INTRODUCTION

Enormous slabs of lithosphere move unevenly over the planet’s spherical surface, resulting in earthquakes. This chapter deals with two types of geological activity that occur because of plate tectonics: mountain building and earthquakes. First, we will consider what can happen to rocks when they are exposed to stress.

CAUSES AND TYPES OF STRESS

Stress is the force applied to an object. In geology, stress is the force per unit area that is placed on a rock. Four types of stresses act on materials.

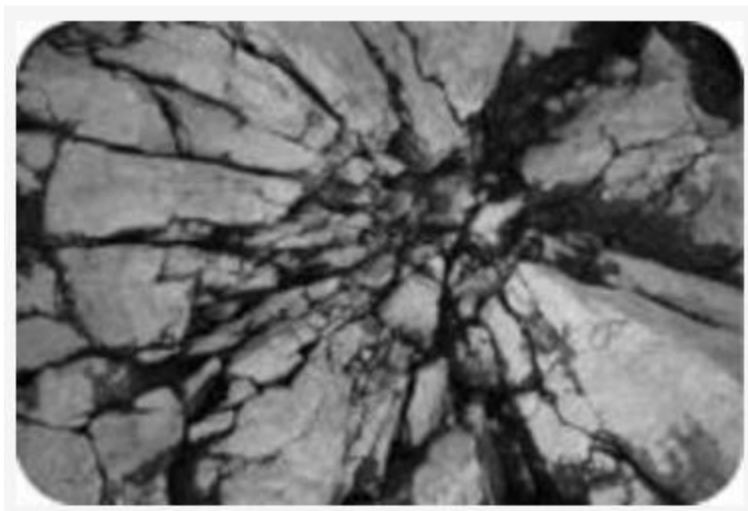


Figure 1. Stress caused these rocks to fracture.

- A deeply buried rock is pushed down by the weight of all the material above it. Since the rock cannot move, it cannot deform. This is called **confining stress.**
- **Compression** squeezes rocks together, causing rocks to fold or fracture (break) (figure 1). Compression is the most common stress at convergent plate boundaries.
- Rocks that are pulled apart are under **tension**. Rocks under tension lengthen or break apart. Tension is the major type of stress at divergent plate boundaries.
- When forces are parallel but moving in opposite directions, the stress is called **shear** (figure 2). Shear stress is the most common stress at transform plate boundaries.

When stress causes a material to change shape, it has undergone **strain** or **deformation.** Deformed rocks are common in geologically active areas.

Figure 2. Shearing in rocks. The white quartz vein has been elongated by shear.

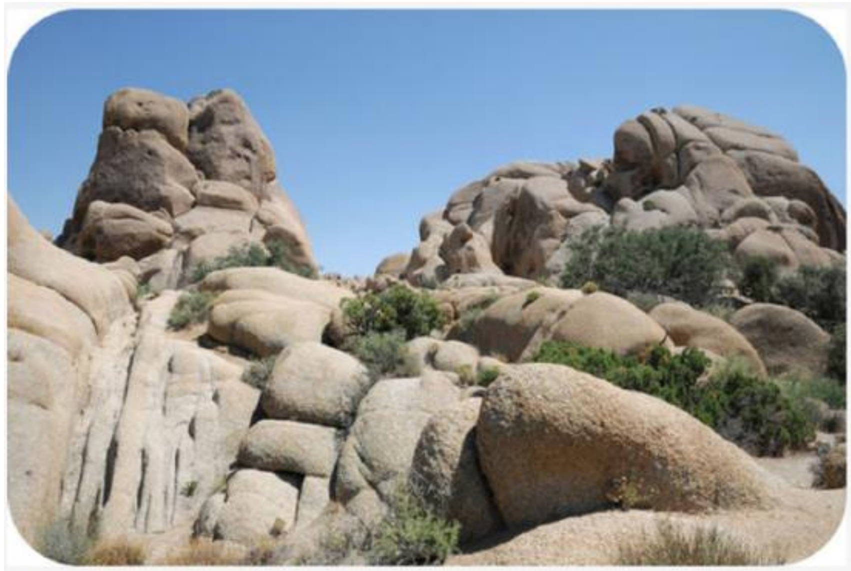
A rock's response to stress depends on the rock type, the surrounding temperature, and pressure conditions the rock is under, the length of time the rock is under stress, and the type of stress.

