Structural geology:

Structural geology is the study of the three-dimensional distribution of rock units with respect to their deformational histories. The primary goal of structural geology is to use measurements of present-day rock geometries to uncover information about the history of deformation (strain) in the rocks, and ultimately, to understand the stress field that resulted in the observed strain and geometries. This understanding of the dynamics of the stress field can be linked to important events in the regional geologic past; a common goal is to understand the structural evolution of a particular area with respect to regionally widespread patterns of rock deformation (e.g., mountain building, rifting) due to plate tectonics.

Methods of Structural Geology:

Structural geologists use a variety of methods

- Measure of rock geometries.
- Reconstruct the deformational histories.
- Calculate the stress field that resulted in that deformation.

Only in a few cases does deformation of rocks occur at a rate that is observable on human time scales. Abrupt deformation along faults, usually associated with earthquakes caused by the fracture of rocks occurs on a time scale of minutes or seconds. Gradual deformation along faults or in areas of uplift or subsidence can be measured over periods of months to years with sensitive measuring instruments.

Causes for deformities or development of structures:

1. Constant mould and remould of the crust by exogenous geological agents (Weathering).
2. Instability of earth's interior resulting in plate tectonics or movements i.e orogenic and epeirogenic movements. The orogenic movements are mainly lateral and involve crustal deformations leading to the formation of mountains. The epeirogenic movements are primarily vertical and involve continental formation.

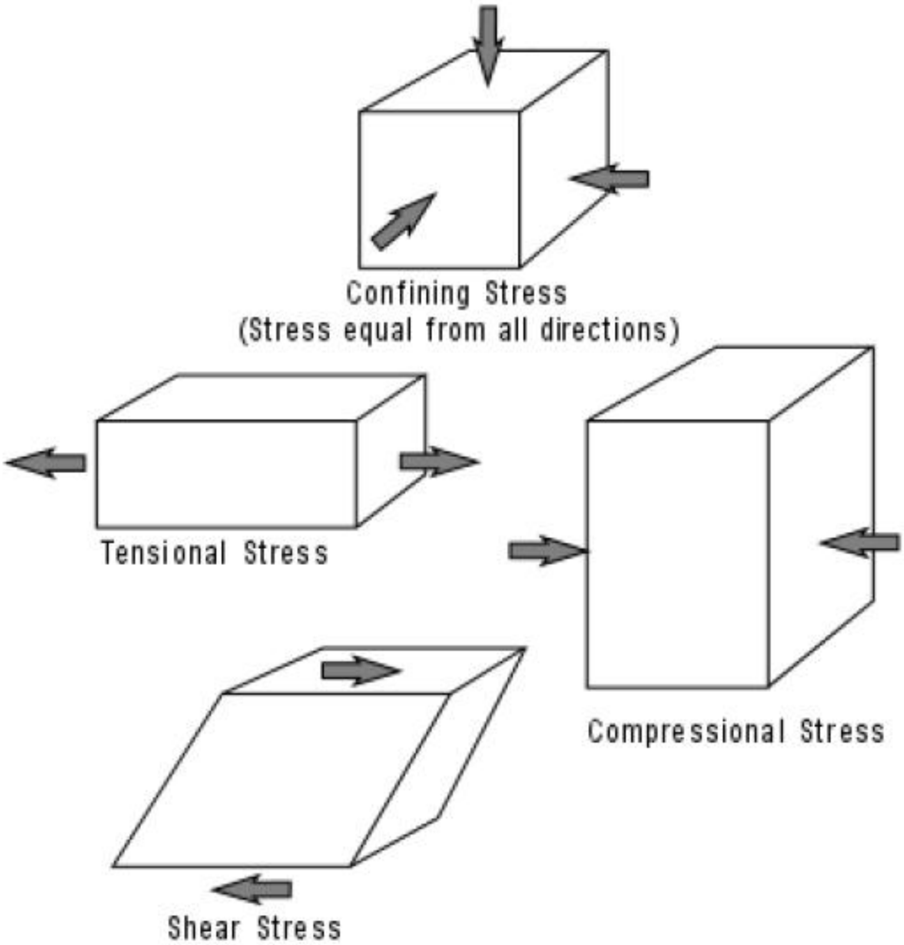
In the Earth the pressure due to the weight of overlying rocks is a uniform stress, and is sometimes referred to as confining stress.

