Plate Tectonics and Earth’s Structure

- Chapter Eight: Plate Tectonics
- Chapter Nine: Earthquakes
- Chapter Ten: Volcanoes
Chapter Nine: Earthquakes

• 9.1 What is an Earthquake?
• 9.2 Seismic Waves
• 9.3 Measuring Earthquakes
Investigation 9A

Earthquakes

- What conditions affect the timing, duration, and intensity of an earthquake?
9.1 What is an earthquake?

- An earthquake is a form of stick-slip motion.
- Stick-slip motion can be compared to a stuck door.
9.1 Stick-slip motion

• Three conditions are needed for stick-slip motion:
  1. Two objects that are touching each other where at least one of the objects can move.
  2. A force, or forces, that will cause the movement.
  3. Friction strong enough to temporarily keep the movement from starting.

Use the stick-slip door model to identify these conditions.
9.1 Friction

- Friction is a resistance to slip that occurs when two objects rub against each other.
9.1 What causes earthquake?

- An **earthquake** is the movement of Earth’s crust resulting from the release of built-up potential energy between two stuck lithospheric plates.
Plate Stick-Slip Motion

Stick-slip motion
The brittle crust sticks and releases.

The upper mantle is plastic and flows.
9.1 What causes earthquakes

- The point below the surface where the rock breaks is called the earthquake focus.
9.1 What causes earthquakes

• As soon as the rock breaks, there is movement along the broken surface causing a split in the surface called a fault.
9.1 The nature of plates

- The seismic waves from an earthquake are usually strongest at the **epicenter**, the point on the surface right above the focus.
Parts of an Earthquake

- Fault
- Epicenter
- Focus
- Seismic waves
9.1 Slickenslides

• The effect of rock moving against rock is evidence of plate boundaries.

• The rock surface moving to the right is called slickensides because it is smooth and polished.
9.1 The nature of plates

- A cracked shell on a hard-boiled egg is similar to lithospheric plates on Earth’s surface.
9.1 The nature of plates

- A moving line of grocery carts is a better example of a moving lithospheric plate.
- Although a plate may be moving as a single unit, its boundaries act like they were made of many small sections like the line of carts.
Cross-Section of the San Andreas Fault Zone

San Gabriel mountains

Los Angeles

Mojave Desert

San Andreas Fault Zone

Crust

Upper mantle

Pacific Plate

North American Plate

Brittle

Plastic
9.1 When do earthquakes happen?

- The release of built-up potential energy causes earthquakes.
- An earthquake is a stress reliever for a lithospheric plate.
- Once a quake occurs, potential energy builds up again.
9.1 When do earthquakes happen?

• The second longest ever recorded earthquake occurred in 1964 in Alaska and lasted for four minutes.

• **Foreshocks** are small bursts of shaking that may precede a large earthquake.
9.1 When do earthquakes happen?

- **Aftershocks** are small tremors that follow an earthquake, lasting for hours or even days after the earthquake.
Investigation 9B

Earthquake Waves and Epicenter

• How do earthquake waves propagate?
• How can we use these waves to find the epicenter of an earthquake?
9.2 Seismic waves

- Seismic waves that travel through Earth’s interior are called **body waves**.
- The two main kinds of body waves are **P-waves** and **S-waves**.
9.2 Seismic waves

• Seismic waves bend when they contact different materials.

• Liquid—like the liquid outer core of Earth—acts as a barrier to S-waves.
• P-waves pass through liquid.
• Waves on the surface, or body waves that reach the surface, are called **surface waves**.
9.2 Measuring seismic waves

- People who record and interpret seismic waves are called **seismologists**.
- Seismic waves are recorded and measured by an instrument called a **seismograph**.
9.2 Measuring seismic waves

- After an earthquake occurs, the first seismic waves recorded will be P-waves.
- S-waves are recorded next, followed by the surface waves.
9.2 Measuring seismic waves

- In a quarter-mile race, the track is so short that fast and slow cars are often just fractions of a second apart.
- In a long race, like the Indianapolis 500, the cars might be minutes apart.
- The time difference between slow and fast cars is related to the length of the race track.
9.2 Measuring seismic waves

- Seismic waves radiate from the focus after the earthquake.
- Three seismic stations can accurately determine the times of body wave arrival.
9.2 Distance to epicenter

- Seismologists use computers to determine the distance to an epicenter.

