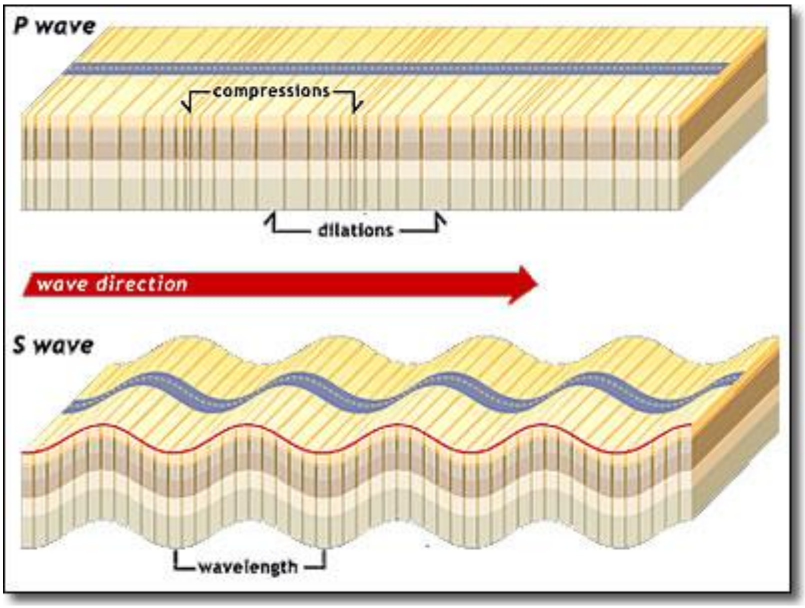
Earthquake Shockwaves

- Body waves

Body waves are of two types: compressional or primary (P) waves and shear or secondary (S) waves. P- and S- waves are called "body waves" because they can travel through the interior of a body such as the Earth's inner layers, from the focus of an earthquake to distant points on the surface. The Earth's molten core can only be travelled through by compressional waves.

P-waves travel fastest, at speeds between 4–8 km/sec (14,000–28,000 km/h) in the Earth's crust. S-waves travel more slowly, usually at 2.5–4 km/sec (9000–14,000 km/h). Sound waves are usually called P-waves and are heard but not often felt. Except in the most powerful earthquakes they generally do not cause much damage. P-waves shake the ground in the direction they are propagating, while S-waves shake perpendicularly or transverse to the direction of propagation (i.e. they displace material at right angles to their path).



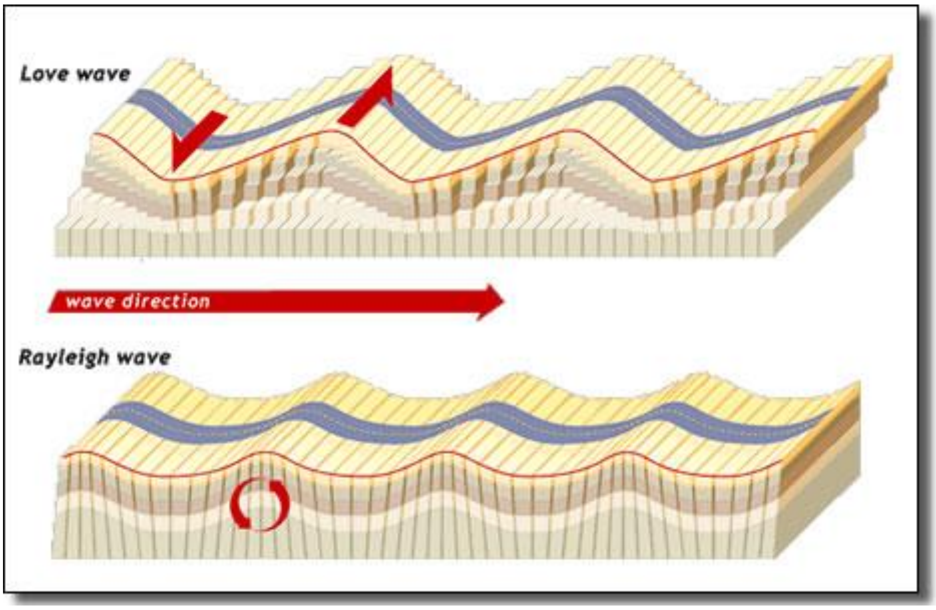
The P-wave is the first to arrive at a location, as it is the fastest. The P wave, or compressional wave, ultimately compresses and expands material in the same direction it is travelling. The next to arrive is the S wave which causes particles to oscillate. S waves can travel through solid material but not through liquid or gas.

