### **Chapter 15 Landforms**

### **Stress and Strain**

**Stress** is the force exerted per unit area, and strain is a material’s response to that force. **Strain** is deformation caused by stress. Strain in rocks can be represented as a change in rock volume and rock shape, as well as fracturing the rock. There are three types of stress: tensional, compressional, and shear. **Tensional stress** involves pulling something apart in opposite directions, stretching and thinning the material. **Compressional stress** involves things coming together and pushing on each other, thickening the material. **Shear stress** involves transverse movement of the material moving past each other, like a scissor. (9 Crustal Deformation and Earthquakes – An Introduction to Geology, n.d.)

### **Deformation**

When rocks are stressed, the resulting strain can be elastic, ductile, or brittle, called **deformation**. **Elastic deformation** is strain that is reversible after the stress is released. For example, when compressing a spring, it elastically returns to its original shape after releasing it.

479

**Ductile deformation** occurs when enough stress is applied to a material that the changes are permanent, and the material is no longer able to revert to its original shape. For example, if a spring is stretched too far, it can be permanently bent out of shape. Note that concepts related to ductile deformation apply at the visible (macro) scale, and deformation is more complicated at a microscopic scale. Research of plastic deformation, which touches on the atomic scale, is beyond the scope of introductory texts. The yield point is the amount of strain at which elastic deformation is surpassed, and permanent deformation is measurable. Brittle deformation is when the material undergoes another critical point of no return. When sufficient stress to pass that point occurs, it fails and fractures. (9 Crustal Deformation and Earthquakes – An Introduction to Geology, n.d.)

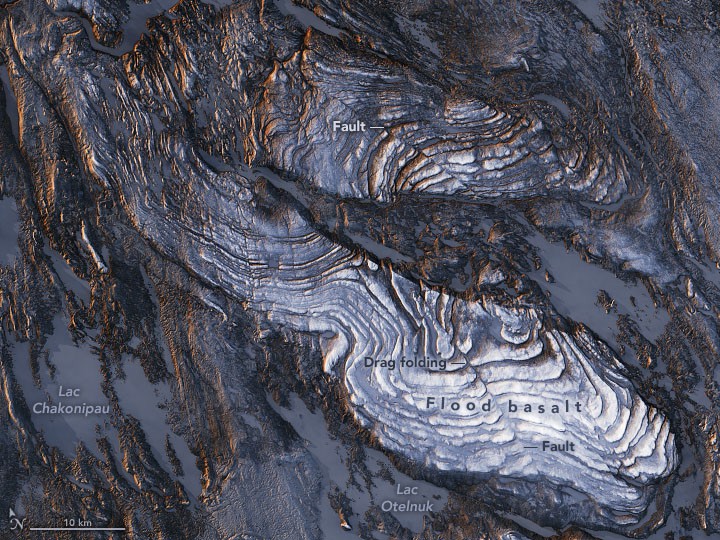


Figure 15.1 “Deformation” by NASA’s Earth Observatory is licensed under Public Domain.

480

Important factors that influence how a rock will undergo elastic, ductile, or brittle deformation is the intensity of the applied stress, time, temperature, confining pressure, pore pressure, strain rate, and rock strength. **Pore pressure** is the pressure exerted by fluids inside of the open spaces (pores) inside of a rock or sediment.

**Strain rate** is how quickly material is deformed. **Rock strength** is a measure of how readily a rock will respond to stress. Shale has low strength, and granite has high strength.

Removing heat, such as decreasing temperature, makes the material more rigid. Likewise, heating materials make them more ductile.

Heating glass makes it capable of bending and stretching. Regarding strain response, it is easier to bend a piece of wood slowly without breaking it.

Sedimentary rocks are essential for deciphering the geologic history of a region because they follow specific rules. First, sedimentary rocks are formed with the oldest layers on the bottom and the youngest on top. Second, sediments are deposited horizontally, so sedimentary rock layers are originally horizontal, as are some volcanic rocks, such as ash falls. Finally, sedimentary rock layers that are not horizontal are deformed in some manner – often looking like they are tiling into the earth. Scientists can trace the deformation a rock has experienced by seeing how it differs from its original horizontal, oldest-on-bottom position. This deformation produces geologic structures such as folds, joints, and faults that are caused by stresses.

481

### **Stress and Mountain Building**

The sheer power and strength of two or more converging continental plates smash upwards that create mountain ranges. Stresses from geologic uplift cause folds, reverse faults, and thrust faults, which allow the crust to rise upwards. The subduction of oceanic lithosphere at convergent plate boundaries also builds mountain ranges. 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 15.2 “Folding” is licensed under Creative Commons Attribution-ShareAlike 4.0 International.

###### Folds

Geologic folds are layers of rock that are curved or bent by **ductile deformation**. Terms involved with folds include axis, which is the line along which the bending occurred, and limbs, which are the dipping beds that make up the sides of the folds. Compressional forces most commonly form folds at depth, where hotter

482

temperatures and higher confining pressures allow ductile deformation to occur.

**Folds** are described by the orientation of their axes, axial planes, and limbs. They are made up of two or more dipping beds, dipping in opposite directions, which come together along a line, called the axis. Each set of dipping beds is known as a **fold limb**. The plane that splits the fold into two halves is known as the **axial plane**. (9 Crustal Deformation and Earthquakes – An Introduction to Geology, n.d.)

