EARTHQUAKES

noun: sudden and violent shaking of the ground caused by a release of energy when rocks slip past each other beneath Earth's surface

www.deq.nc.gov/geological-survey

EQ I.Q.

Tectonic Plates: massive pieces of rocks that divide Earth's crust (lithosphere)

Fault: a fracture between two rocks where movement has taken place

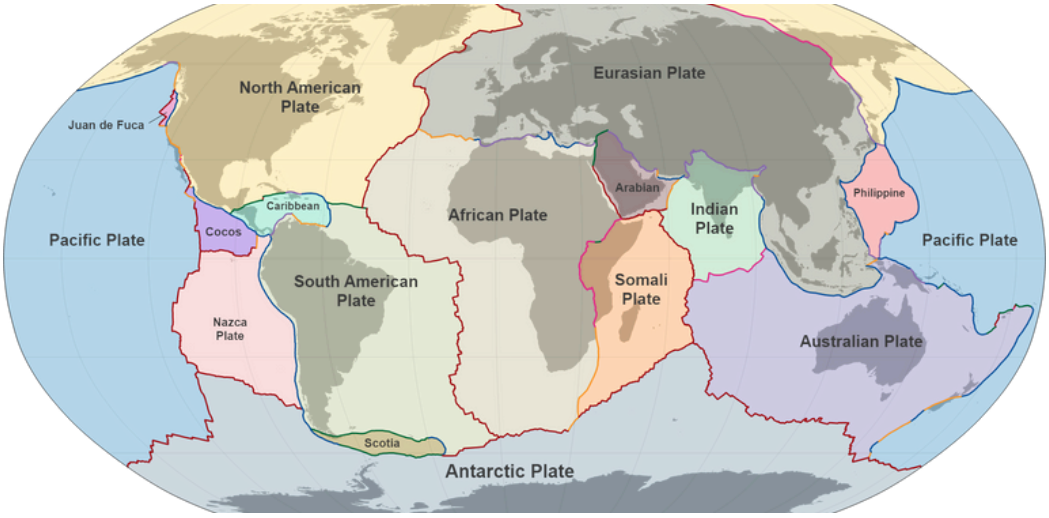
Hypocenter: the location deep inside Earth's crust where an earthquake originates

Epicenter: the location directly above the hypocenter, on Earth's surface

Seismic Waves: energy waves that travel through Earth after earthquakes, volcanic eruptions, or landslides

Seismologist: an Earth scientist who studies earthquakes and seismic waves

Seismograph: an instrument that records the motion of the ground during an earthquake



Most, but not all, earthquakes occur at the boundaries between tectonic plates. Tectonic plates are always moving but can get 'stuck' at their boundaries because of complexity of the fault geology and frictional stress. When the stress becomes too great, the rocks can break and slip past each other along the fault, releasing the energy of the stress into the Earth. This energy radiates as seismic waves like ripples on a pond and shakes the ground beneath us - **earthquakes**! The red lines on the map above show where plate boundaries exist.

Geoscientists study earthquakes in order to save lives. Nearly half a million earthquakes occur each year. Although most don't cause damage, it's important to educate those living in seismic zones about earthquake hazards, how to stay safe, and how to construct earthquake-sound structures.

Photos: www.photos.wikimedia.org

Largest EQs Since 1922

Magnitude	Location	Year
9.5	Valdivia, Chile	1960
9.2	Prince Edward Is., Alaska	1964
9.1	N. Sumatra, Indonesia	2004
9.1	Tohoku, Japan	2011
9.0	Kamchatka, Russia	1952
8.8	Bio-Bio, Chile	2010
8.8	Ecuador-Columbia	1906
8.7	Rat Islands, Alaska	1965
8.6	Assam, Tibet	1950
8.6	N. Sumatra, Indonesia	2012
8.6	N. Sumatra, Indonesia	2005
8.6	Andreanof Is., Alaska	1957
8.6	Unimak Is., Alaska	1946
8.5	Banda Sea, Indonesia	1938
8.5	Atacama, Chile	1922

Continental Drift vs. Plate Tectonics

The idea of 'continental drift' was theorized by Alfred Wegner in 1912. He used evidence such as fossils, rocks, and continental edge matching to propose that the continents drifted around Earth. Because he couldn't provide a mechanism for the drifting, his hypothesis was largely discredited. Paleomagnetism research and understanding of seafloor spreading led to the Theory of Plate Tectonics being widely accepted in the 1960s.

Did you Know?

The Ring of Fire is the most seismically and volcanically active zone in the world because of the amount of tectonic plate movement, especially the Pacific Plate. Nearly 90% of all earthquakes on Earth happen in this region.

