Chapter 8: Earthquakes and Earth’s Interior

Section 8.1: What is an Earthquake?
Textbook pp 218-221
Earthquakes

• More than 30,000 earthquakes occur in the world each year. Most are minor and do very little damage.

• About 75 major earthquakes take place each year. Most occur in remote regions and do little or no damage.
Sometimes a large earthquake occurs near a city, which can be highly destructive.

(This photo was taken in Kobe, Japan right after the 1995 earthquake.)
Even between earthquakes, the plates will creep and cause alterations in the earth’s surface.

Town of Hollister, C A. The San Andreas fault runs sub-parallel at 1.5 miles west.
Offset curb on 7th Street, Hollister, CA
Discrepant Event, Hollister CA.

See the curve in the street?
Bridge across San Andreas Fault at Parkfield, CA.
Do you see the San Andreas Fault offset at the Parkfield Bridge railing?

Which directions(s) do you think the two plate boundaries are moving at this site?
This stream bed running across the San Andreas Fault has been offset during a past earthquake.
Focus and Epicenter and Fault

- **The focus** of an earthquake is the place within Earth where the earthquake starts.
- **The epicenter** is the location on the surface directly above the focus.

Faults are fractures in the Earth where plate movement has occurred.
The 1906 San Francisco Earthquake caused the western side of the San Andreas Fault to 5 meters to the north compared to its eastern side.
As the two plates attempt to slide past each other, forces within Earth slowly change (deform) the crustal rocks on both sides of the fault.

Elastic energy is stored in the rock while the forces cause it to bend.

Finally the energy overcomes the rock’s resistance, and it slips at the rock’s weakest point (the focus).
Elastic Rebound Hypothesis

- The **springing back** of the rock into its original place is called **elastic rebound**.

- When rocks are **deformed**, they first **bend** and then **break**, releasing **stored energy**.

- This explanation is called the **elastic rebound hypothesis**.
KEY IDEA: Most earthquakes are produced by the rapid release of elastic energy stored in rock that has been subjected to great forces. When the strength of the rock is exceed, it suddenly breaks, causing the vibrations of an earthquake.
Aftershocks & Foreshocks

The movements that follow a major earthquake often produce smaller earthquakes called **aftershocks**.
• These aftershocks are weaker than the main earthquake, but can sometimes destroy structures weakened by the main quake.
Small earthquakes called **foreshocks** often come **before** a major earthquake. These foreshocks can happen days or even years before the major quake.

Some parts of the San Andreas Fault show a slow, gradual movement known as **fault creep**. This movement happens fairly smoothly.

Pressure Ridge, California Route 25.
Anatomy of an Earthquake: Focus, Fault, Epicenter
8.2 Measuring Earthquakes

The first attempts to measure and locate earthquakes were made by the early Chinese. Seismographs are instruments that record earthquake waves. They can be used on the earth’s surface or buried underground.

Text pp 222-228
A seismograph is the instrument that collects data about earthquake data (or seismic waves)...

A seismogram is the actual recording (also called a “trace”) of the seismic activity recorded by the seismogram.
Earthquake Waves

The energy from an earthquake spreads outwards as waves in all directions from the focus.

Two main types of seismic waves are produced by an earthquake: surface waves and body waves.
Surface waves travel over the Earth’s surface

- Some surface waves travel like ocean waves over the surface of the Earth, moving the ground surface up and down. They cause most of the shaking at the ground surface during an earthquake.
Other surface waves are fast and move the ground from side to side.

The two kinds of surface waves occur at the same time.
Body Waves travel through the Earth’s Interior.

P-waves (Primary Waves) are the fastest type of seismic wave. As P-waves travel, the surrounding rock is repeatedly compressed and then stretched.

S-waves (Secondary Waves) arrive after P-waves because they travel more slowly. The rock is shifted up and down or side to side as the wave travels through it.
P waves temporarily change the volume of the material they pass through by compression and then expansion.

P waves can go through the fluid matter of earth, such as large bodies of water and its plastic inner layers, such as the inner core.
S waves temporarily change the shape of the material they pass through. Gases and fluids will not transmit S waves because they do not rebound elastically to their original shape.
A seismogram shows all three types of seismic waves: **surface waves**, **P waves**, and **S waves**.

The waves arrive at different times because they travel at different speeds. Generally, in any solid material, **P waves** travel about 1.7 times faster than **S waves**.

**Surface waves** travel the slowest at about 90 percent of the speed of the **S waves**.
Locating an Earthquake

Just like two cars in a race, even though both P waves and S waves start at the same place and at the same time, the P waves will always win the race because they have the greater velocity.
The greater the interval measured on a seismogram between the arrival of the first P wave and the first S wave, the greater the distance to the earthquake source.
Earthquake Direction

It takes recordings from at least three seismic stations to accurately locate the epicenter of an earthquake.

Draw a circle around each station, using the station as the central point and its distance from the earthquake as the radius.

The epicenter is located at the intersection of all three circles.
Earthquake Zones

About 95% of all major earthquakes occur in a few narrow zones, and most of these are around the Pacific Ocean. This zone is known as the circum-Pacific belt, as well as “The Ring of Fire.”
Measuring Earthquakes

Scientists have used two different types of measurements to describe the size of an earthquake: intensity and magnitude.
Intensity

- **Intensity** is a measure of the amount of earthquake shaking at a given location based on the amount of damage. It is based on personal observation and estimates.