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

Three kinds of differential stress occur.

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

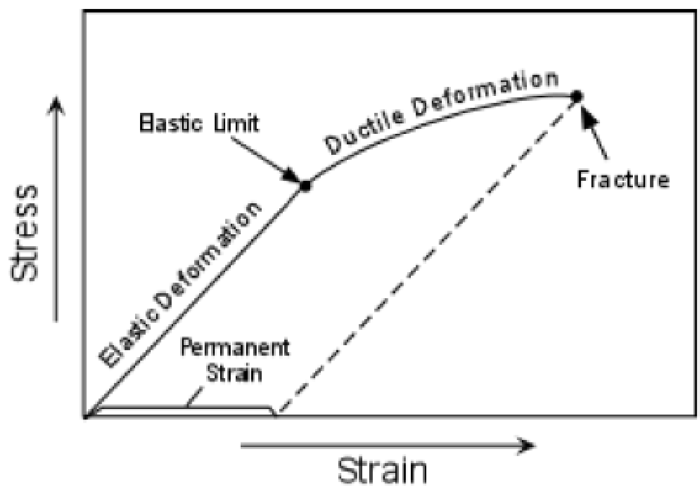
When rocks deform they are said to strain. A strain is a change in size, shape, or volume of a material.



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.



Evidence of Former Deformation:

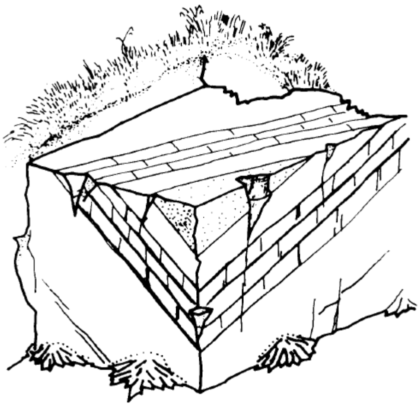
Evidence of deformation that has occurred in the past is very evident in crustal rocks. For example, sedimentary strata and lava flows generally follow the law of original horizontality. Thus, when we see such strata inclined instead of horizontal, evidence of an episode of deformation is present.

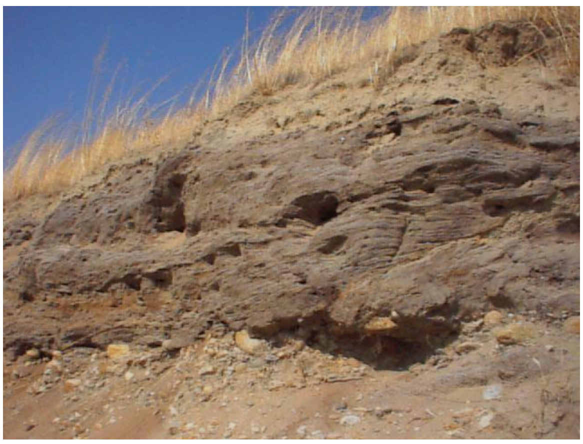
Modern regional structure (macrostructures) is being investigated using seismic tomography[1] and seismic reflection in three dimensions, providing unrivalled images of the Earth's interior, its faults and the deep crust. Further information from geophysics such as gravity and airborne magnetics can provide information on the nature of rocks imaged in the deep crust.

Rock microstructure or texture of rocks is studied by structural geologists on a small scale to provide detailed information mainly about metamorphic rocks and some features of sedimentary rocks, most often if they have been folded. Textural study involves measurement and characterisation of foliations, crenulations, metamorphic minerals, and timing relationships between these structural features and mineralogical features.

