Structural Geology Notes

Rock deforms when stresses experienced by the rock exceed the rock's strength.

Pressure is a system of forces that has the same magnitude (intensity) in all directions. A change in pressure applied to a (homogeneous, isotropic, elastic) spherical rubber ball would cause the ball to change its size/volume but not its shape. For example, an *increase* in pressure would cause the spherical ball to deform into a *smaller* sphere.

Differential stress is a system of forces that is not the same in all directions. The maximum compressive stress is always 90° from the minimum compressive stress. Applying a differential stress to a spherical rubber ball would cause the ball to change shape (into an ellipsoid of some sort) without necessarily changing its volume.

Under relatively low temperature/pressure conditions in Earth's upper crust, a rock subjected to a sufficiently large differential stress might develop fractures. In an extension fracture (a mode I fracture to an engineer), the fracture develops in a plane that includes the greatest compressive stress, and the two sides of the opening fracture (the *fracture faces*) move away from each other in the direction of the least compressive stress. See Figure 10.7 in the AGI/NAGT Laboratory Manual in Physical Geology for an illustration of an extension fracture.

A ***fault*** is a surface or zone along which there is shear displacement -- displacement parallel to the fault. The two blocks that are bounded by the fault move parallel to the fault surface, relative to each other.

There are many active faults (faults along which displacement has occurred in the past few hundred years and that can generate earthquakes today) and fault zones in the United States, including the San Andreas, San Jacinto, Whittier-Elsinore, Newport-Inglewood, Malibu Coast, Cucamonga, Santa Monica, Sierra Madre, Nacimiento, Hayward, Garlock, Wasatch, Genoa, Denali, and the faults of the Cascadia and Aleutian subduction zones. A great source of information on active faults in the US is provided by the US Geological Survey via their interactive "Quaternary Fault and Fold Database of the United States" (https://earthquake.usgs.gov/hazards/qfaults/).

The orientation of a geologic surface is described by geoscientists using ***strike and dip***. ***Strike*** is the azimuth (direction) of a horizontal line on the inclined surface. ***Dip*** can be thought of as the steepest path down an inclined surface, which is always perpendicular to strike. So a ball released on an inclined surface will tend to roll down the dip of that surface. The direction in which the ball rolls is the ***dip direction*** -- an azimuth that is always perpendicular to the strike azimuth. Dip directions range from 0° (north) through 90° (east), 180° (south), 270° (west) and back to north at 360° = 0°. The ***dip angle*** is the dihedral angle formed between the inclined surface and a horizontal plane -- it is the measure of how steep the inclined surface is, relative to a horizontal plane. Dip angles range from 0° for a horizontal plane to 90° for a vertical plane.

We use the orientation of a fault -- the strike and dip of the fault -- to help us categorize faults as dip-slip, strike-slip, or oblique-slip faults. Refer to Figure 10.11 in the AGI/NAGT Laboratory Manual in Physical Geology for an illustration of different types of faults.

- The relative motion of the two blocks separated by a ***dip-slip fault*** is parallel to the dip (dip vector) of the fault surface. The slip vector parallels the dip vector in a dip-slip fault.

  There are two general types of dip-slip fault, depending on whether the block above the fault surface (called the *hanging-wall block* because it hangs above the fault surface) moves down or up the fault surface, as observed relative to the block below the fault surface (the *footwall block*).

- A ***normal fault*** develops where the crust is being stretched/extended, causing the hanging-wall block to slide down the fault surface (see Fig. 10.11A in the AGI/NAGT Laboratory Manual in Physical Geology).
- A ***reverse fault*** develops where the crust is being shortened/compressed, causing the hanging-wall block to slide up the fault surface (see Fig. 10.11B in the AGI/NAGT Laboratory Manual in Physical Geology).

• The relative motion of the two blocks separated by a ***strike-slip fault*** is parallel to the strike of the fault surface (see Fig. 10.11C in the AGI/NAGT Laboratory Manual in Physical Geology). The slip vector parallels the strike vector.

There are two general types of strike-slip fault, depending on whether the block across the fault from an observer moves to the right or to the left.

- A ***right-lateral strike-slip fault*** is one in which the block on the other side the fault moves to the right relative to an observer (see Fig. 10.12 in the AGI/NAGT Laboratory Manual in Physical Geology).
- A ***left-lateral strike-slip fault*** is one in which the block on the other side the fault moves to the left relative to an observer.

• The relative motion of two blocks separated by an ***oblique-slip fault*** is parallel to the fault surface but is not parallel to either the strike or dip of the fault surface.

