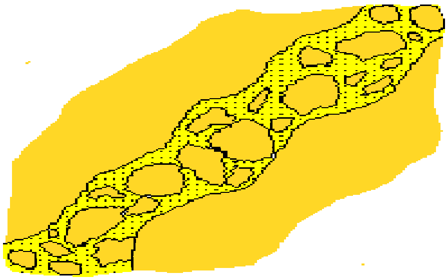
HOW ROCKS RESPOND TO FAULTING

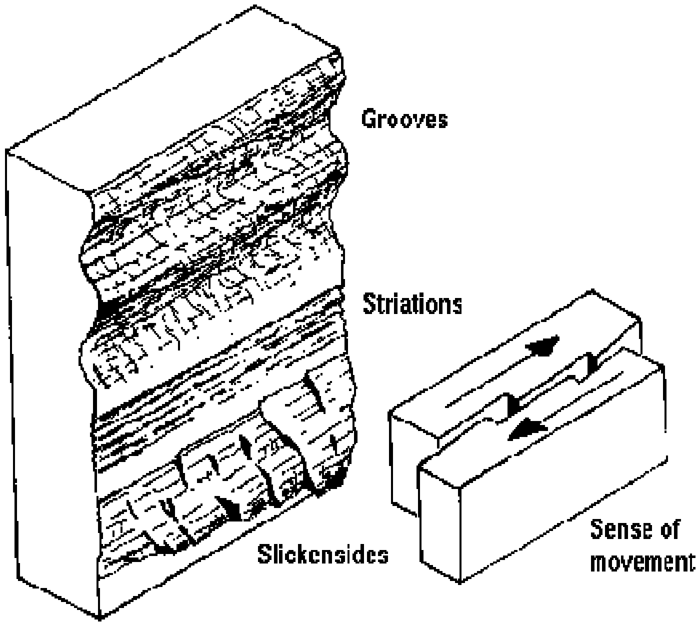
Evidence of Movement on Faults

Slikensides are scratch marks that are left on the fault plane as one block moves relative to the other. Slickensides can be used to determine the direction and sense of motion on a fault.

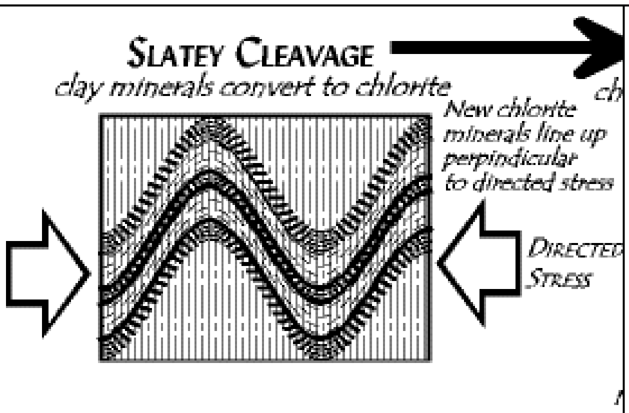
Fault Breccias are crumbled up rocks consisting of angular fragments that were formed as a result of grinding and crushing movement along a fault.



Breccia

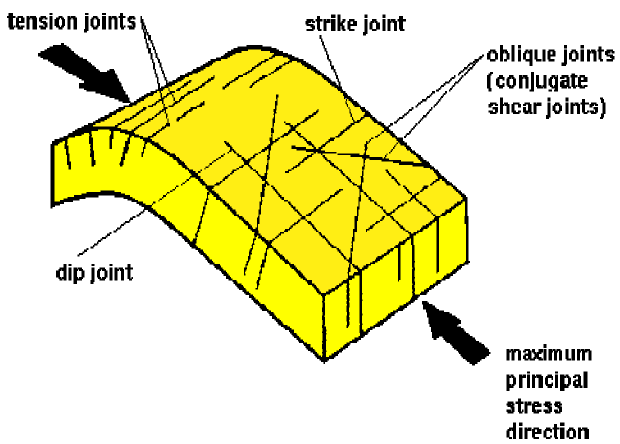


Fault breccias and slickensides form at the fault plane. This is the boundary between the upthrow and downthrow blocks as they move and grind against each other. If the rocks are shattered into separate angular and unsorted fragments a fault breccias is produced that may at depth be crushed to a dust called gouge. Slickensides may give an indication of the relative movement as the small ridges face the direction that the opposite block moved.



