

Earthquakes and Faults – Laboratory 10

(name)

Background

Faults

Faults are surfaces across which rock material has lost cohesion, and across which there has been perceptible displacement. The attitude of a fault is its strike and dip. Strike-slip faults are characterized by surfaces of displacement that dip steeply, i.e., at ~90 degrees. Displacements along such surfaces are commonly horizontal (parallel to strike) and in a right-lateral or left-lateral sense.

Strike-slip Faults

Right-lateral Strike-slip Faults

As shown in Figure 1, if a fence has been offset along a right-lateral strike-slip fault, then if a bird were to fly along the fence toward the fault it would have to turn to the right to continue flying over the offset segment. Would the bird have to swerve to the right as it encountered the fault, if it flew in from the north rather than the south? The answer to the question is yes. It doesn't matter which direction the bird flies along the fence. It will always have to turn to the right to continue its flight.

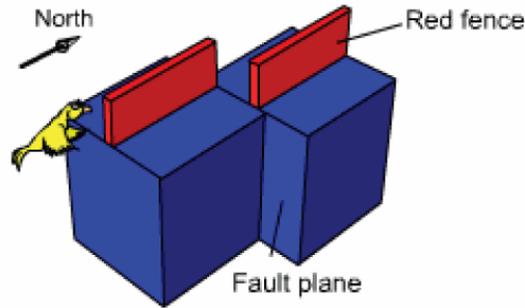
Left-lateral Strike-slip Faults

As illustrated in Figure 1 for a left-lateral fault the bird would have to turn to the left to continue flying over the offset segment. Again this statement is true regardless of which direction the bird flies from.

General Characteristics of Strike-slip Faults

Displacements on strike-slip faults can vary from a few centimeters to 100's of kilometers. Strike-slip faults are the source of many of the moderate to large earthquakes (4.0 to 7.0 Richter magnitude) that affect planet Earth. The classic example of a right-lateral strike-slip fault is the San Andreas fault while the Garlock fault represents an example of large left-lateral strike-slip fault. Both faults are located in California.

Recognizing right-lateral strike-slip faults



Recognizing left-lateral strike-slip faults

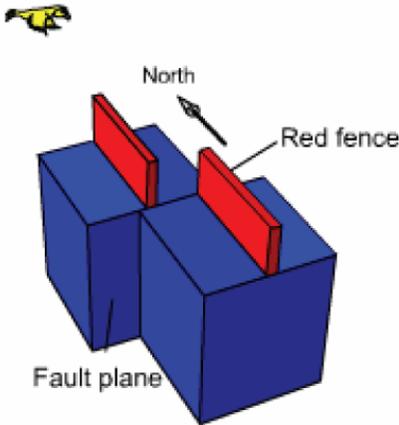


Figure 1. Recognizing the two types of strike-slip faults.

Dip-slip Faults

Displacements associated with normal and reverse faults occur along surfaces that commonly dip between $\sim 60^\circ$ and $\sim 30^\circ$ degrees. In Figure 2 the blocks of material on either side of a reverse or normal fault are called the hanging and foot walls. If you could walk along the fault surface, then your feet would be on the foot wall, while the rest of your body would be in the hanging wall. If the hanging wall has moved down relative to the foot wall, then the fault is a normal fault. If on the other hand, the hanging wall has moved up relative to the foot wall, then the fault is a reverse fault. Because movement is parallel to dip, normal and reverse faults are called dip-slip faults. A low-angle ($\sim 30^\circ$) dip-slip fault in which the hanging wall moved up relative to the foot wall is called a thrust fault. Displacements on dip-slip faults range from a few millimeters to 10's of kilometers or more.

Classifying dip-slip faults

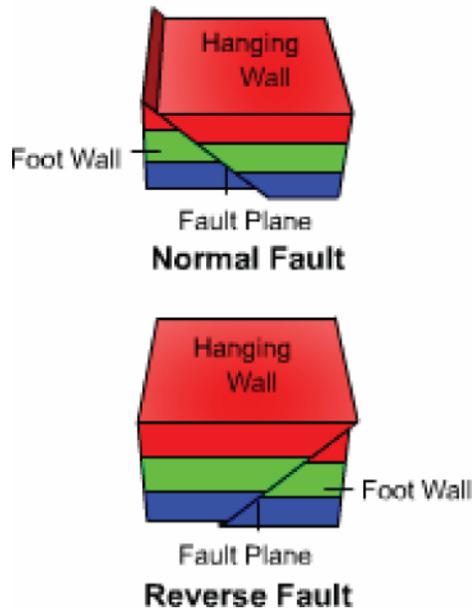


Figure 2. Characteristics of dip-slip faults.