Outcrop:

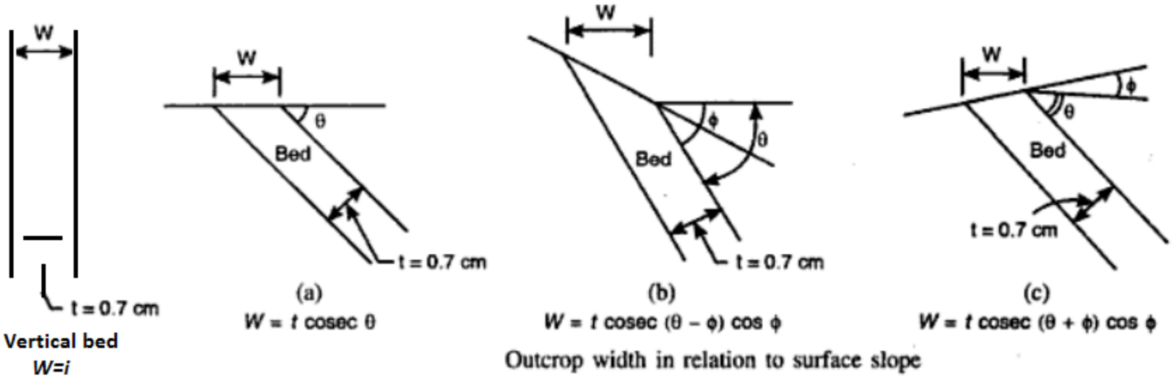
An outcrop is a visible exposure of bedrock or ancient superficial deposits on the surface of the Earth. It is the generalised term used to refer the exposed folds, faults, joints etc.





1- Tomography refers to imaging by sections or sectioning, through the use of any kind of penetrating wave.

The shape and width of the outcrop of the inclined bed depends upon the direction and amount of its dip and the surface slope of the region as the following figure reveal.

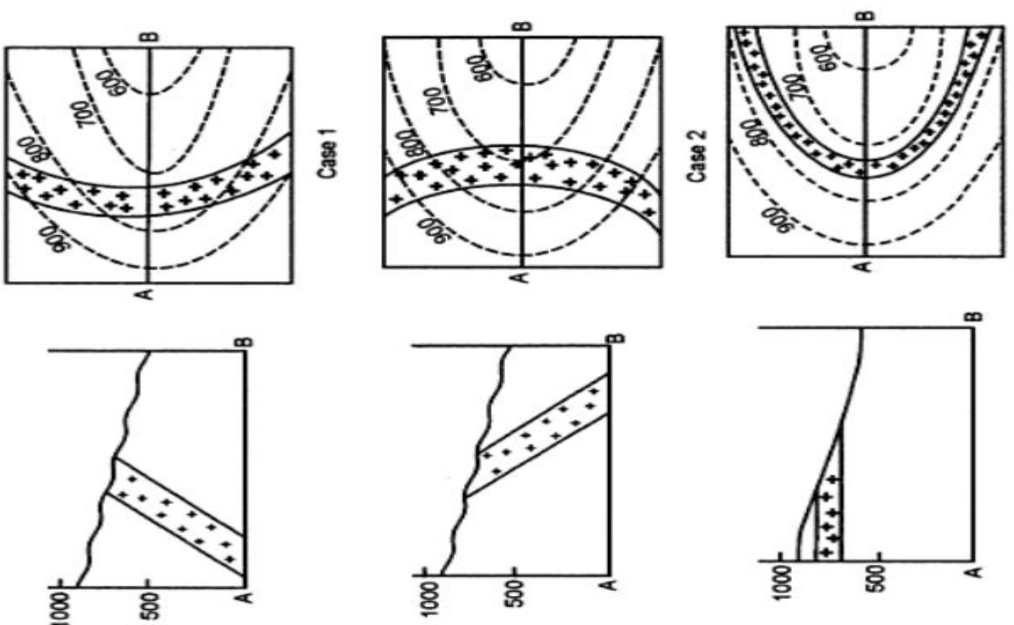


a - Inclined bed b - Surface slope and dip direction of bed are towards the same side c - Surface slope and dip direction of bed are in opposite direction

In general, the flatter the slope of the ground, the wider will be the outcrop. If the direction of the slope of the ground and the direction of dip coincide, the outcrop of the given bed will be wider than when these directions are opposed. When a bed is vertical, the width of the outcrop will be minimum.

A few cases of V-shaped outcrops in a valley may also be seen, which are depicted as followed.