SLATY CLEAVAGE forms when rocks split along thin parallel planes

- It gives a parallel orientation of microscopic platy minerals
- The planes of cleavage form at right angles to the maximum stress and parallel to the axial plain of the fold
- Slaty cleavage only occurs in softer incompetent rocks such as shale which will bend and alter shape as it folds
- Since the nature of cleavage is dependent on scale, slaty cleavage is defined as having 0.01 mm or less of space occurring between layers.

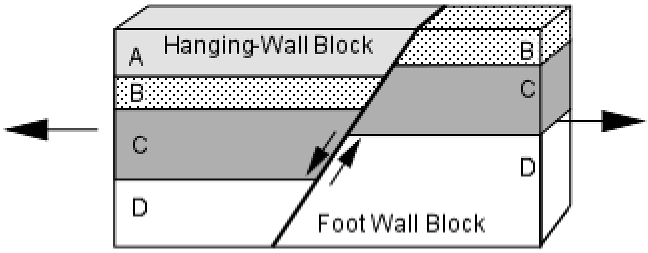


RADIAL JOINTS form when a rock is folded and it splits along lines of weakness

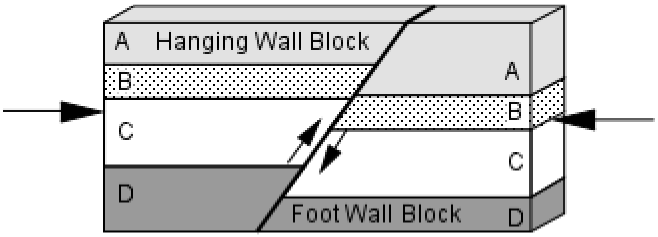
- These joints are at right angles to the bedding planes and make a radial pattern
- They form best on outer edge of an anticline
- They form where tensional forces extend the rock
- They only form in competent rocks such as sandstone and limestone that are more rigid and liable to fracture

FAULTING

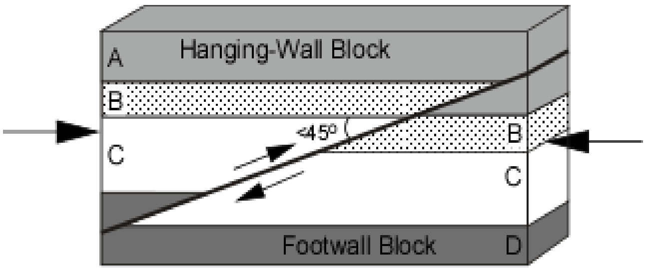
Faults - Faults occur when brittle rocks fracture and there is an offset along the fracture. When the offset is small, the displacement can be easily measured, but sometimes the displacement is so large that it is difficult to measure.



Normal Fault
Extensional Stress



Reverse Fault
Compressional Stress



Thrust Fault
Compressional Stress

Types of Faults

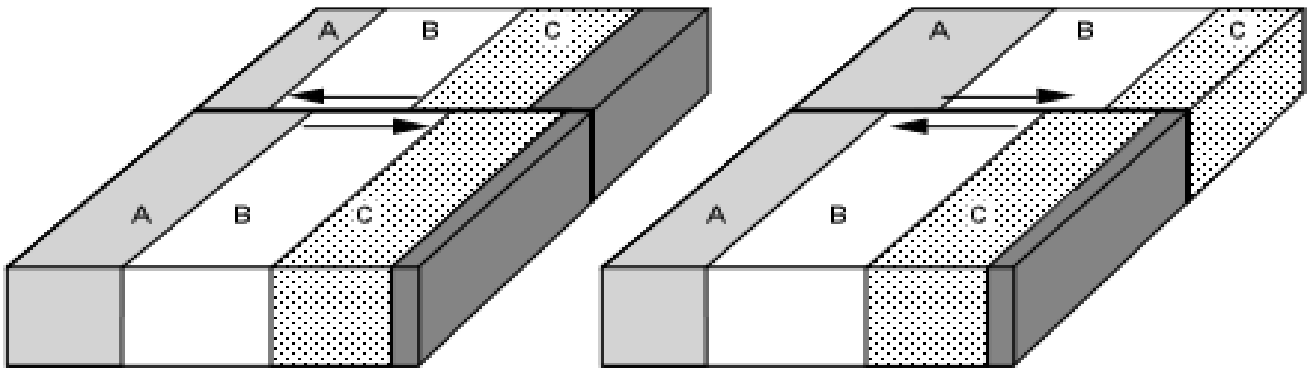
Faults can be divided into several different types depending on the direction of relative displacement. Since faults are planar features, the concept of strike and dip also applies, and thus the strike and dip of a fault plane can be measured. One division of faults is between dip-slip faults, where the displacement is measured along the dip direction of the fault, and strike-slip faults where the displacement is horizontal, parallel to the strike of the fault.