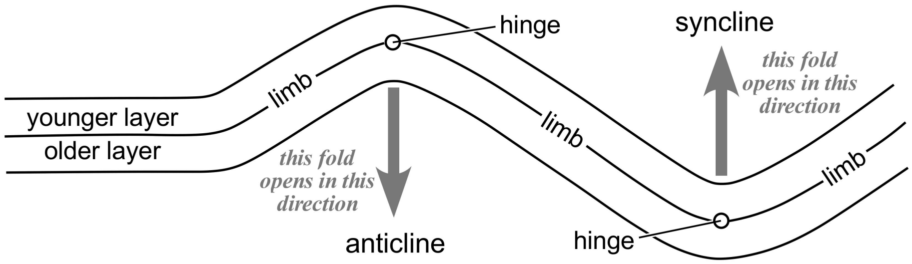
In some instances, application of a differential stress to a layered rock (an originally parallel sequence of sedimentary beds or a foliated metamorphic rock) causes the layers to be folded. There are a staggering number of terms related to folded rock, so we will keep it simple here. See Figs. 10.14-15 in the AGI/NAGT Laboratory Manual in Physical Geology for an illustration of some relevant fold terms.

The point along a fold where the surface is most tightly folded is called the ***hinge*** (or, in some cases, the ***axis***) of the fold. The fold ***limbs*** are the flatter parts of the surface, on either side of the hinge/axis. If you considered all of the hinges/axes of a set of layers in a single fold, those hinges would form a ***hinge surface*** (or ***axial surface***) See Fig. 10.14A-C in the AGI/NAGT Laboratory Manual in Physical Geology.

We say that a given fold ***closes*** toward its hinge, and ***opens*** away from the hinge (see Fig. 10.14D in the AGI/NAGT Laboratory Manual in Physical Geology).

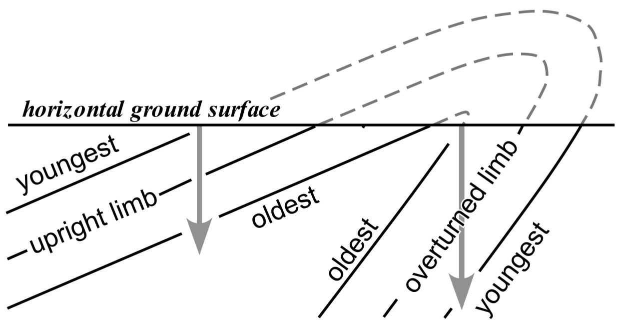
We use the terms "anticline" and "syncline" to describe folded sedimentary or meta-sedimentary layers in which we know the relative ages of the beds. An ***anticline*** is a fold in which the folded layers are older in the direction that the fold opens. Another way of identifying an anticline is that, starting from the fold limbs and moving inward toward the hinge/axial surface, the folded layers become progressively older in an anticline.

A ***syncline*** is a fold in which the folded layers are younger in the direction that the fold opens. Another way of identifying a syncline is that, starting from the fold limbs and moving inward toward the hinge/axial surface, the folded layers become progressively younger in a syncline.



In some instances, a layer is folded like an accordion, so that there might be a syncline next to an anticline next to another syncline next to another anticline, and so on. (Unless the layers are faulted, there can't be two anticlines or two synclines next to each other in the same layer.)

A fold limb is said to be ***upright*** if the *age* of the beds increase downward in a vertical direction. This is the same age progression that occurs in a continuous undeformed sequence of sedimentary layers. A fold limb is ***overturned*** if the age of the beds decreases downward in a vertical direction.



cross section through a fold with an overturned limb

A structural ***dome*** occurs when layered rock bends over the top of an isolated uplift, as might be caused by upwelling magma or other localized basement uplift. The *beds dip away from the center of a dome* -- they are inclined downward away from the center of the dome. As the uplifted center of the dome is subjected to erosion, *older beds are exposed in the middle of the dome* and progressively younger beds ring the outside of the dome. A geologic map of a structural dome displays a bull's eye pattern of formations with the oldest in the middle and beds dipping away from the center of the dome.

A structural ***basin*** occurs when layered rock bends as some localized area of basement subsides, perhaps due to cooling or faulting. The *beds dip toward from the center of a basin* -- they are inclined downward toward from the center of the basin. As basin is subjected to erosion, *younger beds are exposed in the middle of the basin* and progressively older beds ring the outside of the basin. A geologic map of a structural basin displays a bull's eye pattern of formations with the youngest in the middle and beds dipping toward the center of the basin.