(The left side figures show geological settings and right side figures show contour pattern and outcrop appearance)



Case 1: When beds dip in the direction opposite to the slope of the valley: V points *up* the valley.
Case 2: When beds dip in the same direction as the slope of the valley and at a greater angle: V points *down* the valley.
Case 3: When beds are horizontal or dip in the same direction as the slope of the valley and at a smaller angle: V points *up* the valley and is longer than in Case 1.

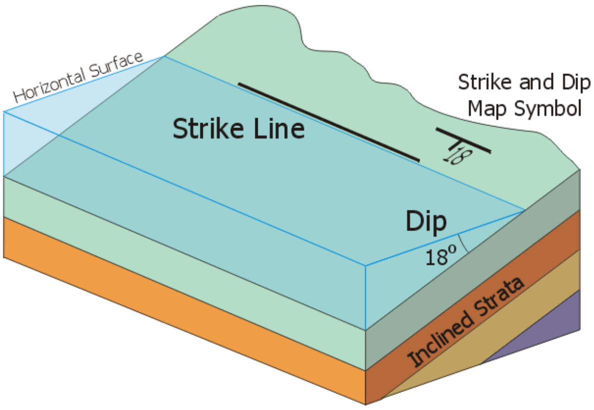
Valleys and shapes of outcrops

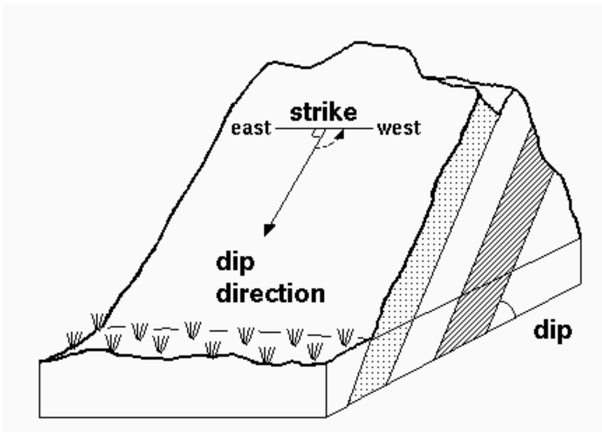
Attitudes:

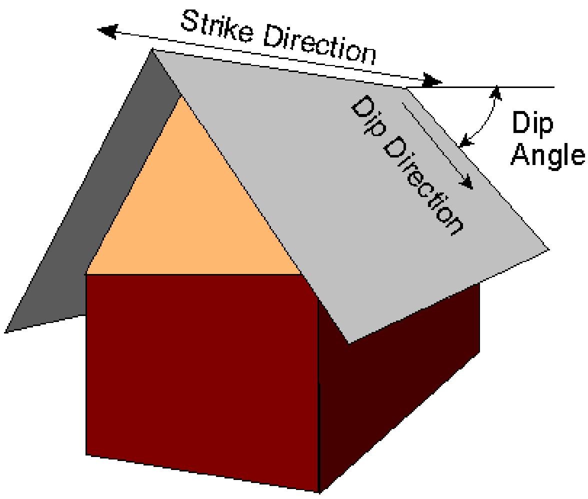
In geometry the orientation, angular position, or attitude of an object such as a line, plane or rigid body is part of the description of how it is placed in the space it is in. Namely, it is the imaginary rotation that is needed to move the object from a reference placement to its current placement. A rotation may not be enough to reach the current placement. It may be necessary to add an imaginary translation, called the object's location (or position, or linear position). The location and orientation together fully describe how the object is placed in space. The above mentioned imaginary rotation and translation may be thought to occur in any order, as the orientation of an object does not change when it translates, and its location does not change when it rotates.

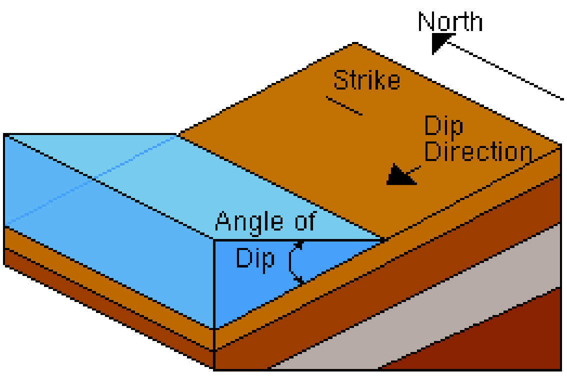
Strike & Dip:

Strike and dip refer to the orientation or attitude of a geologic feature. The strike line of a bed, fault, or other planar feature is a line representing the intersection of that feature with a horizontal plane. The dip gives the steepest angle of descent of a tilted bed or feature relative to a horizontal plane









Representation of Strike & Dip:

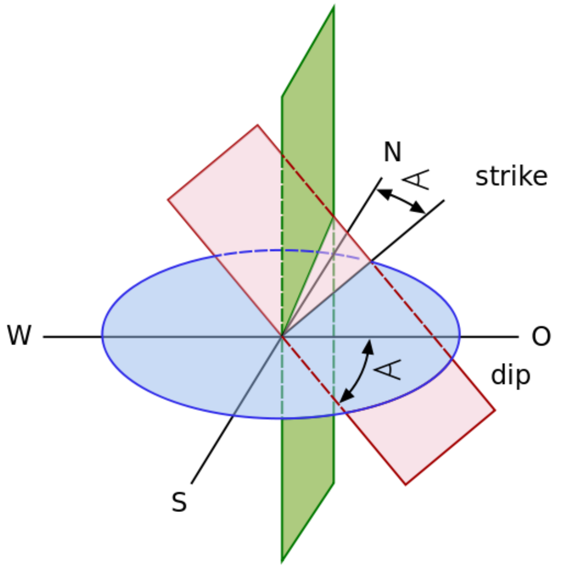
On a geologic map, this is represented with a short straight line segment oriented parallel to the strike line. Strike (or strike angle) can be given as either a quadrant compass bearing of the strike line (N25°E for example) or in terms of east or west of true north or south, a single three digit number representing the azimuth, where the lower number is usually given (where the example of N25°E would simply be 025, and the other value of 205 is discarded), or the azimuth number followed by the degree sign (example of N25°E would be 25° or 205°).

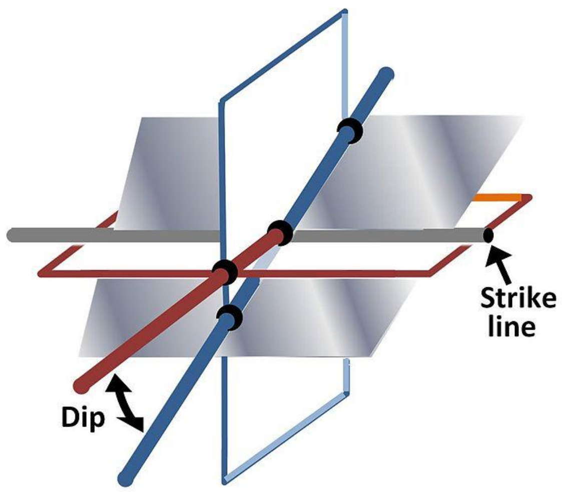
Dip is given by the number (0°-90°) as well as a letter (N,S,E,W) with rough direction in which the bed is dipping. One technique is to always take the strike so the dip is 90° to the right of the strike, in which case the redundant letter following the dip angle is omitted. The map symbol is a short line attached and at right angles to the strike symbol pointing in the direction which the planar surface is dipping down. The angle of dip is generally included on a geologic map without the degree sign. Beds that are dipping vertically are shown with the dip symbol on both sides of the strike, and beds that are flat are shown like the vertical beds, but with a circle around them. Both vertical and flat beds do not have a number written with them.

Another way of representing strike and dip is by dip and dip direction. The dip direction is the azimuth of the direction the dip as projected to the horizontal (like the trend of a linear feature in trend and plunge measurements), which is 90° off the strike angle. For example, a bed dipping 30° to the South, would have an East-West strike (and would be written 90°/30° S using strike and dip), but would be written as 30/180 using the dip and dip direction method.