Dip Slip Faults - Dip slip faults are faults that have an inclined fault plane and along which the relative displacement or offset has occurred along the dip direction. Note that in looking at the displacement on any fault we don't know which side actually moved or if both sides moved, all we can determine is the relative sense of motion.

For any inclined fault plane we define the block above the fault as the ***hanging wall block*** and the block below the fault as the ***footwall block.***

- ***Normal Faults*** - are faults that result from horizontal tensional stresses in brittle rocks and where the hanging-wall block has moved down relative to the footwall block.
- ***Reverse Faults*** - are faults that result from horizontal compressional stresses in brittle rocks, where the hanging-wall block has moved up relative the footwall block.
- A ***Thrust Fault*** is a special case of a reverse fault where the dip of the fault is less than 15^{o}. Thrust faults can have considerable displacement, measuring hundreds of kilometres, and can result in older strata overlying younger strata.

Strike Slip Faults / Tear Faults - are faults where the relative motion on the fault has taken place along a horizontal direction. Such faults result from shear stresses acting in the crust. Strike slip faults can be of two varieties, depending on the sense of displacement. To an observer standing on one side of the fault and looking across the fault, if the block on the other side has moved to the left, we say that the fault is a ***left-lateral strike-slip fault***. If the block on the other side has moved to the right, we say that the fault is a ***right-lateral strike-slip fault***. The famous San Andreas Fault in California is an example of a right-lateral strike-slip fault. Displacements on the San Andreas fault are estimated at over 600 km.



Left-Lateral Strike-Slip Fault

Right-Lateral Strike-Slip Fault

Shear Stress

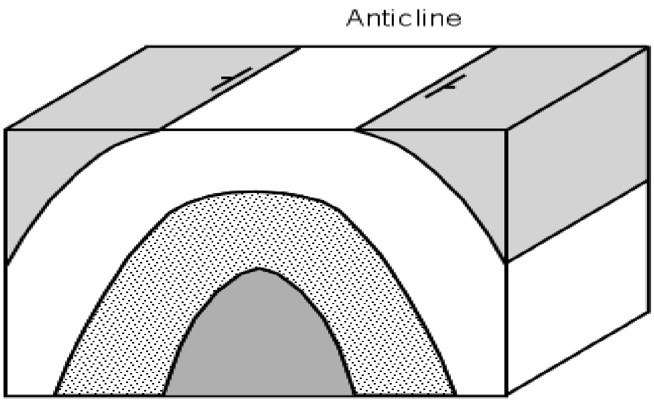
FOLDING

Anticlines are folds where the originally horizontal strata has been folded upward, and the two limbs of the fold dip away from the hinge of the fold.