Earthquake Shockwaves

- Surface waves

Surface waves, in contrast to body waves can only move along the surface. They arrive after the main P and S waves and are confined to the outer layers of the Earth. They cause the most surface destruction. Earthquake surface waves are divided into two different categories: Love and Rayleigh.

Love waves have a particle motion, which, like the S-wave, is transverse to the direction of propagation but with no vertical motion. Their side-to-side motion (like a snake wriggling) causes the ground to twist from side to side, that's why Love waves cause the most damage to structures. Rayleigh waves create a rolling, up and down motion with an elliptical and retrograde particle motion confined to the vertical plane in the direction of propagation. Surface waves are generally not generated by deep earthquakes.



Particle motion for Rayleigh and Love waves are different: Rayleigh waves have retrograde particle motion confined to the vertical plane of motion, whereas Love waves have purely transverse motion in the horizontal plane.

Earthquakes radiate seismic energy as both body and surface waves but deep earthquakes generally do not generate surface waves.

Secondary impacts of Earthquakes

Secondary hazards resulting from an earthquake may include a tsunami, which can have far reaching impacts spatially (for example Indian Ocean 2004), or landslides (for example Kashmir 2005) and liquefaction (for example Christchurch 2011), which are localised impacts. Landslides occur when earthquake (seismic) waves loosen rock or unconsolidated material on steep slopes; material loses cohesive strength and moves downwards under the influence of gravity. Landslides are more common on hilly or mountainous areas, and may hit small settlements within its topography, and block or destroy roads and railways, making it difficult to rescue people or supply emergency aid and rebuilding materials. Liquefaction occurs in lowland areas where shaking sorts the ground material to the point where it acts as a fluid.

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Primary and secondary effects of earthquakes

Earthquakes effects: primary and secondary	
Primary effects	happen immediately and occur as a direct result of the ground shaking like buildings collapsing.
Ground shaking	Ground shaking is most direct effect with cracks in land and structures, falling masonry and / or collapse. animation: http://earthquake.usgs.gov/regional/nca/simulations/
Secondary effects	occur as a result of the primary effects, for example, fires due to ruptured gas mains.
Ground displacement	may not be life threatening; however, it impacts on buildings, bridges and roads.
Landslides	are movements of masses of rock or debris down a slope. Slope failure can be triggered by, for example, earth tremors. Photo: http://earthquake.usgs.gov/learn/glossary/?term=landslide
Liquefaction	occurs when the shaking of silts, sands and gravels causes them to lose their load bearing capacity. Buildings and other structures, may thus sink into the ground. Liquefaction Hazard Map: http://earthquake.usgs.gov/regional/nca/qmap/ Liquefaction photo:http://reliefweb.int/sites/reliefweb.int/files/resources/49488655AFEE6C258525773000766AF5-Full_Report.pdf
Tsunamis	are ocean waves with extremely long wavelengths, generated by earthquake tremors. Graph: http://earthquake.usgs.gov/learn/glossary/?term=tsunami

Volcanic Explosivity

Volcanoes are extrusive features found on the Earth's surface, ranging from gentle fissure eruptions to explosive composite cones. This range of volcano types reflects the amount of energy released during an eruption (see the table below). Supervolcanoes also exist, such as Yellowstone in the USA or Taupo in New Zealand, with large calderas and very long time periods between eruptions, but when they happen they may have a significant impact on the world. The Yellowstone eruption 2.1 million years ago was 6000 times larger than the Mount St Helens eruption of 1980, and 500 times greater than the Mount Pinatubo eruption of 1991. The shape of volcanoes is mainly related to the type of lava erupted, of which there are three main types; basalt, andesite and rhyolite.

