

Seismic Signatures

How do I read a seismogram?

Background pages to accompany: [IRIS' Animation: "Seismograms of Common Events"](#)
 The animations in this set were done in collaboration with the U.S. Geological Survey.
 Most of the information and graphics comes from www.usgs.gov

What is a seismogram, and what can it record?

A seismogram is the record of ground movement detected by a seismometer and portrayed on a time-versus-amplitude graph (Figure 1). Seismograms show how the ground moves with the passage of time.

Seismometers can detect local ground movement caused by large distant events, as well as by the movement caused by large and small events close to the seismometer (Figure 2). Microseisms can be caused by environmental noise (wind, lightening, rain), motor vehicles, and people at or near the station. By noting which sites have recorded the signals and comparing the signal character, seismologists can determine the probable source and location of the signal*.

In the past, seismograms were recorded on seismic drums using ink and paper (See Hot Link to "Seismographs"), but seismograms are now recorded electronically by computers. This has streamlined our ability to analyze the data to locate and determine the magnitude of earthquakes world wide (Figure 4).

HOT Links to Related Resources:

Animations: [Vertical seismograph](#)
[3-Component Seismogram](#)

Video: [Seismic Waves: P, S, and Surface](#)

Interactives: [Locating An Earthquake Using Triangulation](#)

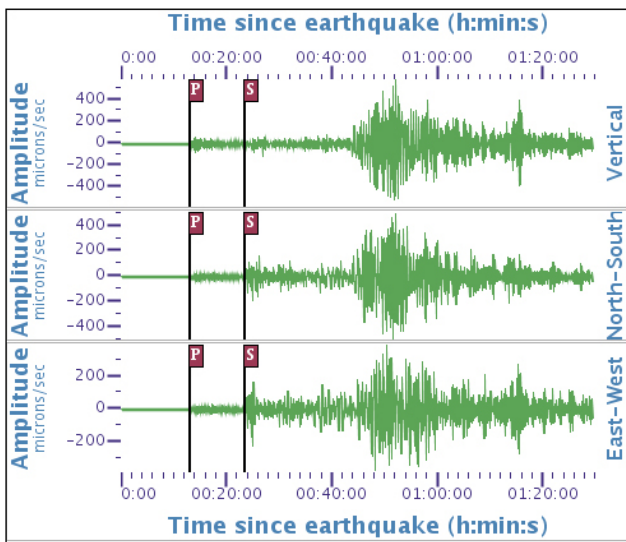


Figure 1— A seismograph has 3 sensors that record N-S, E-W, and vertical motion on 3 seismograms. The different behavior of P, S, and surface waves explain how a single seismograph station can have 3 different seismograms: 1) The vertical component shows the compressive P wave bumping up from beneath; it has very little horizontal movement; 2) The shearing S wave has mostly side-to-side motion; 3) The surface waves have an effect on all components.

