Seismographs

Background page to accompany the animations on the website: **IRIS Animations**

Link to Vocabulary (Page 3)

Introduction

A seismograph detects, amplifies, and records earthquakes as well as other ground motion. The word seismograph is often used synonymously with seismometer, but there is a distinction. The seismometer is the ground-motion detector part of the seismograph system. In the drawings in Figure 1 and in our simple animations the seismometer includes the inertial mass and the spring, and the seismograph is the entire assembly that also amplifies the slightest movements in the earth and records the signal (the seismogram).

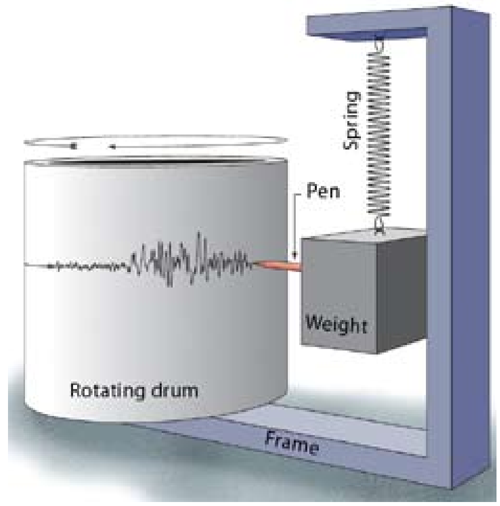


Figure 1: *Although modern seismographs are more compact and record the data on a computer, the graphics above and below show the principal of seismograph operation. Seismographs are designed so that slight earth vibrations move the instruments; the suspended mass, however, tends to remain at rest, and its recording stylus (pen) records this difference in motion.*

Seismograph Principle

Seismographs operate on the principle of inertia of stationary objects, such as the inertial mass in Figures 1 and 2, and in the animations. The inertial mass remains stationary unless a force is applied to it. The weight thus tends to remain stationary following sudden movement, while the frame and drum move with the ground. Seismometers used in earthquake studies are designed to be highly sensitive to ground movements, so that movements as small as 1/10,000,000 centimeters (distances almost as small as atomic spacing) can be detected at very quiet sites. The largest earthquakes (such as the magnitude 9.1 Sumatra-Andaman Islands earthquake in 2004) create ground motions over the entire Earth that can be several centimeters high thousands of miles away from the epicenter.

Seismograms (Figure 3) are the graphs of the motion of the ground versus time. They are the squiggles left by the pen or produced by digital computer records. Seismograms are used to calculate the location and magnitude of an earthquake. (*Excerpt from: USGS Earthquake Hazards Program Website*.)

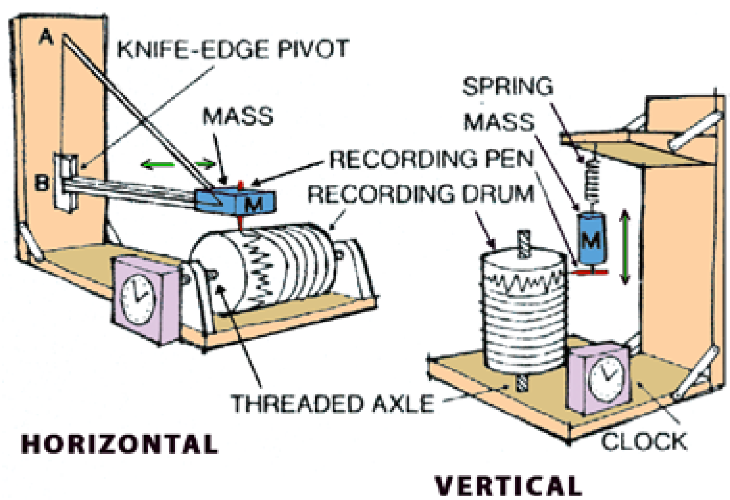
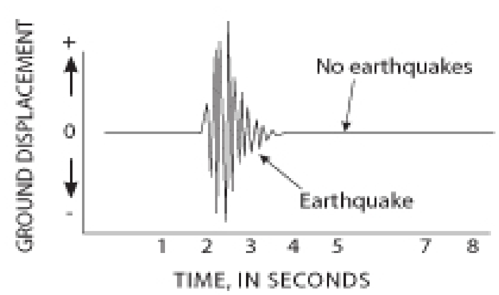


Figure 2*—The horizontal seismograph (above left moves only in the horizontal plane. Vertical seismographs ((Figure 1 and above right) use a "soft" link between the earth-anchored instrument and the suspended mass. In this design, the mass hangs from a spring, which absorbs some of the motion and causes the mass to lag behind actual motion. (From USGS.gov.)*