500,000
Average number of earthquakes (EQ) worldwide each year

100,000
Average number of worldwide EQs that can be felt each year

9.2
Magnitude of largest EQ recorded in the US (Alaska, 1964)

100
Average number of worldwide EQs that cause damage each year

9.5
Magnitude of largest EQ ever recorded on Earth (Chile, 1960)

$360 billion
Amount of property damage caused by the 2011 Tohoku EQ in Japan

Measuring Earthquakes

Modified Mercalli Scale – Intensity

- **Intensity** is the effect that an earthquake has on Earth's surface at a given location and is based on responses such as people feeling shaking, items falling from shelves, damage to buildings, and finally, total destruction.
- This qualitative intensity scale was developed by American seismologists Harry Wood and Frank Neumann in 1931. The 12-step scale is based on increasing intensity, from Roman numerals I to XII.
- The Mercalli Scale is a more meaningful way to express earthquake severity to nonscientists since it refers to effects that are experienced during an earthquake and not on the quantity of energy released.

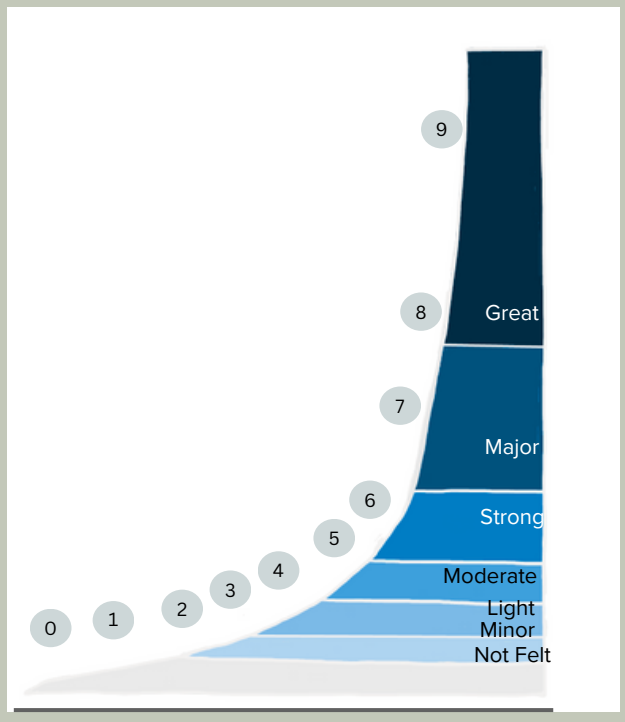
Moment Magnitude Scale – Magnitude

- **Magnitude** scales are a quantitative measure of the "size" or strength of an earthquake based on measurement of the energy of the seismic waves.
- Magnitude determination is made by identifying specific seismic waves on a seismogram and measuring their timing, amplitude, frequency, orientation, and duration.
- The Moment Magnitude Scale is a logarithmic scale that compares seismic wave amplitude. This means that an increase of one unit on the scale (e.g. M3.0 to M4.0) is equal to a 30x (30 times) increase in energy released.
- The Richter Scale is not a useful tool for measuring large earthquakes as it was developed to be used in southern California for only one type of earthquake.

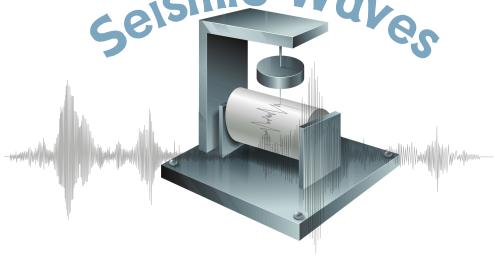
Modified Mercalli Scale

		Magnitude Scale
I	Not felt except by seismic instruments	1.5
II	Felt by a few persons, especially on upper floors	2
III	Felt by several; vibration like a passing truck; hanging objects may swing	2.5
IV	Felt indoors by many; dishes rattle, walls creak, stationary autos shake	3
V	Felt by most; many awakened; windows and plaster crack; trees shaken	3.5
VI	Many objects fall; damaged chimneys; broken windows; isolated landslides	4
VII	Heavy furniture moves; some people lose balance; tree damage; landslides	4.5
VIII	Many find it difficult to stand; very heavy furniture moves; monuments fall	5
IX	Some forcibly thrown to the ground; buildings shift off foundations	5.5
X	Many buildings are destroyed; ground cracks; rail lines bent; landslides	6
XI	Few structures left standing; bridges destroyed; pipes broken	6.5
XII	Total destruction; seismic waves seen on ground; objects thrown into the air	7
		7.5
		8

Moment Magnitude Scale



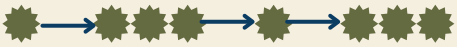
Seismic Waves



Earthquakes are recorded using **seismographs** (instrument) which makes a recording of the seismic waves, called a **seismogram**. Seismographs have sturdy bases with a heavy weight that hangs from a wire or spring. When an earthquake occurs, seismic waves radiate out from the hypocenter. The wire or spring on the seismograph absorbs this energy so that the weight doesn't move - only the base of the seismograph shakes. The difference between the shaking base and the stationary weight is what is recorded on the seismogram. In order to record ground motion in three dimensions, each seismograph has three sensors that record ground motion up and down, east and west, and north and south.