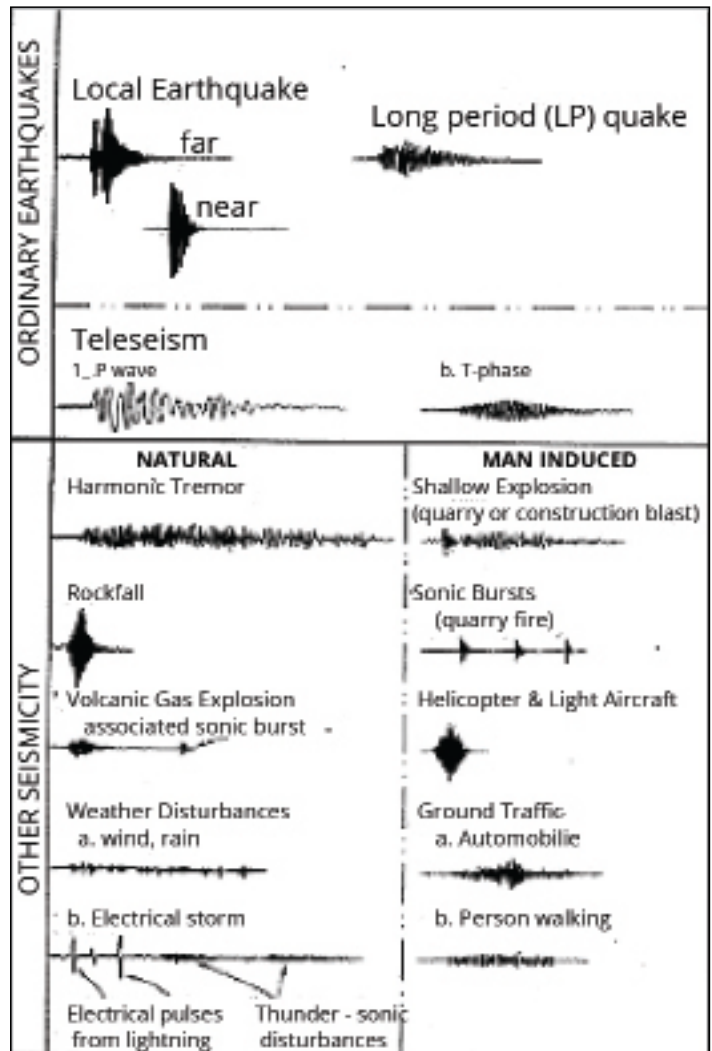


Figure 2—This USGS graphic shows typical seismograms from ordinary earthquakes, plus the signals that you might see from other ground-shaking events. Note that it takes considerable training to be able to read seismograms.

How do I read a seismogram?

As mentioned previously, seismograms record more than earthquakes, and it isn't always clear what all the different wiggles represent, even with training (Figure 3). But let's look at a simple seismogram from an earthquake (Figure 1) with the understanding that seismic waves travel discrete paths with distinct behavioral differences, important information in interpreting seismograms.

When an earthquake occurs, it releases energy in the form of seismic waves that radiate from the earthquake source in all directions. The different types of energy waves shake the ground in different ways and travel through the earth at different velocities. Ground vibrations are similar to sound waves in air, but span a wide frequency range that extends well below the threshold for human hearing.

For a large earthquake, the compressive P wave will be the first jolt that is bigger than the background noise (the microseisms). Because P waves are the fastest seismic waves, they are usually the first recorded.

The next set of seismic waves on your seismogram will be the S waves that travel at about 0.6 times the velocity of P waves. These are generally higher amplitude than the P waves. They travel with a shearing motion which slows them, but can cause greater ground motion.

The surface waves (Love and Rayleigh waves) are often the largest and longest wave sets on the seismogram. Surface waves travel slower than S waves. They travel across the surface of the globe.

For really close earthquakes, the body and surface waves may appear on the seismogram simultaneously.

The amplitude of the waves is related to:

- 1) the magnitude of the earthquake,
- 2) the direction the wave traveled when it hit the seismometer (from below or at an angle?),
- 3) the medium the wave traveled in: soft sediment can amplify waves that were small when traveling through solid rock.

Regional stations equidistant from a distant earthquake could have markedly different amplitudes if they are located on different substrates, though the P-, S-, and surface-wave arrival times will be about the same.

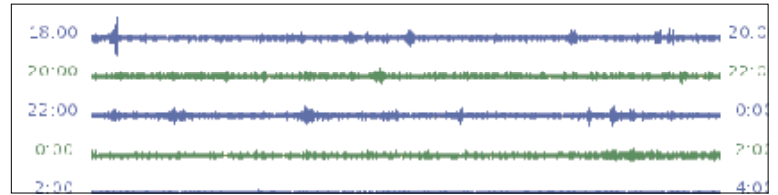


Figure 3— Seismogram taken from a USArray Seismic Station shows wiggles of ambient “noise” and some possible small regional earthquakes. During periods of no earthquakes the seismogram records a straight line except for small wiggles caused by local disturbance or “noise”.