Earthquakes

Earthquakes are a shaking and vibrating of the land surface. Such a phenomenon commonly is produced when Earth material ruptures during brittle failure along an old or new fault releasing stored up elastic strain energy as heat and seismic waves. However, it is important to note that not all earthquakes are generated by movement along brittle faults. In fact, earthquakes can be generated during volcanic eruptions and nuclear explosions. Here, for the sake of simplicity, we only consider earthquakes generated during rupture along a new or old fault.

Seismic waves are waves of energy that elastically distort the material that they travel through. Hence, after a seismic wave has passed through a body of Earth material, the body of material returns to its original form.

Hypocenter and Epicenter

The region of initiation of seismic energy within the Earth during an earthquake is the focus or hypocenter (Figure 3). This is the initial region along which a new fault forms or an old fault ruptures. From the focus, slip along the fault spreads quickly. The position on the land surface immediately above the hypocenter is the epicenter (Figure 3).

As rupture along a fault initiates, waves of energy travel outward from the hypocenter in a spherical fashion (Figure 3). These waves of energy are strongest nearest the hypocenter but gradually grow weaker further away from the site of initial rupture.

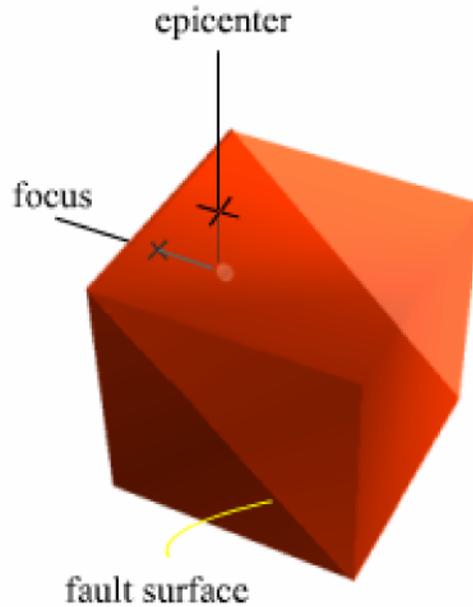


Figure 3. Hypocenter and epicenter.

Body and Surface Waves

Seismic waves include body and surface waves. The former type of wave emanates spherically from the hypocenter traveling *entirely within* the interior of the Earth while the latter travels along *the surface* of the Earth emanating from the epicenter. Body waves are compressional or P-waves and shear or S-waves. Surface waves are Love and Rayleigh waves.

P- and S-waves

P-Waves

As the energy associated with P-waves moves outward in spherical fashion from the hypocenter it produces a series of contractions and expansions (Figure 4). During contractions the distances between atoms in the material that the P-wave is passing through shorten, and as a result there is a small decrease in volume. During expansions the distances between atoms in the material increase, and there is a small increase in volume. Following the complete passing of a P-wave, elastic Earth material returns to its original form. P-waves can pass through liquids, solids, and gasses.

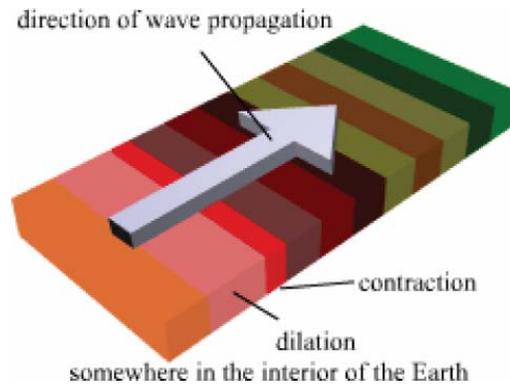


Figure 4. Characteristics of P-waves.

S-Waves

In contrast to P-waves, S-waves emanating outward in a spherical fashion from the hypocenter produce shape rather than volumetric changes in Earth material (Figure 5). When an S-wave passes through the Earth it displaces particles of Earth material in a direction perpendicular to the direction that they are moving. As a result, a planar surface would take on the form of the corrugations in a tin roof. Because liquids can not support a shape change, S-waves do not travel through Earth material that is in a liquid state.