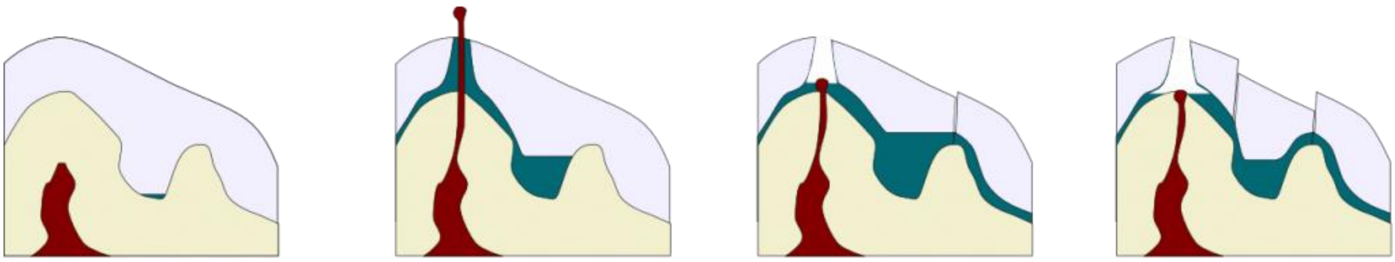
Volcanic Explosivity Index

VEI	Classification	Description	Ejecta volume	Frequency	Occurrences*
0	Hawaiian	non-explosive	< 10,000 m³	daily	many
1	Hawaiian/Strombolian	gentle	> 10,000 m³	daily	many
2	Strombolian/Vulcanian	explosive	> 1,000,000 m³	weekly	3477*
3	Vulcanian/Pelean	severe	> 10,000,000 m³	yearly	868
4	Pelean/Plinian	cataclysmic	> 0.1 km³	≥ 10 yrs	278
5	Plinian	paroxysmal	> 1 km³	≥ 50 yrs	84
6	Plinian/Ultra-Plinian	colossal	> 10 km³	≥ 100 yrs	39
7	Plinian/Ultra-Plinian	super-colossal	> 100 km³	≥ 1000 yrs	5 (+2 suspected)
8	Ultra-Plinian	mega-colossal	> 1,000 km³	≥ 10,000 yrs	0

Secondary impacts of Volcanic Eruptions

Significant secondary volcanic hazards involve water (often from melted snow or ice) in the form of lahars and jokulhlaups.

A jokulhlaup is a flood of meltwater issuing from underneath an ice cap or glacier. This happens when a volcano erupts underneath the ice and melts the ice so that it forms a lake, either in a crater or at the crater side where it is dammed by the ice. Eventually the warm meltwater will have sufficient volume to lift the ice away from the bedrock. When this happens the water bursts out underneath the ice carrying with it glacial moraines and blocks of ice. This moraine then becomes a fluvial deposit (sandur) as the jokulhlaup deposits the material in lowland area or valleys. The speed and volume of the event will wash away anything in its path and change the route of river channels. The best examples of jokulhlaups occur in Iceland, where the main road along the south coast has often been cut and bridges washed away. The Eyjafjallajokull (EFJ) eruption of 2010, which was infamous for its ash clouds disrupting aeroplanes, also created jokulhlaups (such as the Makarfljot river), but these were anticipated and the main road was closed and breaches made in the road embankment to allow water and deposits to pass through without causing major damage.



Initially, a caldera contains a small sub-glacier lake | When a volcano erupts, the caldera gets filled. | The high pressure created breaks the ice cap and form a sub-glacial water stream | The ice cap above the caldera pushes the water out of the caldera

Lahars consist of water mixed with volcanic deposits flowing rapidly along existing valleys. They are caused by either heavy rainfall, a result of humid air being seeded with volcanic ash which accelerates condensation, the formation of clouds and rain; or the emptying of a crater lake; or through the melting of snow and ice due to the heat from an eruption at high altitude; or a mudslide/landslide on the flank of the volcano. The dangers from lahars are their fast velocity, the amount of material carried (they can contain boulders 10m in diameter!), and the great distances they can travel. The town of Armero, Colombia, was buried by a lahar from the Nevado del Ruiz volcano in 1985 after pyroclastic flows melted 10 per cent of the snow and ice cover on the volcano. Several small lahars were funnelled into 6 major river valleys and grew in size with the addition of river water. The lahars travelled at 60 km/hr and in places were 50m deep. Within 2.5 hours of the eruption, lahars had travelled 100 km and killed 23,000 people, mostly in the town of Armero which was at the exit of a canyon. The main pulse arrived at 11.35 p.m. so people were in their homes asleep and unable to escape. Buildings and people were swept away and buried by 2-5 m of deposits. A further 10 lahar surges prevented the escape of any who initially survived.