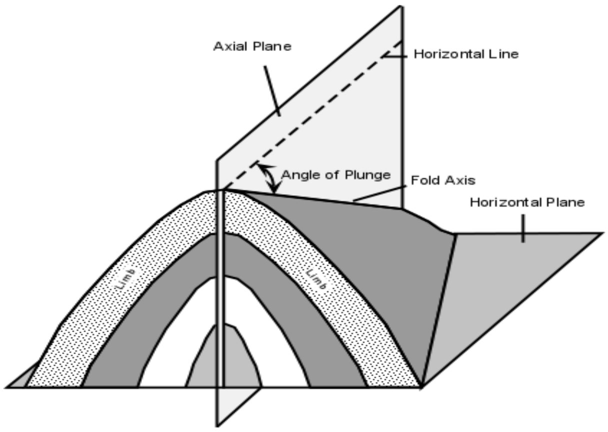
Folding of Ductile Rocks

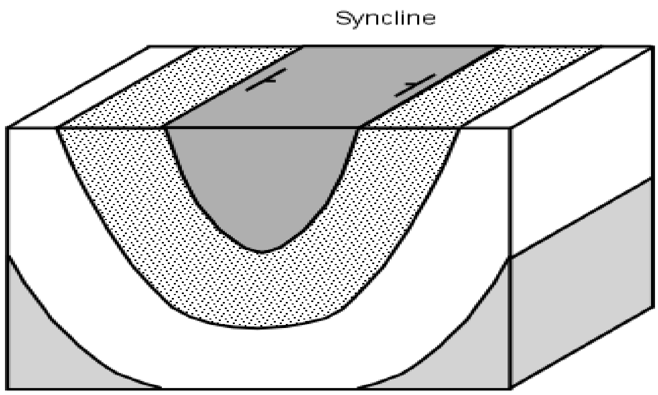
When rocks deform in a ductile manner, instead of fracturing to form faults, they may bend or fold, and the resulting structures are called *folds*. Folds result from compressional stresses acting over considerable time. Because the strain rate is low, rocks that we normally consider brittle can behave in a ductile manner resulting in such folds.

We recognize several different kinds of folds.



Synclines are folds where the originally horizontal strata have been folded downward, and the two limbs of the fold dip inward toward the hinge of the fold. Synclines and anticlines usually occur together such that the limb of a syncline is also the limb of an anticline.

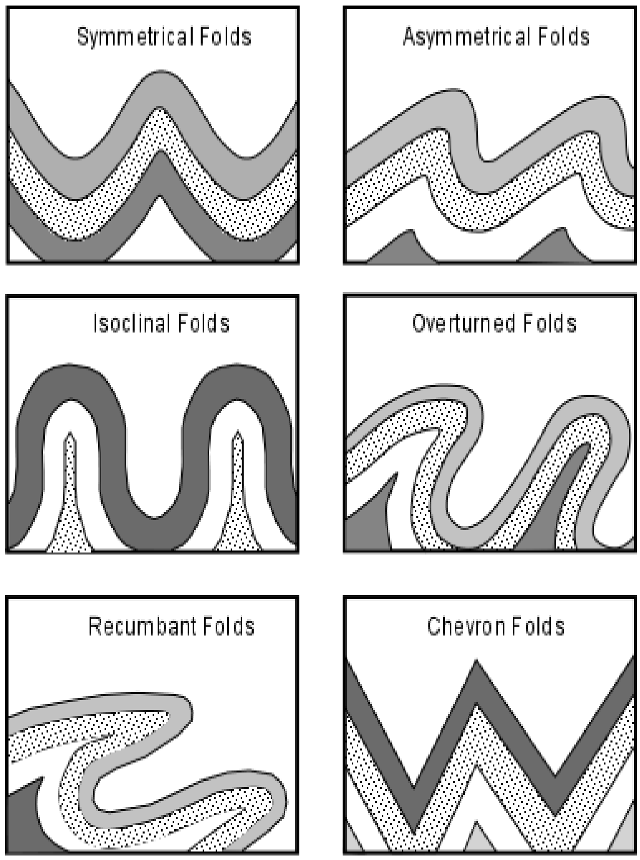




Classification of Folds

Folds can be classified based on their appearance.

- If the two limbs of the fold dip away from the axis with the same angle, the fold is said to be a *symmetrical fold*.
- If the limbs dip at different angles, the folds are said to be *asymmetrical folds*.
- If the compressional stresses that cause the folding are intense, the fold can close up and have limbs that are parallel to each other. Such a fold is called an *isoclinal fold* (iso means same, and cline means angle, so isoclinal means the limbs have the same angle). Note the isoclinal fold depicted in the diagram below is also a symmetrical fold.
- If the folding is so intense that the strata on one limb of the fold becomes nearly upside down, the fold is called an *overturned fold*.
- An overturned fold with an axial plane that is nearly horizontal is called a *recumbent fold*.
- A fold that has no curvature in its hinge and straight-sided limbs that form a zigzag pattern is called a *chevron fold*.