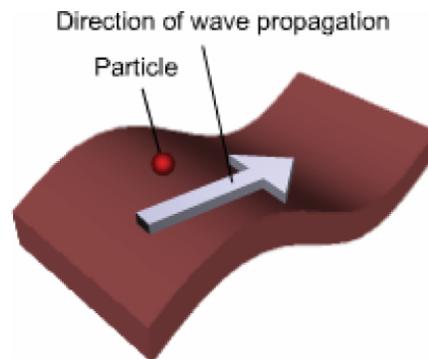


Figure 5. Characteristics of S-waves.

Speeds of P- and S-Waves

Near the Earth's surface in continental regions P-waves can travel at speeds around 6 km/sec while S-waves travel at speeds around 3.5 km/sec. Because P-waves are faster than S-waves they arrive at seismic stations earlier than S-waves. They are therefore referred to as primary waves while the slower traveling S-waves, arriving a little later than the P-waves at the seismic station, are sometimes called secondary waves.

Surface Waves

Rayleigh Waves

Rayleigh waves as they move along the surface of the Earth form a wave that is much like an ocean wave (Figure 6). In other words they displace the land surface at right angles to the direction that they are moving. This displacement, though superficially like that produced by an S-wave, dies out with depth.

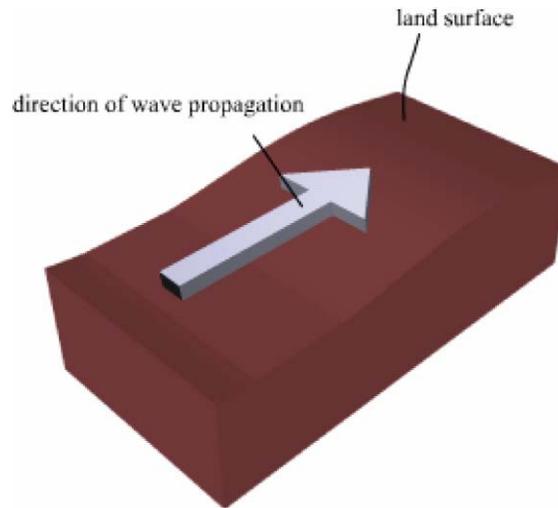


Figure 6. Characteristics of Rayleigh waves.

Love Waves

Love waves displace Earth material at the surface in a horizontal snake-like motion (Figure 7). Love waves do not travel through water.

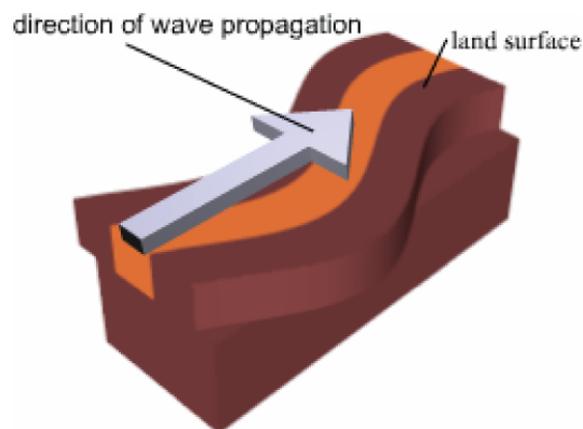


Figure 7. Characteristics of Love waves.

Earthquake Magnitudes

The amplitude of the squiggly curve of the seismogram provides information about the energy released during an earthquake. The Richter magnitude scale, is determined by the amplitudes of the P- and S-waves as measured at a distance of 100 km (62.1 miles) from the epicenter of an earthquake. This scale is logarithmic, with commonly reported magnitudes varying from 1 to about 9. Each unit increase in magnitude corresponds to a ten-fold increase in amplitude. For example, a magnitude 2 earthquake produces a signal with an amplitude that is ten times larger than a magnitude 1 signal. A magnitude 3 earthquake would produce a signal with an amplitude one hundred times larger than a magnitude 1 signal.

Though the above ideas seem straight forward enough, energy in a wave is in fact a function of both amplitude and frequency. This latter parameter is the number of waves that pass a given point each second. Frequency differs from one earthquake to another. The most energetic earthquakes have a higher proportion of low frequency waves than do the least energetic. Taking these factors in to consideration, seismologists have estimated that there is a thirty-two-fold increase in energy in going from one Richter unit to the next. In other words, a magnitude 3 earthquake releases 1024 times (32×32) the energy of a magnitude 1 earthquake.