Rocks have three possible responses to increasing stress (illustrated in figure 3):

- **elastic deformation**: the rock returns to its original shape when the stress is removed.
- **plastic deformation**: the rock does not return to its original shape when the stress is removed.
- **fracture**: the rock breaks.

Faults

A rock under enough stress will fracture. If there is no movement on either side of a fracture, the fracture is called a **joint**, as shown in (figure 10).



If the blocks of rock on one or both sides of a fracture move, the fracture is called a **fault** (figure 11). Sudden motions along faults cause rocks to break and move suddenly. The energy released is an earthquake.

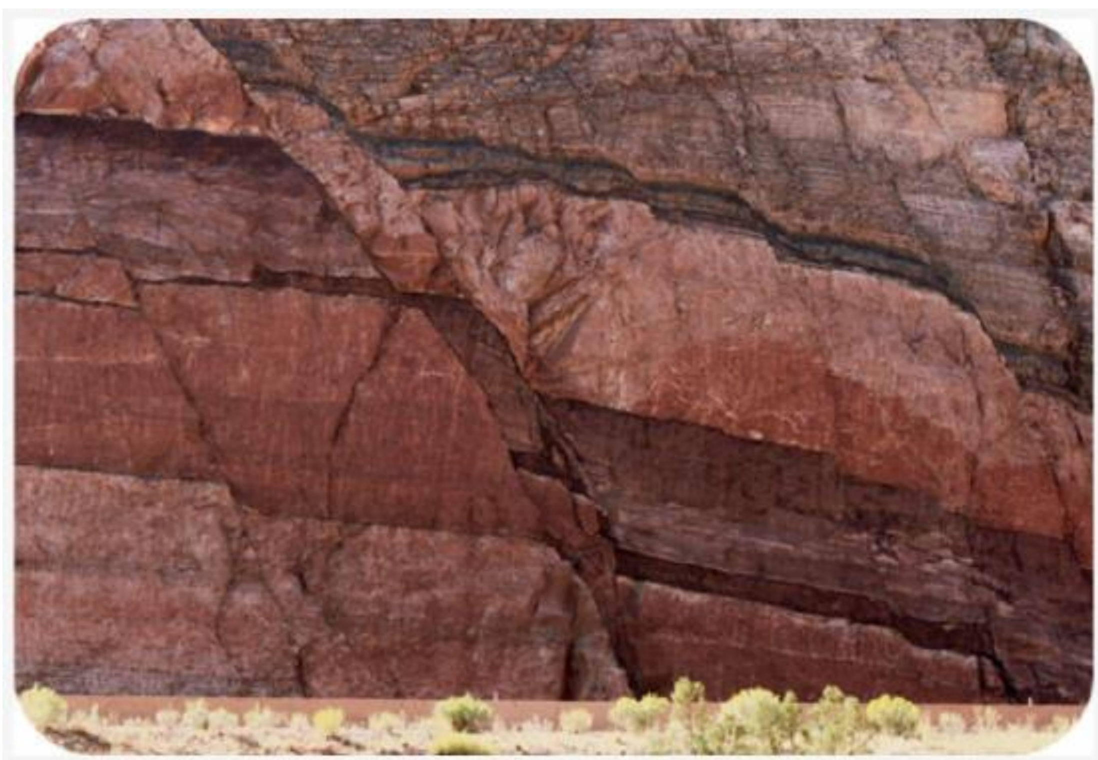


Figure 11. Faults are easy to recognize as they cut across bedded rocks.

Slip is the distance rocks move along a fault. Slip can be up or down the fault plane. Slip is relative, because there is usually no way to know whether both sides moved or only one. Faults lie at an angle to the horizontal surface of the Earth. That angle is called the fault's **dip.** The dip defines which of two basic types a fault is. If the fault's dip is inclined relative to the horizontal, the fault is a **dip-slip fault** (figure 12). There are two types of dip-slip faults. In **normal faults**, the hanging wall drops down relative to the footwall. In **reverse faults**, the footwall drops down relative to the hanging wall.