- The **Modified Mercalli Scale** rates an earthquake’s intensity in terms of the earthquake’s effects at different locations.

- The same earthquake can receive different Mercalli scale ratings at different locations.
Magnitudes

- **Magnitudes** are quantitative measurements. They rely on calculations using seismographs.

- **Magnitudes** measure the size of seismic waves, or the amount of energy released at the source of the earthquake.
Moment Magnitude Scale

The moment magnitude scale is the most widely used measurement for earthquakes.

It is the only magnitude scale that estimates the energy released by earthquakes.
<table>
<thead>
<tr>
<th>Moment Magnitudes</th>
<th>Effects Near Epicenter</th>
<th>Estimated Number per Year</th>
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<tbody>
<tr>
<td>&lt; 2.0</td>
<td>Generally not felt, but can be recorded</td>
<td>&gt; 600,000</td>
</tr>
<tr>
<td>2.0–2.9</td>
<td>Potentially perceptible</td>
<td>&gt; 300,000</td>
</tr>
<tr>
<td>3.0–3.9</td>
<td>Rarely felt</td>
<td>&gt; 100,000</td>
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<tr>
<td>4.0–4.9</td>
<td>Can be strongly felt</td>
<td>13,500</td>
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<tr>
<td>5.0–5.9</td>
<td>Can be damaging shocks</td>
<td>1,400</td>
</tr>
<tr>
<td>6.0–6.9</td>
<td>Destructive in populous regions</td>
<td>110</td>
</tr>
<tr>
<td>7.0–7.9</td>
<td>Major earthquakes; inflict serious damage</td>
<td>12</td>
</tr>
<tr>
<td>8.0 and above</td>
<td>Great earthquakes; destroy communities near epicenter</td>
<td>0–1</td>
</tr>
<tr>
<td>Year</td>
<td>Location</td>
<td>Deaths (est.)</td>
</tr>
<tr>
<td>-------</td>
<td>------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>1886</td>
<td>Charleston, South Carolina</td>
<td>60</td>
</tr>
<tr>
<td>1906</td>
<td>San Francisco, California</td>
<td>1500</td>
</tr>
<tr>
<td>1923</td>
<td>Tokyo, Japan</td>
<td>143,000</td>
</tr>
<tr>
<td>1960</td>
<td>Southern Chile</td>
<td>5700</td>
</tr>
<tr>
<td>1964</td>
<td>Alaska</td>
<td>131</td>
</tr>
<tr>
<td>1970</td>
<td>Peru</td>
<td>66,000</td>
</tr>
<tr>
<td>1971</td>
<td>San Fernando, California</td>
<td>65</td>
</tr>
<tr>
<td>1985</td>
<td>Mexico City</td>
<td>9500</td>
</tr>
<tr>
<td>1988</td>
<td>Armenia</td>
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<tr>
<td>1989</td>
<td>Loma Prieta, California</td>
<td>62</td>
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<tr>
<td>1990</td>
<td>Iran</td>
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<td>1993</td>
<td>Latur, India</td>
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<tr>
<td>1994</td>
<td>Northridge, California</td>
<td>57</td>
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<td>1995</td>
<td>Kobe, Japan</td>
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<td>1999</td>
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<tr>
<td>2001</td>
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<tr>
<td>2001</td>
<td>Bhuj, India</td>
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8.3: Destruction from Earthquakes, pp 228-232
Alaska 1964, 9.2
The 1964 “Good Friday Earthquake” in Alaska lasted 3 to 4 minutes and registered 9.2 on the moment magnitude scale.

Seismic Vibrations

The damage to buildings and other structures from earthquake waves depend on several factors. These factors include the intensity and duration of the vibrations, the nature of the material on which the structure is built, and the design of the structure.
All multistoried buildings in Anchorage were damaged. The more flexible wood-framed buildings and steel-framed were less damaged.
Engineers have learned since then that unreinforced stone or brick buildings are the most dangerous threats during earthquakes.
Liquefaction
When loose soils or sediments are saturated with water, earthquakes can cause **liquefaction**. Under these conditions, what was once stable ground can “shake” into a thick liquid, unable to support buildings or other structures.
Buildings and bridges may settle and collapse, while underground storage tanks and sewer lines may float toward the surface.
• Most deaths associated with the 1964 Alaskan quake were caused by seismic seawaves, or tsunamis.
A tsunami triggered by an earthquake occurs where a slab of the ocean floor is displaced vertically along a fault.

A tsunami also can occur when the vibration of a quake sets an underwater landslide into motion.
Once formed, a tsunami resembles the ripples created when a pebble is dropped into a pond.

A tsunami travels across the ocean at 500 to 950 km per hour.

When the wave enters shallower coastal water, the waves are slowed down, but “pile up” onto each other, to heights that are at times over 30 meters in height.
Other Dangers

With many earthquakes, the greatest damage to structures is from landslides and ground subsidence, or the sinking of the ground triggered by the vibrations.
Fire is also a threat after an earthquake. The greatest destruction after the 1906 San Francisco earthquake was caused by fires started after gas and electrical lines were cut.