The seismic moment is another way of measuring the magnitude of an earthquake. It is determined by the strength of the rock, surface area of rupture, and the amount of rock displacement along the fault that generated the earthquake.

Earthquake Intensities

When an earthquake occurs the land surface vibrates and shakes, and as a result streets, houses, fences, bridges, and other structures are damaged. If we can determine how much damage has occurred then we can determine the intensity of the earthquake. The modified Mercalli scale was developed to specifically measure the effect of an earthquake on people and buildings.

The modified Mercalli scale varies from I XII, with higher Roman numerals indicating greater intensity. In general, we would expect intensity to decrease outward away from the epicenter. However, over the last 50 years or so buildings and roads have been built under different types of engineering codes, and as a result such man-made structures have differing resistance to ground shaking during an earthquake. Hence, Mercalli intensities may vary from region to region and country to country as a function of building code and other related factors.

The Laboratory

Calculating the epicenter and magnitude of an earthquake

Using the three seismograms on the following pages,

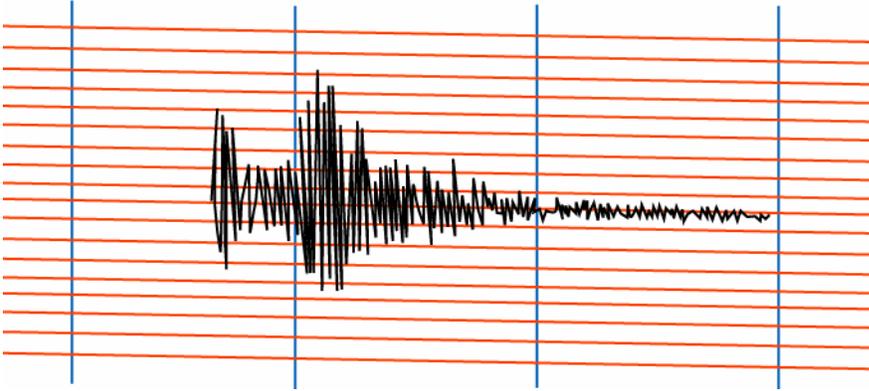
- (1) Find the S-P separation by measuring the distance in millimeters from the beginning of the P-wave to the beginning of the S-wave.

- (2) Convert millimeters to seconds. 1 mm = 1 second, i.e., 12 mm = 12 seconds.
- (3) Calculate the epicentral distance from each seismic station using the approximation that 1 second of difference between P and S arrival times corresponds to an 8 kilometer distance, i.e., 12 sec X 8 km/sec = 96 km.

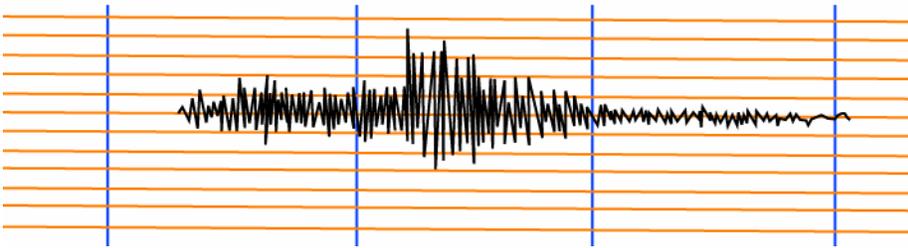
Station	Millimeters	Seconds	kilometers
PLM			
GLA			
BAR			

- (4) Locate the seismic station for each seismogram on the fault map. Draw circles from each seismic station using the epicentral distance from step 3.
- (5) The three circles should intersect (or nearly so) at a point that represents the epicenter. Label this point on your fault map.
- (6) Calculate the Richter magnitude of the earthquake using the PLM seismogram.
 - a. Measure the distance in millimeters from the central reference line to the maximum amplitude
 - b. Using the graph labeled "The Richter Scale" plot your distance and amplitude values. Draw a line to connect them and record the magnitude.
- (7) Locate on the attached map and name all of the major faults.
- (8) What major fault in southern California did the earthquake occur on?

