Earth Science
Chapter 5: Earthquakes
Lecture Notes

I. **Earthquakes**
   A. Definition:
      i. A shaking and trembling that results from the sudden movement of part of the Earth's crust.
      ii. Throw a pebble into a pond - ripple effect
      iii. More than 1 million per year on the planet
      iv. Most common cause is faulting
      v. Entire fault (i.e. San Andres Fault) doesn't all move at the same time. Energy is released at different places at anyone time
   B. Tsunamis:
      i. Caused by undersea earthquake
      ii. Travel at > 400 MPH (700-800KPH)
      iii. Heights up to 20 meters
   C. Seismic Waves
      i. **Focus**: Point of origin under the surface of an earthquake
      ii. **Epicenter**: Place on the surface directly above the focus
         1. Most violent shaking occurs at the epicenter
      iii. Primary Waves: P waves
         1. Fastest moving of the waves
         2. Travel through solid, liquids and gases
         3. "Push-pull" type of wave
      iv. Secondary Waves: S Waves
         1. Second to arrive
         2. Travel through solid but not liquid or gas
         3. "S" shaped waves
         4. Rock particles move at right angles to the direction of the wave
      v. Surface Waves: L Waves
         1. Slowest moving of the waves
         2. Travel across the surface of the Earth
         3. Originate on the earth's surface
         4. Cause the most damage of all the waves
      vi. Seismograph
         1. Detects and measures intensity of the earthquake
         2. Records earthquakes on a **seismogram**
         3. Richter Scale
            a. Each number represents a magnitude 10x greater than previous number.

5-1 Forces in Earth's Crust

The movement of Earth's plates creates enormous forces that squeeze or pull the rock in the crust. A force that acts on rock to change its shape or volume is **stress.** Stress adds energy to the rock. The energy is stored in the rock until it changes shape or breaks.

Three different kinds of stress can occur in the crust. **Tension, compression, and shearing work over millions of years to change the shape and volume of rock. Tension** pulls on the crust, stretching rock so that it becomes thinner in the middle. **Compression** squeezes rock until it folds or breaks. **Shearing** pushes a mass of rock in two opposite directions.

When enough stress builds up in rock, the rock breaks, creating a fault. A fault is a break in the rock of the crust where rock surfaces slip past each other. **Most faults occur along plate boundaries, where the forces of plate motion push or pull the crust so much that the crust breaks. There are three main types of faults: normal faults, reverse faults, and strike-slip faults.**

Tension causes a normal fault. In a **normal fault,** the fault is at an angle, and one block of rock lies above the fault while the other block lies below the fault. The block of rock that lies above is called the **hanging wall.** The rock that lies below is called the **footwall.** Compression causes reverse faults. A **reverse fault** has the same structure as a normal fault, but the blocks move in the opposite direction. Shearing creates strike-slip faults. In a **strike-slip fault,** the rocks on either side of the fault slip past each other sideways, with little up or down motion.

Over millions of years, the forces of plate movement can change a flat plain into landforms produced by folding, stretching, and uplifting Earth's crust. These landforms include anticlines and synclines, folded mountains, fault-block mountains, and plateaus. A fold in rock that bends upward into an arch is an anticline. A fold in rock that bends downward to form a valley is a syncline. Anticlines and synclines are found on many parts of the Earth's surface where compression forces have folded the crust. The collision of two plates can cause compression and folding of the crust over a wide area. When two normal faults cut through a block of rock, fault movements may push up a fault-block mountain. The forces that raise mountains can also uplift, or raise plateaus. A **plateau** is a large area of flat land elevated high above sea level.

5-2 Earthquakes and Seismic Waves

An **earthquake** is the shaking that results from the movement of rock beneath Earth's surface. The area beneath Earth's surface where rock under stress breaks to cause an earthquake is called the **focus.** The point on the surface directly above the focus is called the **epicenter.** During an earthquake, vibrations called seismic waves move out from the focus in all directions. **Seismic waves carry energy from an earthquake away from the focus, through Earth's interior, and across the surface.**

There are three categories of seismic waves: P waves, S waves, and surface waves. **P waves** compress and expand the ground like an accordion. **S waves** vibrate from side to side and up and down. When P waves and S waves reach the surface, some become surface waves. **Surface waves** move more slowly than P waves and S waves, but they can produce severe ground movements.

There are three commonly used methods of measuring earthquakes: the Mercalli scale, the Richter scale, and the moment magnitude scale. The **Mercalli scale** was developed to rate earthquakes according to the level of damage at a given place. An earthquake's **magnitude** is a number that geologists assign to an earthquake based on the earthquake's strength. The **Richter scale** is a rating of an earthquake's magnitude based on the size of the earthquake's seismic waves. The seismic waves are measured by a **seismograph.** A seismograph is an instrument that records and measures seismic waves. Geologists today often use the **moment magnitude scale,** a rating system that estimates the total energy released by an earthquake. An earthquake's magnitude tells geologists how much stored energy was released by the earthquake. The effects of an earthquake increase with magnitude.