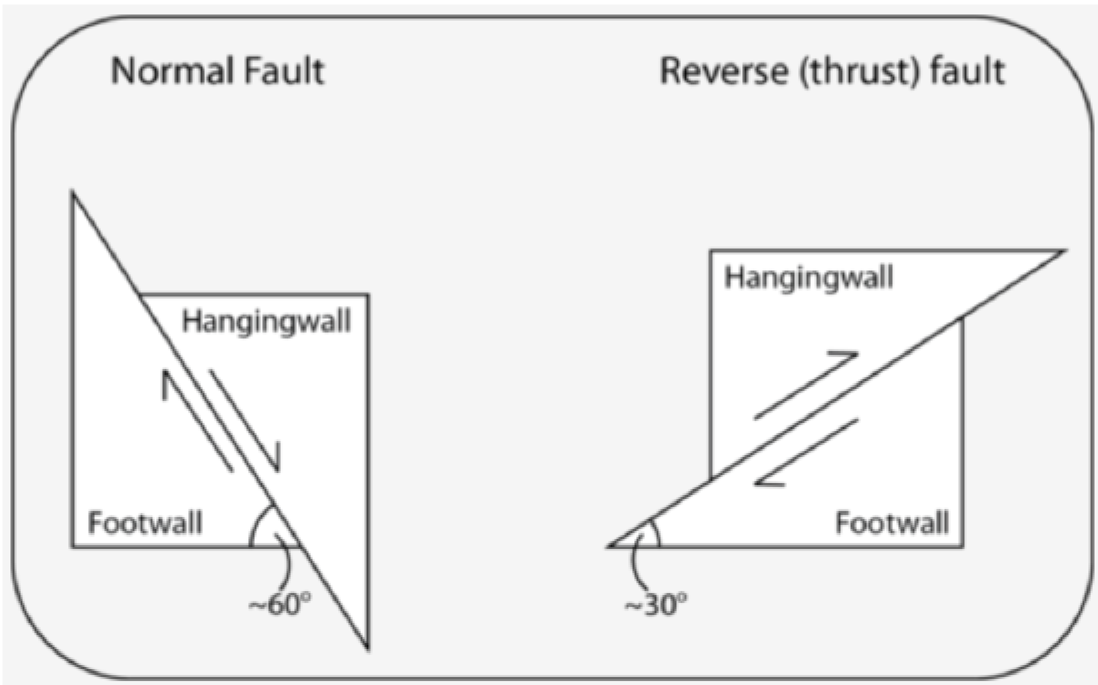


Figure 12. This diagram illustrates the two types of dip-slip faults: normal faults and reverse faults. Imagine miners extracting a resource along a fault. The hanging wall is where miners would have hung their lanterns. The footwall is where they would have walked.

Here is an animation of a normal fault.

A **thrust fault** is a type of reverse fault in which the fault plane angle is nearly horizontal. Rocks can slip many miles along thrust faults (**Figure** 13).

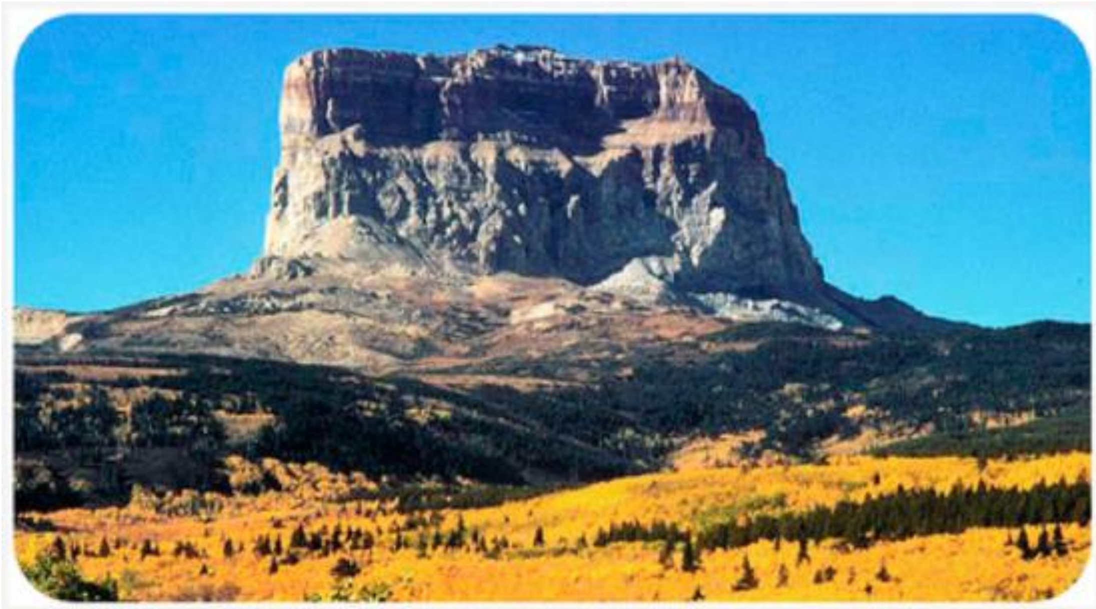


Figure 13. At Chief Mountain in Montana, the upper rocks at the Lewis Overthrust are more than 1 billion years older than the lower rocks.