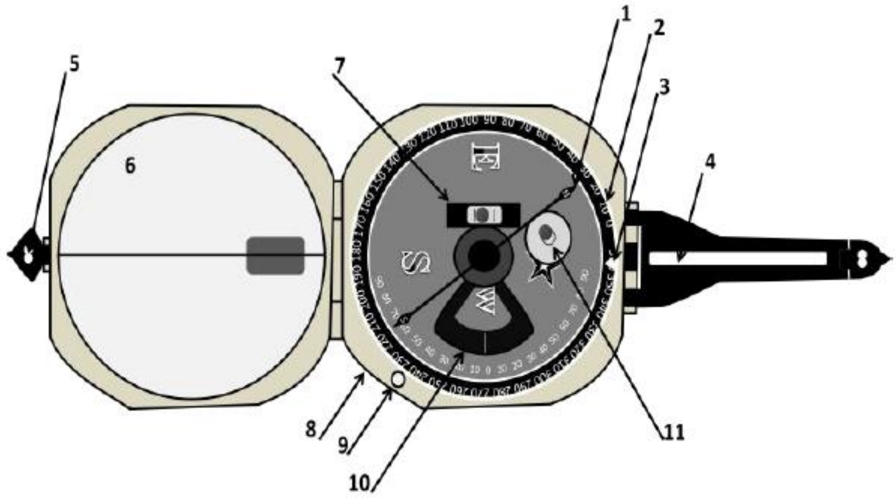
Strike and dip are determined in the field with a compass and clinometer or a combination of the two, such as a Brunton compass named after D.W. Brunton a Colorado miner. Compass-clinometers which measure dip and dip direction in a single operation are often called "stratum" or "Klar" compasses after a German professor.

Any planar feature can be described by strike and dip. This includes sedimentary bedding, faults and fractures, cuestas, igneous dikes and sills, metamorphic foliation and any other planar feature in the Earth. Linear features are measured with very similar methods, where "plunge" is the dip angle and "trend" is analogous to the dip direction value.





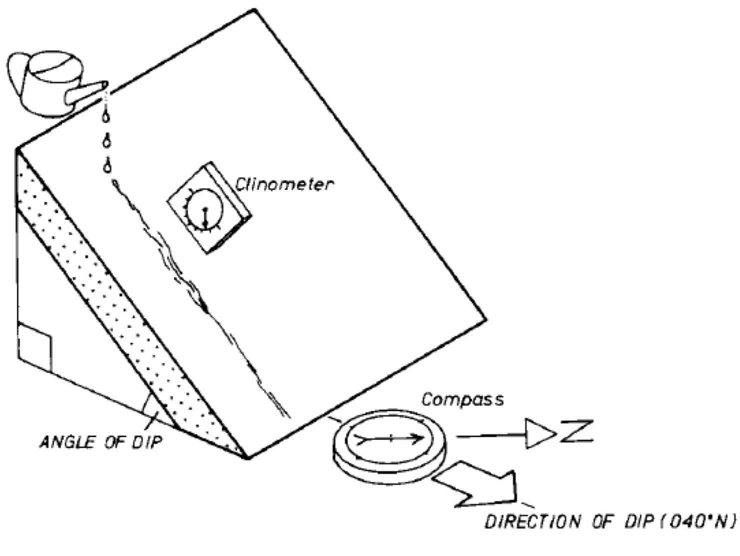
The various parts of the Brunton are depicted below.

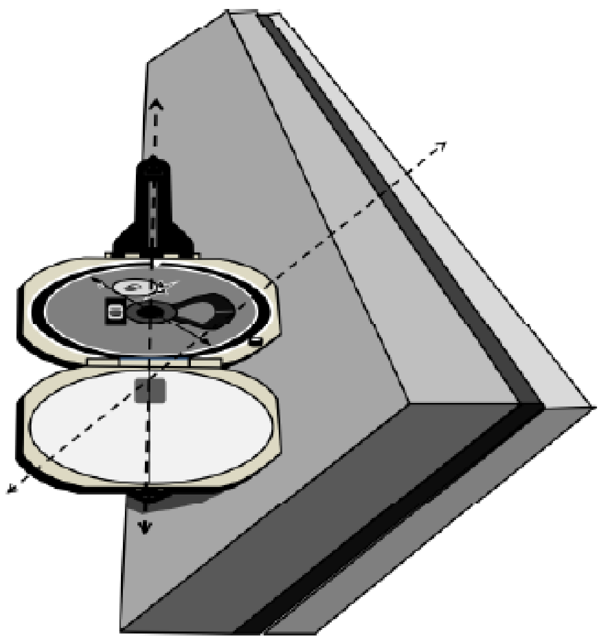


1. Bearing Needle
2. Graduated Circle
3. Zero Pin
4. Large Sight with Peep Sight
5. Small Sight
6. Mirror
7. Long Level
8. Adjusting Screw
9. Lift Pin
10. Vernier
11. Round Level