**Symmetrical folds** have mirrored limbs across their axial planes. The limbs of a symmetrical fold are inclined at the same, but opposite, angle indicating equal compression on both sides of the fold. **Asymmetrical folds** have dipping, non-vertical axial planes, where limbs dip into the ground at different angles. **Recumbent folds** are very tight folds with limbs compressed near the axial planes and are generally horizontal, and overturned folds are where the angles on both limbs dip in the same direction. The fold axis is where the axial plane intersects the strata involved in the fold. A horizontal fold has a horizontal fold axis. When the axis of the fold plunges into the ground, the fold is called a **plunging fold**.

483



Figure 15.3 “Rock Folding” by Colin Park is licensed under Creative Commons Attribution-ShareAlike 4.0 International.

###### Anticline

**Anticlines** are arch-like (“A”-shaped) folds, with downward curving limbs that have beds that dip away from the central axis of the fold. They are convex-upward in shape. In anticlines, the oldest rock strata are in the center of the fold along the axis, and the younger beds are on the outside. An antiform has the same shape as an anticline, but in antiforms, the relative ages of the beds in the fold cannot be determined. Oil geologists have an interest in anticlines because they can form oil traps, where oil migrates up along the limbs of the fold and accumulates in the high point along the axis of the fold. (9 Crustal Deformation and Earthquakes – An Introduction to Geology, n.d.)

484



Erdölquelle

Erdgas

Undurchlässiger

Schieferton

Erdöl

Poröses Speichergestein

Ausgangsgestein

Figure 15.4 “Anticline Trap” is licensed under the Creative Commons Attribution-Share Alike 3.0 Unported.

###### Syncline

**Synclines** are trough-like (“U” shaped), upward-curving folds that have beds that dip in towards the fold’s central axis. They are concave-upward in shape. In synclines, the older rock is on the outside of the fold, and the youngest rock is on the inside of the fold along the axis. A synform has the shape of a syncline but, like an antiform, does not distinguish between the ages of the units.

485

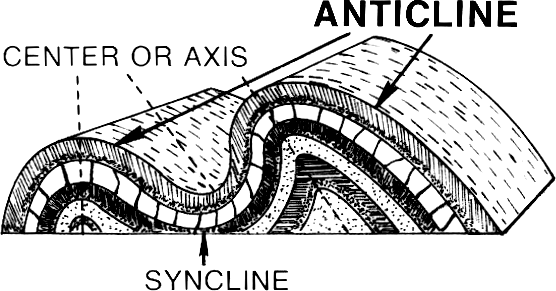


Figure 15.5 “Anticline” by Pearson Scott Foresman is licensed under Public Domain.

###### Monocline

**Monoclines** are step-like folds, in which flat rocks are upwarped or downwarped, then continue flat. They are relatively common on the Colorado Plateau, where they form “reefs,” ridges that act as topographic barriers and should not be confused with ocean reefs. Capitol Reef National Park is an example of a monocline in Utah. Monoclines can be caused by bending of shallower sedimentary strata as faults grow below them. These faults are commonly called “blind faults” because they end before reaching the surface and can be either normal or reverse faults. (9 Crustal Deformation and Earthquakes – An Introduction to Geology, n.d.)

###### Dome

A **dome** is a symmetrical to semi-symmetrical upwarping of rock beds, like in Utah’s San Rafael Swell. Domes have a shape like an

486

inverted bowl, similar to domes on buildings, like the Capitol Building. Some domes are formed from compressional forces, while other domes are formed from underlying igneous intrusions, by salt diapirs, or even impacts, like upheaval dome in Canyonlands National Park. (9 Crustal Deformation and Earthquakes – An Introduction to Geology, n.d.)

###### Basin

A **basin** is the inverse of a dome. The basin is when rock forms a bowl-shaped depression. The Uinta Basin is an example of a basin in Utah. Technically, geologists refer to rocks folded into a bowl- shape as structural basins. Sometimes structural basins can also be sedimentary basins in which large quantities of sediment accumulate over time. Sedimentary basins can form as a result of folding but are much more commonly produced in mountain building, between mountain blocks or via faulting. Regardless of the cause, as the basin sinks, called **subsidence**, it can accumulate even more sediment as the sediment’s weight causes more subsidence in a positive-feedback loop. There are active sedimentary basins all over the world.

For mountain types refer to video 1



Video 15.1 Types of mountains and how they are formed

<https://www.youtube.com/watch?v=UaaWoqlv9no>

### **Creative Commons Attribution**

An Introduction to Geology by Chris Johnson, Matthew D. Affolter, Paul Inkenbrandt, Cam Mosher is licensed under CC BY- NC-SA 4.0

Natural Disasters and Human Impacts by R. Adam Dastrup, MA, GISP is licensed under CC BY-NC-SA 4.0

Physical Geology – 2nd Edition by Steven Earle is licensed under CC BY-NC-SA 4.0

Geology by Lumen Learning is licensed under CC BY-NC-SA 4.0

Earth Science by Lumen Learning is licensed under CC BY-NC-SA 4.0

488