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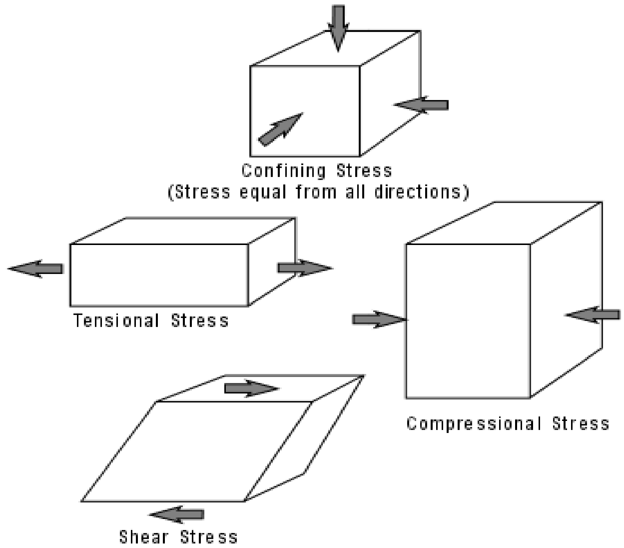
AS GEOLOGY

CASE STUDY REVISION BOOKLET

ROCK DEFORMATION **FOLDING AND FAULTING**

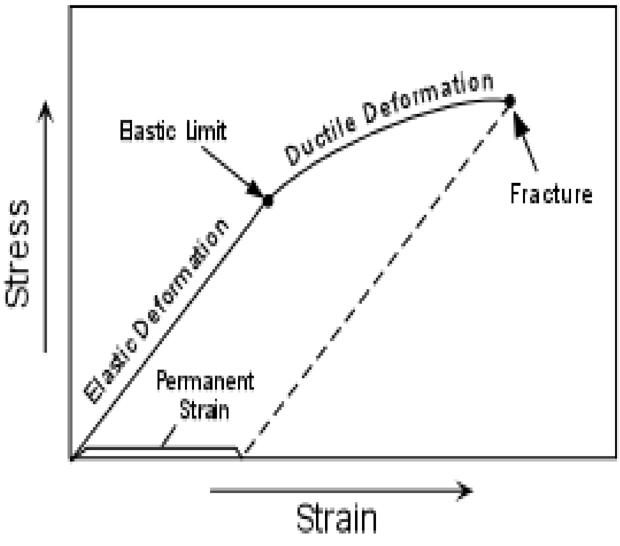


Stress and Strain : Stress is a force applied over an area. One type of stress that we are all used to is a uniform stress, called pressure. A uniform stress is a stress wherein the forces act equally from all directions. In the Earth the pressure due to the weight of overlying rocks is a uniform stress, and is sometimes referred to as confining stress.

If stress is not equal from all directions then we say that the stress is a differential stress. Three kinds of differential stress occur.

1. ***Tensional stress (or extensional stress)***, which stretches rock;
2. ***Compressional stress***, which squeezes rock; and
3. ***Shear stress***, which result in slippage and translation.

Strain is how the rock deforms under stress



Stages of Deformation

When a rock is subjected to increasing stress it passes through 3 successive stages of deformation

- ***Elastic Deformation*** -- wherein the strain is reversible.
- ***Ductile Deformation*** -- wherein the strain is irreversible.
- ***Fracture*** - irreversible strain wherein the material breaks**.**

How a material behaves will depend on several factors. Among them are:

- Temperature - At high temperature molecules and their bonds can stretch and move, thus materials will behave in more ductile manner. At low Temperature, materials are brittle.
- Confining Pressure - At high confining pressure materials are less likely to fracture because the pressure of the surroundings tends to hinder the formation of fractures. At low confining stress, material will be brittle and tend to fracture sooner.
- Strain rate -- At high strain rates material tends to fracture. At low strain rates more time is available for individual atoms to move and therefore ductile behaviour is favoured.
- Composition -- Some minerals, like quartz, olivine, and feldspars are very brittle. Others, like clay minerals, micas, and calcite are more ductile This is due to the chemical bond types that hold them together. Thus, the mineralogical composition of the rock will be a factor in determining the deformational behaviour of the rock. Another aspect is presence or absence of water. Water appears to weaken the chemical bonds and forms films around mineral grains along which slippage can take place. Thus wet rock tends to behave in ductile manner, while dry rocks tend to behave in brittle manner.