIII | Can cause damage of varying severity to poorly constructed buildings. At most, none to slight damage to all other buildings. Felt by everyone. Casualties range from none to a few. | 1,000 to 1,500 per year |
| 6.0 - 6.9 | VII to X | Damage to a moderate number of well-built structures in populated areas. Earthquake-resistant structures survive with slight to moderate damage. Poorly designed structures receive moderate to severe damage. Felt in wider areas; up to hundreds of miles/kilometers from the epicenter. Strong to violent shaking in epicentral area. Death toll ranges from none to 25,000. | 100 to 150 per year |
| 7.0 - 7.9 | VIII or greater | Causes damage to most buildings, some to partially or completely collapse or receive severe damage. Well-designed structures are likely to receive damage. Felt across great distances with major damage mostly limited to 250 km from epicenter. Death toll ranges from none to 250,000. | 10 to 20 per year |
| 8.0 - 8.9 | | Major damage to buildings, structures likely to be destroyed. Will cause moderate to heavy damage to sturdy or earthquake-resistant buildings. Damaging in large areas. Felt in extremely large regions. Death toll ranges from 1,000 to 1 million. | One per year |
| 9.0 and greater | | Near or at total destruction - severe damage or collapse to all buildings. Heavy damage and shaking extends to distant locations. Permanent changes in ground topography. Death toll usually over 50,000. | One per 10 to 50 years |

Earthquake magnitude is measured by the amount of energy released at the focus of the earthquake. Geologists analyze data from the recorded P and S waves and use the Richter scale to describe the amount of energy in the largest seismic waves. Looking at the different seismic waves from the five earthquakes, can you determine which had the greatest magnitude? If you look at the seismic waves from earthquake number three, you can see that the P, S, and L waves contain a much larger quantity of energy. Earthquake number four shows the arrival of all three seismic waves very clearly. The P waves arrive first, followed by the S waves. Lastly, the L waves arrive with the most energy.

The Richter scale does not measure the damage an earthquake causes. A strong earthquake in a remote area may cause less damage than a weaker earthquake in a highly populated area. Earthquakes that measure a 4.5 or higher on the Richter scale are strong enough to be felt by seismometers around the world. Weaker earthquakes are measured by nearby seismometers. Each number on the Richter scale increases the strength of the earthquake by a factor of ten. An earthquake that measures a five on the scale emits ten times more energy than one that measures a four. A ranking on the Richter scale can be compared with the Modified Mercalli Intensity scale. Take a moment to view the Richter scale, the effects of each classification, and the average frequency.