Measuring the strike and dip of a geologic feature uses all three functions of the transit compass being the magnetic needle, Round Level, and Long Level. The strike is found by placing the edge of the compass against the inclined rock and adjusting the compass position until the round level is center. With the edge of the compass flush to the rock and the round level center observe and record the bearing. For this example the bearing is N35E. The dip angle will always be orthogonal to the strike.

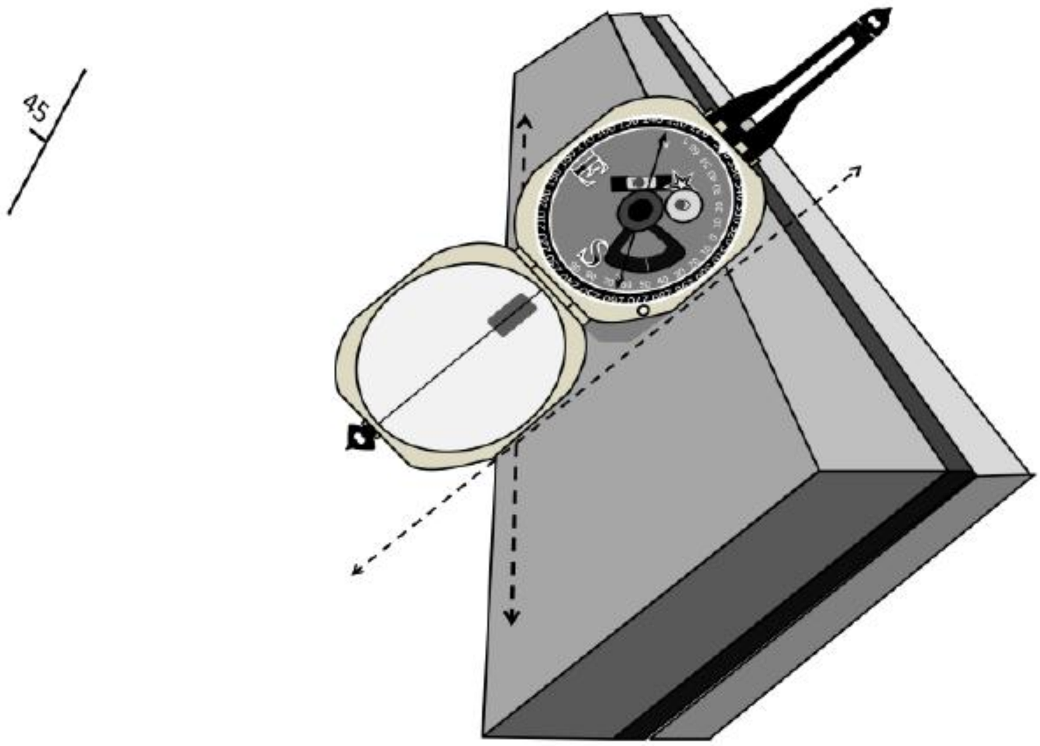
A trick for finding the strike is to pour some water on the rock. The water will flow in the direction of the dip and the strike is orthogonal as stated.