**View seismograms
from the latest earthquakes using:**

Global Seismic Viewer

<http://ds.iris.edu/gsv/>

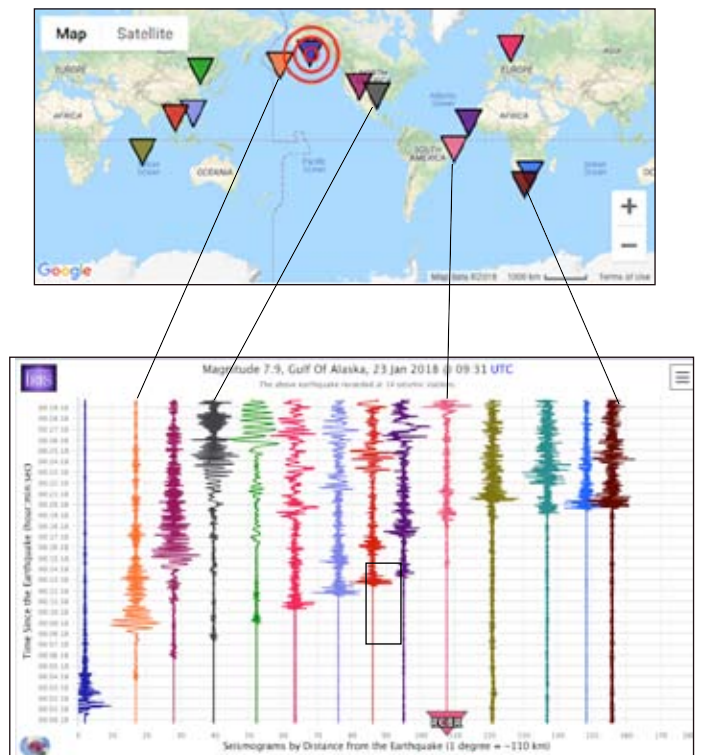


Figure 3—The seismograms from GSV show the arrival times of seismic waves from the M7.9, Gulf of Alaska Earthquake <https://www.iris.edu/hq/retm/event/5366> (Jan 23, 2018) received by worldwide seismic stations (triangles).

Typical seismograms seen at Mount St. Helens

Seismograph stations record ground movement from many sources as shown in the series of animations (see next page, Figure 7 for examples). The four seismograms in Figure 5 include both tectonic and volcanic earthquakes to show how to broadly discern the difference. Sudden seismicity beneath a volcano is a strong indication that magma is ascending (Figure 6). Accelerated seismicity and surface deformation indicates a likelihood that the volcano could erupt.

Seismologists separate volcanic events in the vicinity of Mount St. Helens further into:

- 1) Two types of high-frequency earthquakes occur near the volcano and under the volcano at depths of more than 4 kilometers.
- 2) Medium- and low-frequency earthquakes occur at shallow depths (less than 3 kilometers) within the volcano and increase in number and size before eruptions. Temporal changes in the energy release of the low-frequency earthquakes have been used in predicting all the eruptions since October 1980.
- 3) During and after eruptions, two types of low-frequency emergent surface events occur, including rockfalls and steam or gas bursts from the lava dome (from [Malone SD, Boyko C, Weaver CS.](#))

In 1980, the University of Washington had just completed the establishment of a system of seismometers to help monitor the Cascade volcanoes. The first indications of a major problem came on March 20, when a 4.2 magnitude earthquake was recorded beneath Mount St. Helens. Harmonic tremor, continued daily (Figure 6). Three days later another 4.0 M was recorded, and that evening the earthquakes began occurring in swarms centered directly beneath the volcano, at a rate of about 15 per hour. By March 25, M4 events were shaking the volcano at a rate of about 3 per hour. On the same day, several overflights revealed new fractures on the glacier surfaces and a number of avalanches and rockfalls. (From [How Volcanoes Work.](#))

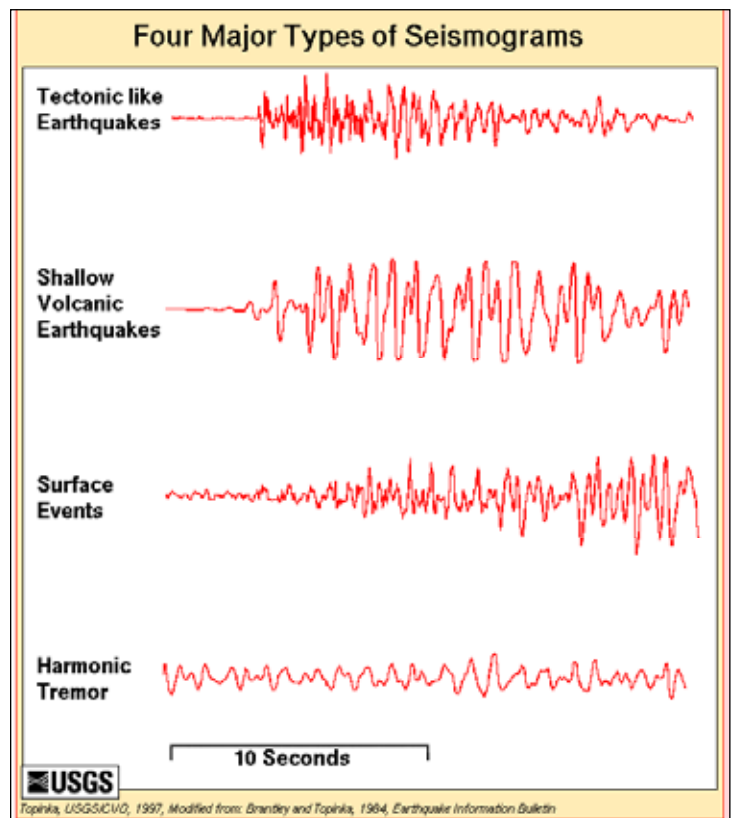


Figure 5—Seismograms recognized at Mount St. Helens:

- (1) deep earthquakes and those located away from the volcano, which produce high-frequency signatures and sharp arrivals similar to tectonic earthquakes,
- (2) shallow earthquakes, located under the dome at depths of less than 3 kilometers, which produce medium-to-low-frequency seismic arrivals,
- (3) surface events, such as gas and tephra events, rockfalls associated with dome growth, and snow and rock avalanches from the crater walls, which produce complicated signatures with no clear beginning or end, and
- (4) harmonic tremor, which is a long-lasting, very rhythmic signal whose origin is not well understood but which is often associated with active volcanoes.

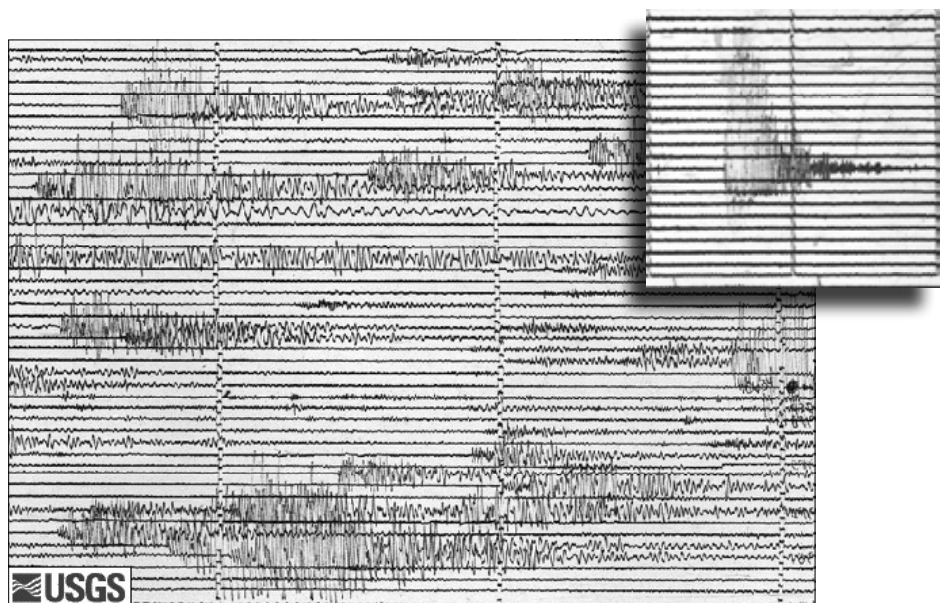


Figure 6—Seismogram upper right shows M4 earthquake March 20, 1980. Helicorder shows 48 hours of harmonic tremor March 21 to 23 (USGS).