Figure 3: *Seismogram. The horizontal axis = time (measured in seconds) and the vertical axis = ground displacement usually measured in fractions of millimeters (nanometers). When there is NO earthquake reading there is just a straight line except for small wiggles caused by local disturbance or "noise." Also, old-style rotating drums make a small marker jump every minute.*



[From IRIS Onepager # 7, "**How Does a Seismometer Work?**"]

Three-component Seismometers

Following an earthquake, the ground responds to P, S, and surface waves by moving in all directions, not just up and down (Figure 4). A single seismograph pendulum works in only one direction, and cannot give a complete picture of wave motions from other directions. To overcome this problem, modern seismograph stations have three separate instruments to record motion in the x, y, an z axes: (1) one to record the horizontal north-south waves, (2) another to record horizontal east-west waves, and (3) a vertical one that records up-down ground motions. This combination of instruments tells a seismologist the general direction of the seismic wave source, the magnitude at its source, and the character of the wave motion. Instruments at other stations must be used to get a precise fix on the earthquake's epicenter.

Touch link for Animations on:
3-Component Seismograph

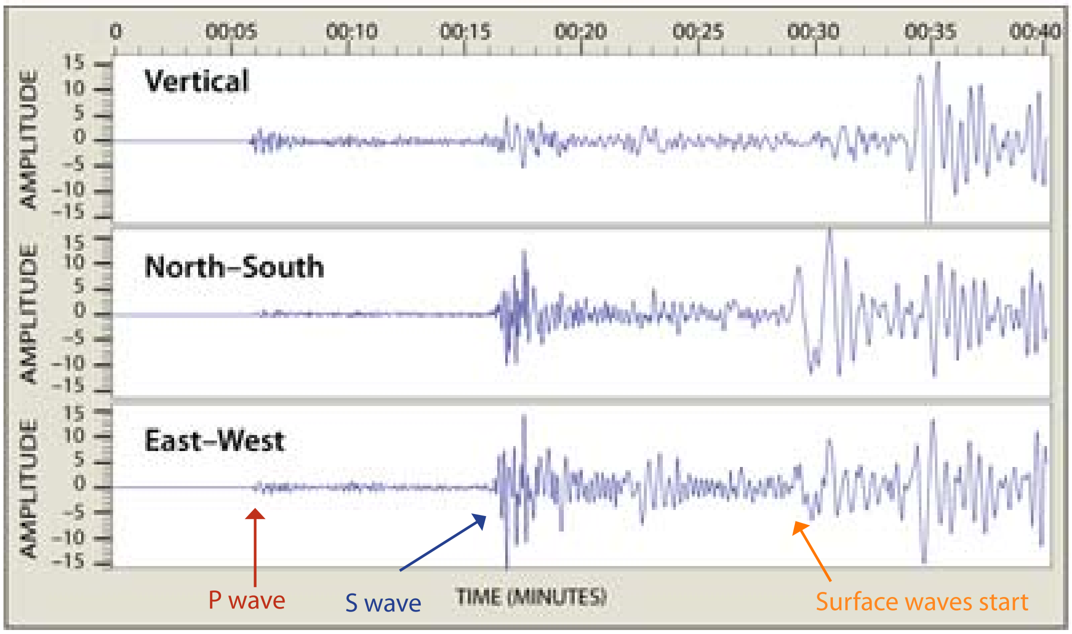


Figure 4: This three-component seismogram was recorded from an earthquake about 10,000 km (6,000 miles) from the seismometer. The initial wave (P wave) arrives at about 6 minutes from the start of the plot. The signal is largest on the vertical component showing that the movement is largely up-down. The subsequent S wave, at about 16 minutes, is largest on the two horizontal components (north-south and east-west), which shows that this shear wave has more sideways movement than vertical movement. The surface waves are much slower and arrive about 15 minutes later. The first surface wave, at about 30 minutes, includes primarily horizontal motion (Love wave) while the second surface wave at 35 minutes includes both horizontal and vertical motion (Rayleigh wave).

Figure 5 : Photograph of a modern three-component borehole seismometer. Three seismometers are stacked inside a tube with electronic circuitry. The instrument is encased in a vertical drill hole. The seismometers detect the motion and send a signal to the seismograph to be amplified and recorded

INTERNET LINKS

See Tools for "Exploring Earthquakes" on IRIS E&O page:
http://www.iris.edu/hq/programs/education_and_outreach

How Does a Seismometer Work?

USGS: History of seismometers from 152 AD until 1900

Earthquake Topics: History, Earthquakes, Seismology

Seismographs in Schools

http://www.iris.edu/hq/sis

IRIS's Seismographs in Schools Program serves K-12 teachers across the country and around the world using seismic instruments (such as the AS-1 seismometer in Figure 6) or real-time seismic data available on the Internet. Additionally, our site includes tools to share seismic data in real-time, classroom activities, and technical support documents for seismic instruments. Our hope is to bridge the gap between science classrooms to create an international educational seismic network.