P Waves

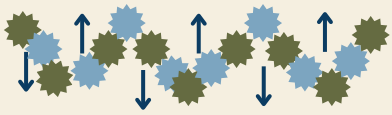
- Primary waves - push/pull motion
- Pushes particles forward in a straight line
- Fastest travel time of all seismic waves & are the first to arrive on a seismogram
- Can travel through solids, liquids, and gases
- Travel 5-7 km/sec in Earth's crust; >8 km/sec in Earth's mantle and core; 1.5 km/sec in water; 0.3 km/sec in air



Imagine pulling a slinky back & releasing it

S Waves

- Secondary waves - shear motion
- Shears particles perpendicular to the direction of wave movement
- Slower than P waves in solids so will arrive on a seismogram after P waves
- Can not travel through liquids/fluids, so S waves do not travel through air, water, or molten rock (Earth's outer core)
- Travel 3-4 km/sec in Earth's crust; 4.5 km/sec in Earth's mantle; 2.5-3.0 km/sec in the solid inner core



Surface Waves

- P wave energy and S wave energy can combine to form surface waves at the Earth/air interface (at Earth's surface)
- The two types of surface waves are Rayleigh waves and Love waves
- **Raleigh waves** are generated by the interaction of P and S waves at Earth's surface and move the surface in an elliptical motion
- **Love waves** are generated by the interaction of multiple S (shear) waves and move the ground horizontally.
- Ground shaking from surface waves is much greater than from P and S waves and cause building failure and collapse

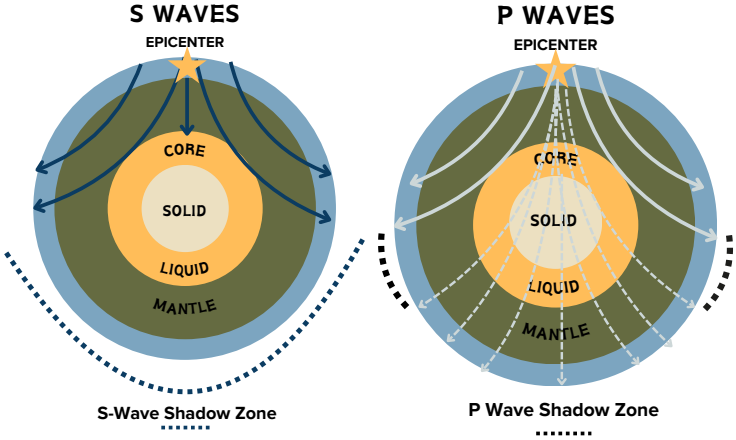
Dark Shadows

There are places on Earth's surface where seismographs can't detect seismic waves from an earthquake, after the waves have passed through Earth.

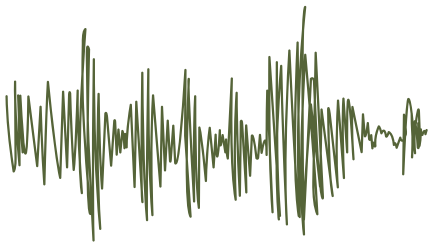
Fluids (liquids and air) cannot be sheared. Therefore, S waves (shear waves) cannot travel through Earth's liquid outer core. This phenomenon creates an S-wave shadow zone.

P waves are refracted or bent from their paths when they encounter the liquid outer core. This refraction creates a P-wave shadow zone.

The study of seismic shadow zones helped scientists in the early 1900s determine that our outer core was liquid. Since then, the data has been used to calculate its size as well.



Photos: www.photos.wikimedia.org



That's Shocking!

Foreshocks: minor earthquakes that occur before a larger earthquake in the same area; can only be identified after a mainshock

Mainshock: the main event earthquake

Aftershocks: smaller earthquakes that occur after the mainshock in the same area that can continue for weeks, months or even years

Currently, earthquakes can't be predicted! Seismologists can only calculate a probability that a significant EQ will occur in a number of years in a certain area.