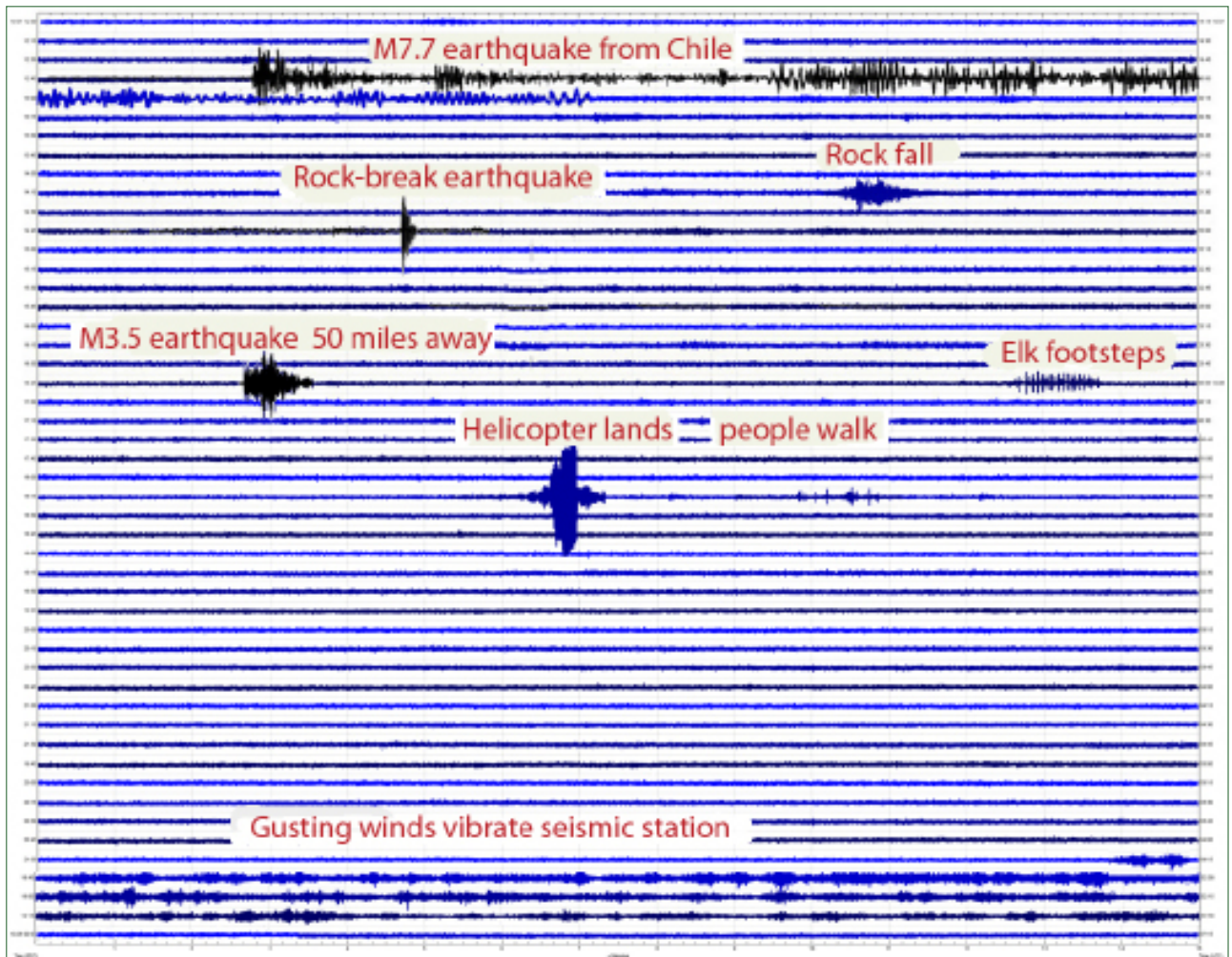


Figure 7A—Composite helicorder that is used for the 6 animations of “Seismograms of Common Events” on the [IRIS Animations page](#). These events have been placed on a single helicorder plot for convenience, though didn’t occur in the same 24-hour period.

Real-time seismogram displays depict ground motion recorded by a seismograph station and are updated every few minutes. Each plot represents 24 hours of data from one station. The plots are “magnified” according to the level of background or ambient seismic noise, which is generated by wind, cultural disturbances and oceanic microseisms. Thus, some sites appear noisier than others. The seismogram is “read” like a book, from left to right and top to bottom (this is the direction that time increases). As with a book, the right end of any horizontal line “connects” with the left end of the line below it.

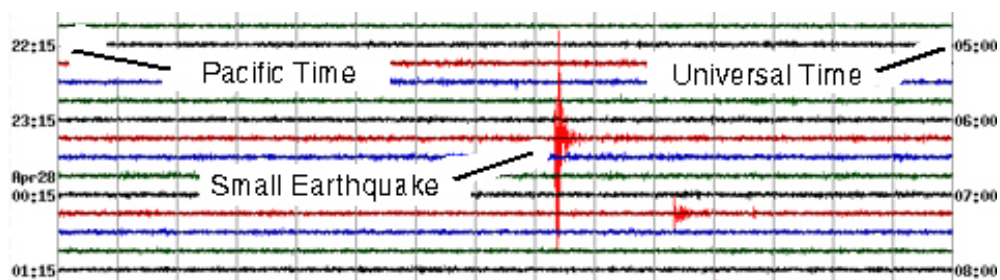
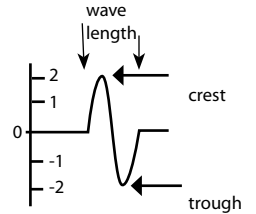


Figure 7B— Helicorder grab from USGS “Real-time Seismograph Displays. Each horizontal line represents 15 minutes of data; four lines per hour. The colors of the horizontal lines have no particular significance except they have a 4-color/hour cycle; they are used to make it easier to distinguish lines from one another and to make it easier to recognize at which quarter-hour of data we are looking. The vertical lines are not part of the seismogram. They were added to indicate equal intervals of time. Time is indicated on the left in local Pacific time, and on the right end in Universal (or Greenwich) time.

