Earthquakes

The movement of Earth's plates creates enormous forces that squeeze or pull the rock in the crust as if it were a candy bar. These forces are examples of **stress**, a force that acts on rock to change its shape or volume. (A rock's volume is the amount of space the rock takes up.) Because stress is a force, it adds energy to the rock. The energy is stored in the rock until the rock changes shape or breaks.

If you try to break a carmel candy bar in two, it may only bend and stretch at first. Like a candy bar, many types of rock can bend or fold. But beyond a certain limit, even these rocks will break.

Types of Stress

Three different kinds of stress can occur in the crust -- tension, compression, and shearing. **Tension, compression, and shearing work over millions of years to change the shape and volume of rock.** These forces cause some rocks to become brittle and snap. Other rocks bend slowly, like road tar softened by the heat of the sun.

Most changes in the crust occur so slowly that they cannot be observed directly. But if you could speed up time so a billion years passed by in minutes, you could see the crust bend, stretch, break, tilt, fold, and slide. The slow shift of Earth's plates causes these changes.

Tension The stress force called **tension** pulls on the crust, stretching rock so that it becomes thinner in the middle. The effect of tension on rock is somewhat like pulling apart a piece of warm bubble gum. Tension occurs where two plates are moving apart.

Compression The stress force called **compression** squeezes rock until it folds or breaks. One plate pushing against another can compress rock like a giant trash compactor.

Shearing Stress that pushes a mass of rock in two opposite direction is called **shearing**. Shearing can cause rock to break and slip apart or to change its shape.

Kinds of Faults

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. The rocks on both sides of a fault can move up or down or sideways. **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**

Normal Faults
Tension in Earth's crust pulls rock apart, causing **normal faults.** In a normal fault, the fault is at an angle, so 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.** When movement occurs along a normal fault, the hanging wall slips downward. Normal fault occur where plates diverge, or pull apart.

Reverse Faults
In places where the rock of the crust is pushed together, compression causes reverse faults to form. A **reverse fault** has the same structure as a normal fault, but the blocks move in the opposite direction. As in a normal fault, one side of a reverse fault lies at an angle above the other side. The rock forming the hanging wall of a reverse fault slides up and over the footwall. Movement along reverse faults produced part of the northern Rocky Mountains in the western United States and Canada.

Strike-Slip Faults
In places where plates move past each other, 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. A strike-slip fault that forms the boundary between two plates is called a transform boundary. The San Andrea's fault in California is an example of a strike-slip fault that is a transform boundary.

Changing Earth's Surface
The forces produced by the movement of Earth's plates can fold, stretch, and uplift the crust. **Over millions of years, the forces of plate movement can change a flat plain into land-forms such as anticlines and synclines, folded mountains, fault-block mountains and plateaus.**

Folding Earth's crust
Sometimes plate movement causes the crust to fold. Have you ever skidded on a rug that wrinkled up as your feet pushed it across the floor? Much as the rug wrinkles, rock stressed by compression may bend without breaking. Folds are bends in rock that form when compression shortens and thickens part of Earth's crust. Individual folds can be only a few centimeters across or hundreds of kilometers wide. You can often see small folds in the rock exposed where a highway has been cut through a hillside.

Geologists use the terms anticline and syncline to describe upward and downward folds in rock. 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 Earth' s surface where compression forces have folded the crust. The central Appalachian Mountains in

Pennsylvania are folded mountains made up of parallel ridges (anticlines) and valleys (synclines).

The collision of two plates can cause compression and folding of the crust over a wide area. Some of the world's largest mountain ranges, including the Himalayas in Asia and the Alps in Europe, formed when pieces of the crust folded during the collision of two plates.

Stretching Earth's Crust

When two normal faults uplift a block of rock, a fault-block mountain forms. Where two plates move away from each other, tension forces create many normal faults. When two of these normal faults form parallel to each other, a block of rock is left lying between them. As the hanging wall of each normal fault slips downward, the block in between moves upward, forming a fault-block mountain.

Uplifting Earth's Crust

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. Some plateaus form when forces in Earth's crust push up a large, flat block of rock. Like a fancy sandwich, a plateau consists of many different flat layers, and is wider than it is tall.

The "four Corners" region of Arizona, Utah, Colorado, and New Mexico is an example of this uplifting.