<table>
<thead>
<tr>
<th>Station name</th>
<th>Arrival time difference between P- and S-waves</th>
<th>Distance to epicenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 seconds</td>
<td>80 km</td>
</tr>
<tr>
<td>2</td>
<td>50 seconds</td>
<td>420 km</td>
</tr>
<tr>
<td>3</td>
<td>30 seconds</td>
<td>250 km</td>
</tr>
</tbody>
</table>
9.2 Distance to epicenter

1. Identify three seismic stations and locate them on a map.
2. Determine the time difference between the arrival of the S-waves and the P-waves at each station (Use chart data).
3. Convert the time differences into distances to the epicenter (Use graph).
4. Set a geometric compass so that the space between the point and pencil on the compass is proportional to the distances that you found in Step 3. (Use graph scale)
5. Draw a circle around each seismic station location.
6. The intersection of the 3 circles is the epicenter!
9.2 Distance to epicenter

Distance to the epicenter vs. Time difference

- Distance to epicenter (km)
- S-P wave time difference (seconds)
Finding the Epicenter

Radius of circle is proportional to distance from epicenter to station
Activity

The Dragon and Toad Mystery

• In this activity, you will learn something about the history of using seismographs.
Geology Connection

2004 Indian Ocean

• Tilly Smith probably never imagined what she learned in geography class would help save lives.
9.3 Measuring Earthquakes

- The **Richter scale** rates earthquakes according to the size of the seismic waves recorded on a seismograph.

<table>
<thead>
<tr>
<th>Level</th>
<th>Magnitude</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro</td>
<td>Less than 2.0</td>
<td>Barely felt</td>
</tr>
<tr>
<td>Very minor</td>
<td>2.0 - 2.9</td>
<td>Recorded but not felt by most people</td>
</tr>
<tr>
<td>Minor</td>
<td>3.0 - 3.9</td>
<td>Little damage but felt by people</td>
</tr>
<tr>
<td>Light</td>
<td>4.0 - 4.9</td>
<td>No serious damage, objects shake</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level</th>
<th>Magnitude</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate</td>
<td>5.0 - 5.9</td>
<td>Major damage to poorly-designed buildings</td>
</tr>
<tr>
<td>Strong</td>
<td>6.0 - 6.9</td>
<td>Serious damage over a 100-mile area or less</td>
</tr>
<tr>
<td>Major</td>
<td>7.0 - 7.9</td>
<td>Serious damage over a larger area</td>
</tr>
<tr>
<td>Great</td>
<td>8.0 - 8.9</td>
<td>Serious damage over several hundred miles</td>
</tr>
<tr>
<td>Rare great</td>
<td>9.0 or greater</td>
<td>Serious damage over several thousand miles</td>
</tr>
</tbody>
</table>
9.3 Measuring Earthquakes

- The largest earthquake recorded occurred in Chile in 1960.
- It was off the Richter scale; seismologists estimated this quake to be 9.5.
9.3 Measuring damage

- The **Mercalli Intensity scale** has 12 descriptive categories.
- Each category is a rating of the damage suffered by buildings, the ground, and people.
<table>
<thead>
<tr>
<th>Mercalli Intensity</th>
<th>Characteristic Effects</th>
<th>Approximate Richter Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Instrumental</td>
<td>Not felt</td>
<td>1</td>
</tr>
<tr>
<td>II. Just perceptible</td>
<td>Felt by only a few people, especially on upper floors of tall buildings</td>
<td>1.5</td>
</tr>
<tr>
<td>III. Slight</td>
<td>Felt by people lying down, seated on a hard surface, or in the upper stories of tall buildings</td>
<td>2</td>
</tr>
<tr>
<td>IV. Perceptible</td>
<td>Felt indoors by many, by few outside</td>
<td>3</td>
</tr>
<tr>
<td>V. Rather strong</td>
<td>Generally felt by everyone; sleeping people may be awakened</td>
<td>4</td>
</tr>
<tr>
<td>VI. Strong</td>
<td>Trees sway, chandeliers swing, bells ring, some damage from falling objects</td>
<td>5</td>
</tr>
<tr>
<td>VII. Very strong</td>
<td>General alarm; walls and plaster crack</td>
<td>5.5</td>
</tr>
<tr>
<td>VIII. Destructive</td>
<td>Felt in moving vehicles; chimneys collapse; poorly constructed buildings seriously damaged</td>
<td>6</td>
</tr>
<tr>
<td>IX. Ruinous</td>
<td>Some houses collapse; pipes break</td>
<td>6.5</td>
</tr>
<tr>
<td>X. Disastrous</td>
<td>Obvious ground cracks; railroad tracks bent; some landslides on steep hillsides</td>
<td>7</td>
</tr>
<tr>
<td>XI. Very disastrous</td>
<td>Few buildings survive; bridges damaged or destroyed; all services interrupted (electrical, water, sewage, railroad); severe landslides</td>
<td>7.5</td>
</tr>
<tr>
<td>XII. Catastrophic</td>
<td>Total destruction; objects thrown into the air; river courses and topography altered</td>
<td>8</td>
</tr>
</tbody>
</table>
9.3 Where do earthquakes occur?

- Earthquakes commonly occur at the boundaries of lithospheric plates.
- This is because plate boundaries tend to be zones of seismic activity.
Earthquakes and Plate Boundaries