(Text from USGS: <http://earthquake.usgs.gov/monitoring/helicorders/about.php>)

Vocabulary

Amplitude—the maximum disturbance or distance from the constant point. On a seismogram the horizontal time line is flat until there is a ground disturbance which is recorded as wave, or *seismogram*. The amplitude of a seismic wave is the amount the ground moves up or down. Amplitude is one-half the distance between the crest and trough of one wave length. In drawing at right, maximum displacement is $2 + 2 = 4$, so Amplitude = $0.5 * 4 = 2$.



Body Waves—waves that move within the Earth's interior or within a body of rock. P and S waves are body waves.

Earthquake—shaking or trembling of the earth that accompanies rock movements extending anywhere from the crust to 680 km below the Earth's surface. It is the release of stored elastic energy caused by sudden fracture and movement of rocks inside the Earth. Part of the energy released produces seismic waves, like P, S, and surface waves, that travel outward in all directions from the point of initial rupture. These waves shake the ground as they pass by. An earthquake is felt if the shaking is strong enough to cause ground accelerations exceeding approximately 1.0 centimeter/second squared. *Types of earthquakes* include:

A) Tectonic Earthquake: earthquake that occurs when the earth's crust breaks due to geological forces on rocks and adjoining plates that cause physical and chemical changes. **B) Volcanic Earthquakes:** earthquakes that result from tectonic forces which occur in conjunction with volcanic activity. **C) Collapse Earthquakes:** small earthquakes in underground caverns and mines. **D) Explosion Earthquakes:** earthquakes which are the result of the detonation of nuclear and chemical devices

Epicenter—the point on the Earth's surface directly above the *focus* of an earthquake.

Magnitude—The magnitude is a number that characterizes the relative size of an earthquake. Magnitude is based on measurement of the maximum motion recorded by a seismograph. Several scales have been defined, but the most commonly used are (1) local magnitude (ML), commonly referred to as "Richter magnitude," (2) surface-wave magnitude (Ms), (3) body-wave magnitude (Mb), and (4) moment magnitude (Mw). Scales 1-3 have limited range and applicability and do not satisfactorily measure the size of the largest earthquakes. The moment magnitude (Mw) scale, based on the concept of seismic moment, is uniformly applicable to all sizes of earthquakes but is more difficult to compute than the other types. All magnitude scales should yield approximately the same value for any given earthquake..

Moment Magnitude—the preferred measure of earthquake size (magnitude) in which the stiffness of the rock, the average slip on the rupture plane, and the area of the rupture plane are taken into account (the "moment" of the earthquake). See magnitude.

Seismic Wave— an elastic wave generated by an impulse such as an earthquake or an explosion. Seismic waves may travel either through the earth's interior (P and S waves; the fastest waves) or along or near the earth's surface (Rayleigh and Love waves). Seismic waves travel at speeds of several kilometers per second.

Seismicity—the geographic and historical distribution (the "where?" and "how often?") of earthquakes.

Seismogram—A real-time record of earthquake ground motion recorded by a *seismograph*. Seismograms are the records (paper copy or computer image) used to calculate the location and magnitude of an earthquake..



Seismograph—an instrument that records vibrations of the Earth, especially earthquakes. Seismograph generally refers to the *seismometer* and a recording device as a single unit. See [IRIS' Seismographs](#).

Seismology—science that deals with earthquakes and attendant phenomenon including the study of artificially produced elastic waves in the Earth's material.

Seismometer—a sensitive instrument that can detect waves emitted by even the smallest earthquakes. (See *seismograph*.)

Surface Wave—waves that move close to or on the outside surface of the Earth rather than through the deep interior like the faster P or S waves. Two principal types of surface waves, **Love** and **Rayleigh** waves, are generated during an earthquakes. Rayleigh waves cause both vertical and horizontal ground motion, and Love waves cause horizontal motion only. They both produce ground shaking at the Earth's surface but very little motion deep in the Earth. Because the amplitude of surface waves diminishes less rapidly with distance than the amplitude of P or S waves, surface waves are often the most important component of ground shaking far from the earthquake source.

S Waves—secondary body waves that oscillate the ground perpendicular to the direction of wave travel. They travel about 1.7 times slower than P waves. Because liquids will not sustain shear stresses, S waves will not travel through liquids like water, molten rock, or the Earth's outer core. S waves produce vertical and horizontal motion in the ground surface.