Geologists use seismic waves to locate an earthquake's epicenter. When an earthquake strikes, P waves arrive at a seismograph first and S waves next. The farther away the epicenter is, the greater the difference between the two arrival times. This time difference tells scientists how far from the seismograph the epicenter is. The scientists then use the information from three different seismograph stations to plot circles on a map. Each circle shows the distance from one seismograph station to all the points where the epicenter could be located. The single point where the three circles intersect is the location of the earthquake's epicenter.

5-3 Monitoring Earthquakes

Many societies have used technology to try to determine when and where earthquakes have occurred. During the late 1800s, scientists developed seismographs that were much more sensitive and accurate than any earlier devices. A simple seismograph can consist of a heavy weight attached to a frame by a spring or wire. A pen connected to the weight rests its point on a drum that can rotate. As the drum rotates slowly, the pen draws a straight line on paper that is wrapped tightly around the drum. **Seismic waves cause the seismograph's drum to vibrate. But the suspended weight with the pen attached moves very little. Therefore, the pen stays in place and records the drum's vibrations.** The pattern of lines, called a **seismogram,** is the record of an earthquake's seismic waves produced by a seismograph.

To monitor faults, geologists have developed instruments to measure changes in elevation, tilting of the land surface, and ground movements along faults. A tiltmeter measures tilting or raising of the ground. A creep meter uses a wire stretched across a fault to measure horizontal movement of the ground. A laser-ranging device uses a laser beam to detect horizontal fault movements. A network of Earth-orbiting satellites called GPS (global positioning system) helps scientists monitor changes in elevation and tilt of the land as well as horizontal movement along faults.

Seismographs and fault-monitoring devices provide data used to map faults and detect changes along faults. Geologists are also trying to use these data to develop a method of predicting earthquakes. Geologists use the data from seismic waves to map faults, which are often hidden by a thick layer of rock or soil. This practice helps geologists determine the earthquake risk for an area. Geologists use fault-monitoring devices to study the types of movement that occur along faults. **Friction** is the force that opposes the motion of one surface as it moves across another surface. Where friction along a fault is low, the rocks on both sides of the fault slide by each other without much sticking. Stress does not build up, and large earthquakes are unlikely. Where friction is high, the rocks lock together. Stress builds up until an earthquake occurs. Even with data from many sources, geologists can't predict when and where a quake will strike.

5-4 Earthquake Safety

Geologists can determine earthquake risk by locating where faults are active, where past earthquakes have occurred, and where the most damage was caused. In the United States, the risk is highest along the Pacific Coast in the states of California, Washington, and Alaska. The eastern United States generally has a low risk of earthquakes. Geologists use Mercalli scale data to produce intensity maps. These maps show the areas most likely to suffer serious earthquake damage. Geologists also study where earthquakes have occurred in the past to help determine earthquake risk.

Causes of earthquake damage include shaking, liquefaction, aftershocks, and tsunamis. The shaking produced by seismic waves can trigger landslides or avalanches. The types of rock and soil determine where and how much the ground shakes. **Liquefaction** occurs when an earthquake's violent shaking suddenly turns loose, soft soil into liquid mud. As the ground gives way, buildings sink and pull apart. Sometimes, buildings weakened by an earthquake collapse during an aftershock. An **aftershock** is an earthquake that occurs after a larger earthquake in the same area.

When an earthquake jolts the ocean floor, plate movement causes the ocean floor to rise slightly and push water out of its way. The water displaced by the earthquake may form a large wave called a **tsunami.** A tsunami spreads out from an earthquake's epicenter and speeds across the ocean. The height of the wave is low in the open ocean, but the wave grows into a mountain of water as the tsunami approaches shallow water.

The main danger from earthquake strikes is from falling objects and flying glass. **The best way to protect yourself is to drop, cover, and hold.** To prepare for an earthquake, store in a convenient location an earthquake kit containing canned food, water, and first aid supplies.

Most earthquake-related deaths and injuries result from damage to buildings or other structures. **To reduce earthquake damage, new buildings must be made stronger and more flexible. Older buildings may be modified to withstand stronger quakes.** The way in which a building is constructed determines whether it can withstand an earthquake. A **base-isolated building** is designed to reduce the amount of energy that reaches the building during an earthquake. During a quake, the building moves gently back and forth without any violent shaking.

Earthquakes can cause fire and flooding when gas pipes and water mains break. Flexible joints and automatic shut-off valves can be installed to prevent breaking and to cut off gas and water flow.