Here is an animation of a thrust fault.

Normal faults can be huge. They are responsible for uplifting mountain ranges in regions experiencing tensional stress (figure 14).

Figure 14. The Teton Range in Wyoming rose up along a normal fault.

A **strike-slip fault** is a dip-slip fault in which the dip of the fault plane is vertical. Strike-slip faults result from shear stresses (figure 15).

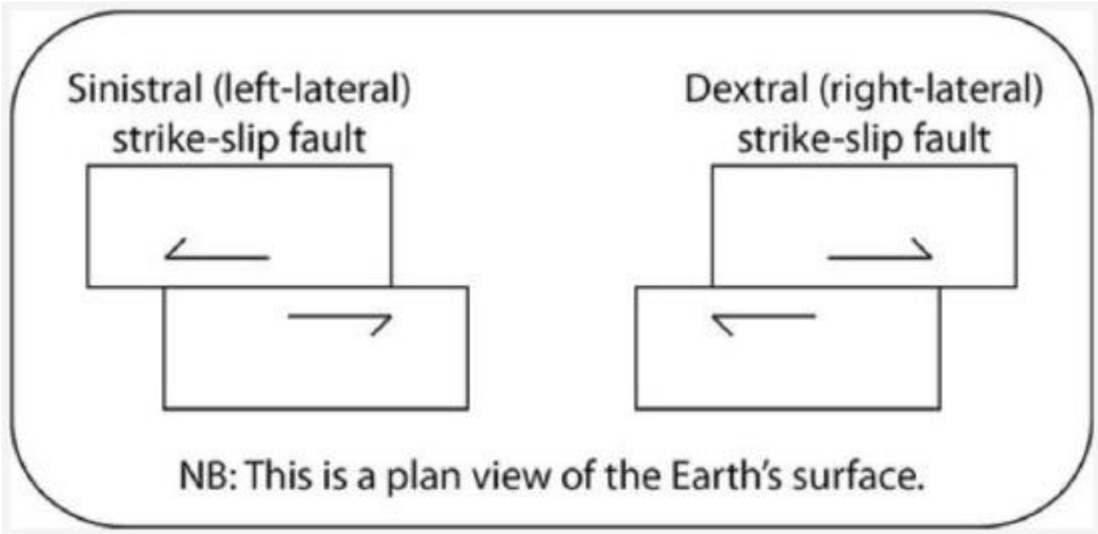


Figure 15. Imagine placing one foot on either side of a strike-slip fault. One block moves toward you. If that block moves toward your right foot, the fault is a right-lateral strike-slip fault; if that block moves toward your left foot, the fault is a left-lateral strike-slip fault.

California's San Andreas Fault is the world's most famous strike-slip fault. It is a right-lateral strike slip fault (figure 16).

Figure 16. The San Andreas is a massive transform fault.

Here is a strike-slip fault animation.

People sometimes say that California will fall into the ocean someday, which is not true. This animation shows movement on the San Andreas into the future.

STRESS AND MOUNTAIN BUILDING

Two converging continental plates smash upwards to create mountain ranges (figure 17). Stresses from this **uplift** cause folds, reverse faults, and thrust faults, which allow the crust to rise upwards.