Figure 6: Photograph of a simple AS-1 vertical seismometer used in IRIS' *Seismographs in Schools* program **http://www.iris.edu/hq/sis**

How does a seismic station work?

From: **http://www.usarray.org/public/about/how**

The buried seismometer is the key instrument at a seismic station. It detects and measures Earth's ground motion. These vibrations are similar to sound waves in air, but span a wide frequency range that extends well below the threshold for human hearing. The seismometer's sensors are extremely sensitive and can pick up a broad spectrum of motions ranging from low-amplitude background vibrations, such as those generated by wind or pounding surf, to signals from local, regional, and distant earthquakes. The sensitivity of the station depends on how quiet the local conditions are—the lower the "background noise" from human and natural sources such as traffic and swaying trees, the more likely the station will be able to detect faint earthquake signals. Sites are chosen to minimize the background noise as much as is practical, while still allowing access for the installation of the equipment.

The seismometer, which is a little larger than a one-gallon paint can, contains delicate moving parts and sophisticated electronics, but operates on a very simple principle. The motion sensor consists of a weight hanging on a spring that is suspended from the frame of the seismometer. When an earthquake occurs, the suspended weight initially remains stationary while the frame moves with Earth's surface. The relative motion between the weight and Earth provides a measure of the ground motion. Three sensors are combined in a single package to measure ground motion in three dimensions.

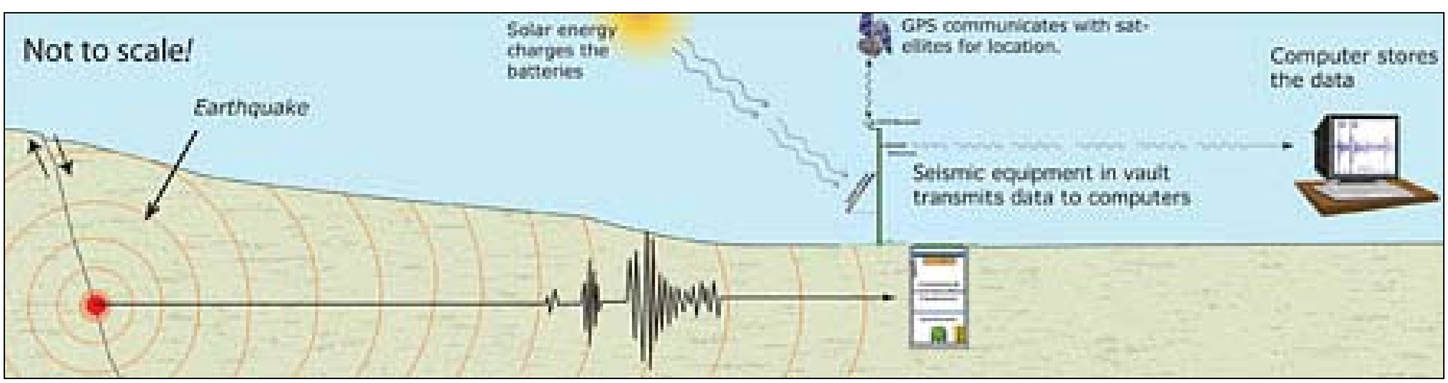
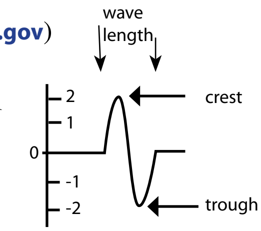


Figure 7: This simplified graphic shows the transmission route from an earthquake to the computer that stores the data. Seismic waves travel as P, S, and surface waves to the seimograph station that is buried under ground in this long-term station. The seismometer detects and measures the motion and instantly transmits that information plus GPS information via satellite to a computer that records the data. In the case of large earthquakes, the computer is set to send alarms immediately to scientists.

Vocabulary

To accompany Background files for **IRIS' Animation page**. (Definitions from **usgs.gov**; **nasa.gov**; and **fema.gov**)



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.

Compression—fractional decrease of volume due to pressure.

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.

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

Focus—the point on the fault at which the first movement or break occurred. Directly beneath the *epicenter* at 1–50 km depth.

Love Waves—*surface waves* that move parallel to the Earth's surface and perpendicular to the direction of wave propagation..

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..

P Wave—the primary body wave; the first seismic wave detected by seismographs; able to move through both liquid and solid rock..Also called compressional or longitudinal waves, they compress and expand (oscillate) the ground back and forth in the direction of travel, like sound waves that move back and forth as the waves travel from source to receiver. P wave is the fastest wave.

Rayleigh Waves—*surface waves* that move in an elliptical motion, producing both a vertical and horizontal component of motion in the direction of wave propagation.

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.

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.**

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.