Earthquakes and Seismic Waves

Earth is never still. Every day, worldwide, there are more than 8,000 earthquakes. An **earthquake** is the shaking and trembling that results from the movement of rock beneath Earth's surface. Most earthquakes are too small to notice. But a large earthquake can produce dramatic changes in Earth's surface and cause great damage.

The forces of plate movement cause earthquakes. Plate movements produce stress in Earth's crust, adding energy to rock and forming faults. Stress increases along a fault until the rock breaks. An earthquake begins. In seconds, the earthquake releases an enormous amount of stored energy.

Most earthquakes begin in the lithosphere within about 100 kilometers of Earth's surface. The **focus** is the area beneath Earth's surface where rock that is under stress breaks, triggering an earthquake. The point on the surface directly above the focus is called the **epicenter.**

Types of Seismic Waves

Like a pebble thrown into a pond, an earthquake produces vibrations called waves. These waves carry energy as they travel outward. During an earthquake, seismic waves race out from the focus in all directions. Seismic waves are vibrations that travel through Earth carrying the energy released during an earthquake. The seismic waves move like ripples in a pond.

Seismic waves carry energy from an earthquake away from the focus, through Earth's interior, and across the surface.

There are three main categories of seismic waves: P waves, S waves, and surface waves. An earthquake sends out two types of waves from its focus: P waves and S waves. When these waves reach Earth's surface at the epicenter, surface waves develop.

P waves

The first waves to arrive are primary waves, or P waves. **P waves** are seismic waves that compress and expand the ground like an accordion. P waves cause buildings to contract and expand.

S waves

After P waves come secondary waves, or S waves. **S waves** are seismic waves that vibrate from side to side as well as up and down. They shake the ground back and forth. When S waves reach the surface, they shake structures violently. Unlike P waves, which travel through both solids and liquids, S waves cannot move through liquids.

Surface Waves

When P waves and S waves reach the surface, some of them become surface waves. **Surface waves** move more slowly than P waves and S waves, but they produce the most severe ground movements. Some surface waves shake buildings from side to side.

Measuring Earthquakes

When an earthquake occurs, people want to know "How big was the quake?" and "Where was it centered?" When geologists want to know the size of an earthquake, they must consider many factors. As a result, there are at least 20 different measures for rating earthquakes, each with its strengths and shortcomings. **Three commonly used methods of measuring earthquakes are the Mercalli scale, the Richter scale and the moment magnitude scale.**

The Mercalli Scale

The **Mercalli scale** was developed to rate earthquakes according to the amount of damage at a given place. The 12 steps of the Mercalli scale describe an earthquake's effects. The same earthquake can have different Mercalli ratings because it causes different amounts of ground motion at different locations.

The Richter Scale

An earthquake's **magnitude** is a number that geologists assign to an earthquake based on the earthquake's strength. Geologists determine magnitude by measuring the seismic waves and fault movement that occur during an earthquake. 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. The Richter scale provides accurate measurements for small, nearby earthquakes. But it does not work well for large or distant earthquakes.

The Moment Magnitude Scale

Geologists today often use the **moment magnitude scale**, a rating system that estimates the total energy released by an earthquake. The moment magnitude scale can be used to rate earthquakes of all sizes, near or far. You may hear news reports that mention the Richter scale. But the number they quote is almost always the moment magnitude for that earthquake.

To rate an earthquake on the moment magnitude scale, geologists first study data from seismographs. The data show what kinds of seismic waves the earthquake produced and how strong they were. The data also help geologists infer how much movement occurred along the fault and the strength of the rocks that broke when the fault slipped. Geologists use all this information to rate the quake on the moment magnitude scale.

Comparing Magnitudes

An earthquake's magnitude tells geologists how much energy was released by the earthquake. Each one-point increase in magnitude represents the release of roughly 32 times more energy. For example, a magnitude 6 quake releases 32 times as much energy as a magnitude 5 quake, and about 1,000 times as much as a magnitude 4 quake.

The effects of an earthquake increase with magnitude. People scarcely notice earthquakes with magnitudes below 3. Earthquakes with a magnitude below 5 are small and cause little damage. Those with a magnitude between 5 and 6 can cause moderate damage. Fortunately, the most powerful earthquakes, with a magnitude of 8 or above, are rare. During the twentieth century, only two earthquakes measured above 9 on the moment magnitude scale. These earthquakes occurred in Chile in 1960 and in Alaska in 1964.

Locating the Epicenter

Geologists use seismic waves to locate an earthquake's epicenter.