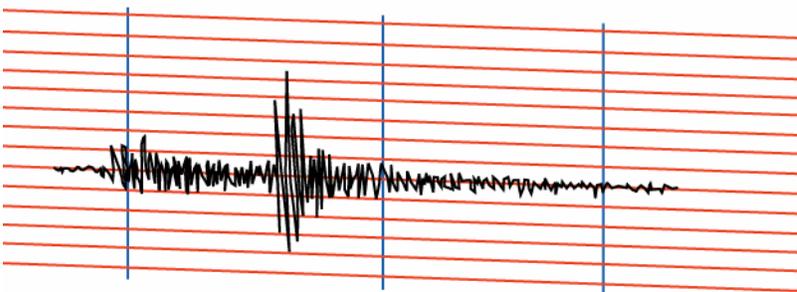
PLM



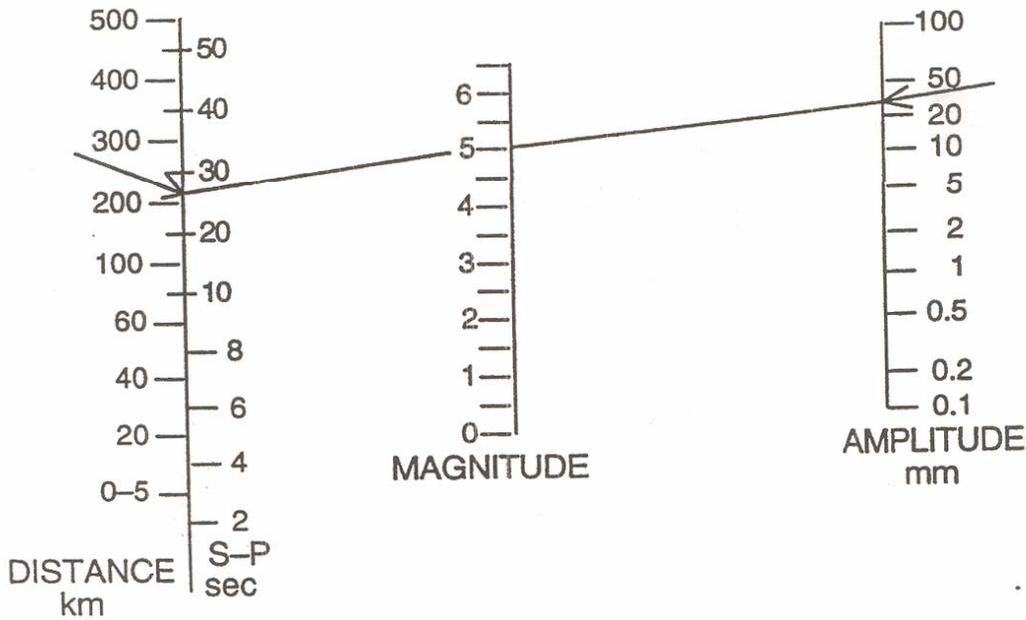
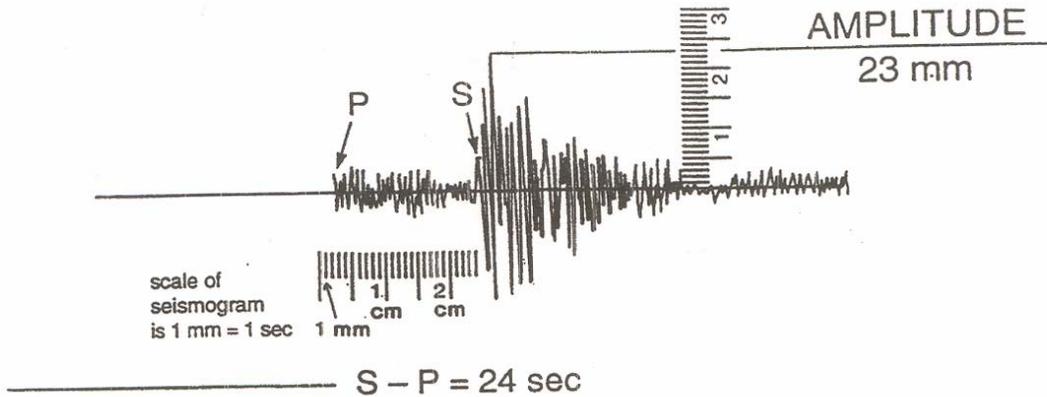
GLA



BAR



THE RICHTER SCALE



Determining the magnitude of an earthquake

1. Find the maximum amplitude recorded by a calibrated seismometer.
2. Find the distance of the seismometer from the epicenter of the earthquake (or the difference in arrival times of the P and S waves).
3. Find and mark these values on the chart.
4. Connect these values with a straight line.
5. Where the line crosses the center scale is the magnitude of the earthquake.