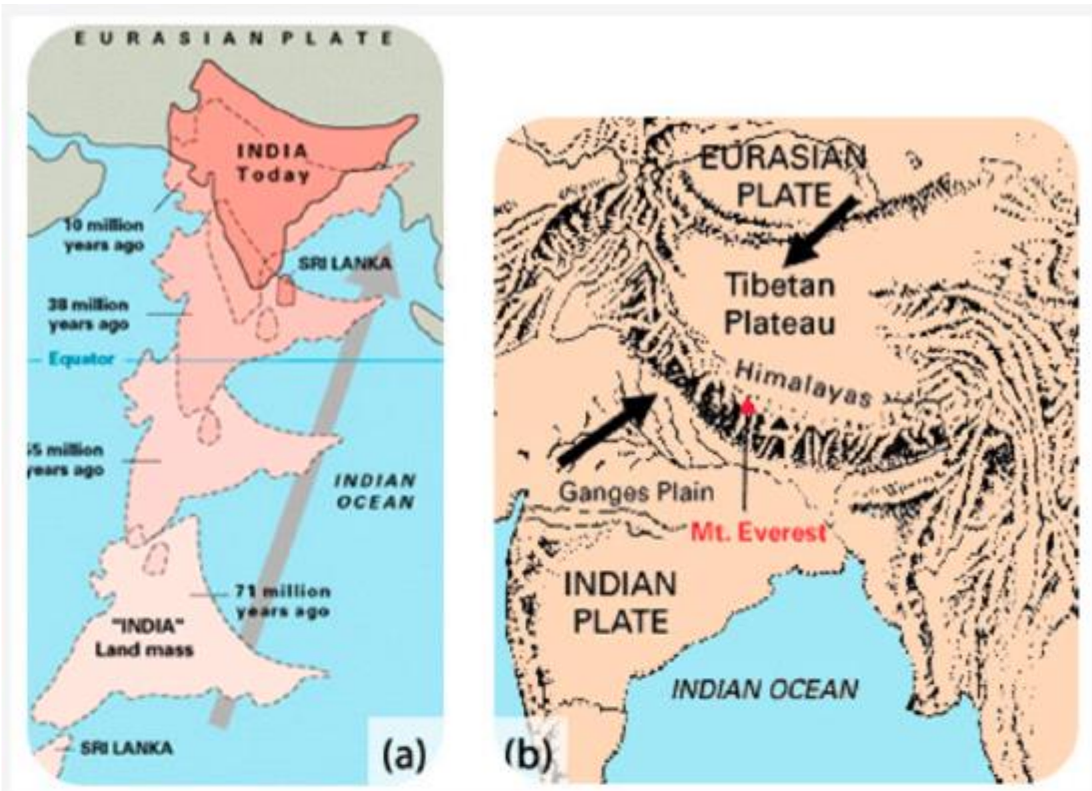


Figure 17. (a) The world's highest mountain range, the Himalayas, is growing from the collision between the Indian and the Eurasian plates. (b) The crumpling of the Indian and Eurasian plates of continental crust creates the Himalayas.

Subduction of oceanic lithosphere at convergent plate boundaries also builds mountain ranges (figure 18).

Figure 18. The Andes Mountains are a chain of continental arc volcanoes that build up as the Nazca Plate subducts beneath the South American Plate.

When tensional stresses pull crust apart, it breaks into blocks that slide up and drop down along normal faults. The result is alternating mountains and valleys, known as a basin-and-range (figure 19).

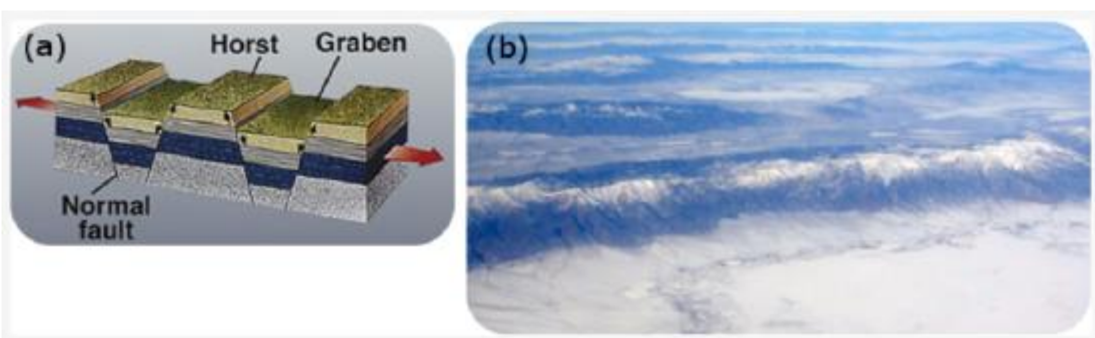


Figure 19. (a) In basin-and-range, some blocks are uplifted to form ranges, known as horsts, and some are down-dropped to form basins, known as grabens. (b) Mountains in Nevada are of classic basin-and-range form.