Seismic waves travel at different speeds. P waves arrive at a seismography first, with S waves following close behind. To tell how far the epicenter is from the seismograph, scientists measure the difference between the arrival times of the P waves and S waves. The farther away an earthquake is, the greater the time between the arrival of the P waves and the S waves.

Geologists then draw at least three circles using data from different seismographs set up at stations all over the world. The center of each circle is a particular seismograph's location. The radius of each circle is the distance from that seismography to the epicenter. The point where the three circles intersect is the location of the epicenter.

Using Seismographic Data
Scientists collect and use seismographic data in a variety of ways. **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.**

Mapping Faults
Faults are often hidden by a thick layer of rock or soil. When Seismic waves encounter a fault, the waves' speed and direction change slightly. Networks of seismographs can measure these changes. Geologists then use the data to map the fault's length and depth. Knowing the location of hidden faults helps scientists determine the earthquake risk for the area.

Monitoring Changes Along Faults
Geologists study the types of movement that occur along faults. How rocks move along a fault depends on how much friction there is between the sides of the fault. **Friction** is the force that opposes the motion of one surface as it moves across another surface. Friction exists because surfaces are not perfectly smooth.

Where friction along a fault is low, the rocks on both sides of the fault slide by each other without much sticking. Therefore stress does not build up, and big earthquakes are unlikely. Where friction is moderate, the sides of the fault jam together. Then from time to time they jerk free, producing small earthquakes. Where friction is high, the rocks lock together and do not move. In this case, stress increases until it is strong enough to overcome the friction force.

Trying to Predict Earthquakes
Even with data from many sources, geologists can't predict when and where a quake will strike. Usually, stress along a fault increases until an earthquake occurs. Yet sometimes stress builds up along a fault, but an earthquake fails to occur. Or, one or more earthquakes may relieve stress along another part of the fault. Exactly what will happen remains uncertain.

Although geologists cannot predict earthquakes, seismographic data in the minutes before an earthquake may contain clues that a quake is about the happen. Scientists are trying to develop an early warning system using such clues. Even a few minutes' warning might allow time for people to evacuate buildings or protect themselves.

The problem of predicting earthquakes is one of many scientific questions that remain unsolved.

How Earthquakes Cause Damage
When a major earthquake strikes, it can cause great damage. **Causes of earthquake damage include shaking, liquefaction, aftershocks, and tsunamis.**

Shaking
The shaking produced by seismic waves can trigger landslides or avalanches. Shaking can also damage or destroy buildings and bridges, topple utility poles, and fracture gas and water mains. S waves, with their side to side and up and down movement, can cause severe damage near the epicenter. As S waves sweep through the ground, they can put enough stress on buildings to tear them apart.

The types of rock and soil determine where and how much the ground shakes. The most violent shaking may occur kilometers away from the epicenter. Loose soil shakes more violently than the surrounding rock. This means a house built on sandy soil will shake more than a house built on solid rock.

Liquefaction
In 1964, when a powerful earthquake roared through Anchorage, Alaska, cracks opened in the ground. Some of the cracks were 9 meters wide. The cracks were created by liquefaction. **Liquefaction** occurs when an earthquake's violent shaking suddenly turns loose, soft soil into liquid mud. Liquefaction is likely where the soil is full of moisture. As the ground gives way, buildings sink and pull apart.

Aftershocks
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. Aftershocks may strike hours, days, or even months later.

Tsunamis
When an earthquake jolts the ocean floor, plate movements 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. In the open ocean, the height of the wave is low. As a tsunami approaches shallow water, the wave grows into a mountain of water.

Steps to Earthquake Safety

What should you do if an earthquake strikes? The main danger is from falling objects and flying glass. **The best way to protect yourself is to drop, cover, and hold.**

If you are indoors when a quake strikes, crouch beneath a sturdy table or desk and hold on to it. If no desk or table is available, crouch against an inner wall, away from the outside of a building, and cover your head and neck with your arms. Avoid windows, mirrors, wall hangings, and furniture that might topple.

If you are outdoors, move to an open area such as a playground. Avoid vehicles, power lines, trees, and buildings. Sit down to avoid being thrown down.

After a quake, water and power supplies may fail, food stores may be closed, and travel may be difficult. People may have to wait days for these services to be restored. To prepare, an earthquake kit containing canned food, water and first aid supplies should be stored where it is easy to reach.