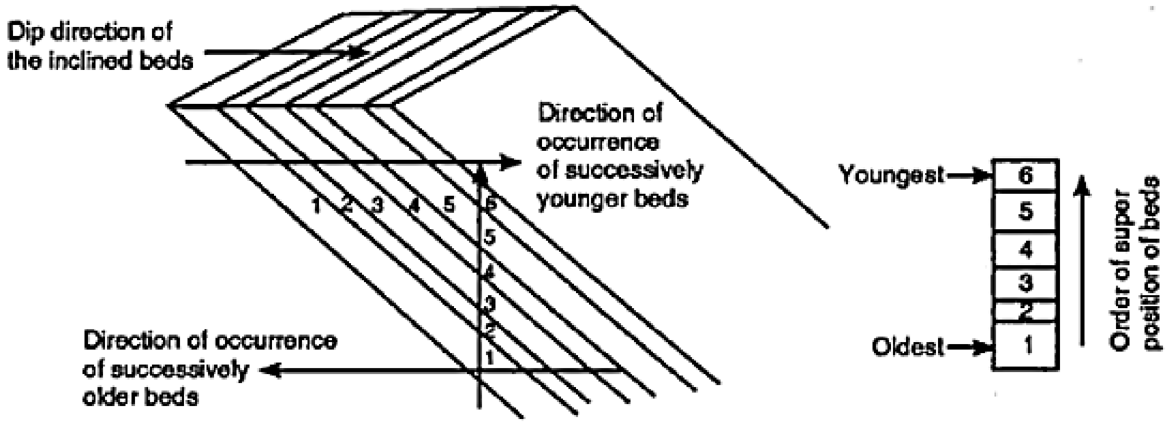


The dip is found by placing the compass flat against the rock orthogonal to the strike. Adjust the lever on the back of the compass until the Long Level is flat. Observe and record the measurement seen on the Vernier. For this example it is 45 degrees (as shown in fig). This may be written as N35E 45.

This may also be annotated on a geologic map with a long line pointing toward N35E and an orthogonal line pointing in the direction of dip with the dip angle annotated adjacent to the symbol.



in inclined strata, successively younger beds are generally found along the dip direction (i.e., when the dip amount of beds is more than the surface slope). But when the dip amount is less than surface slope, successively older beds are encountered along the dip direction.

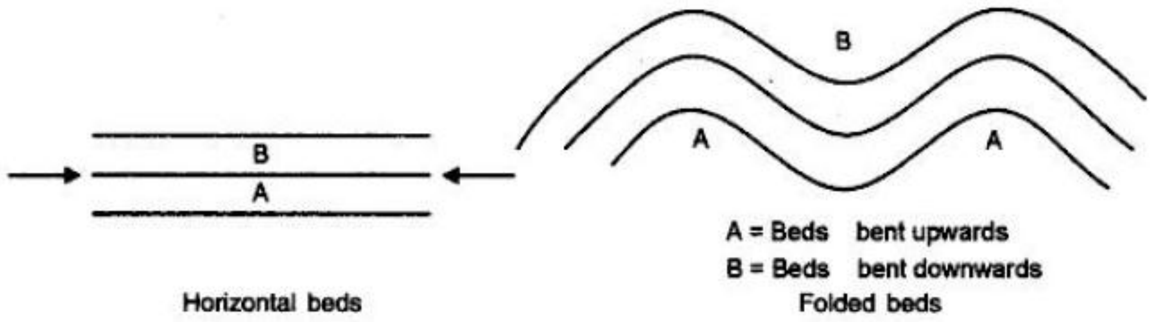


Dip direction and order of superposition

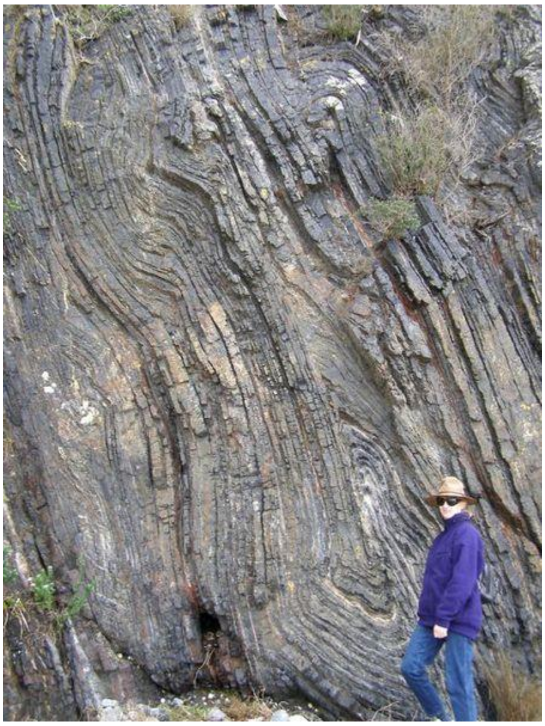
Folds, faults, joints are the most commonly found geological structures in nature:

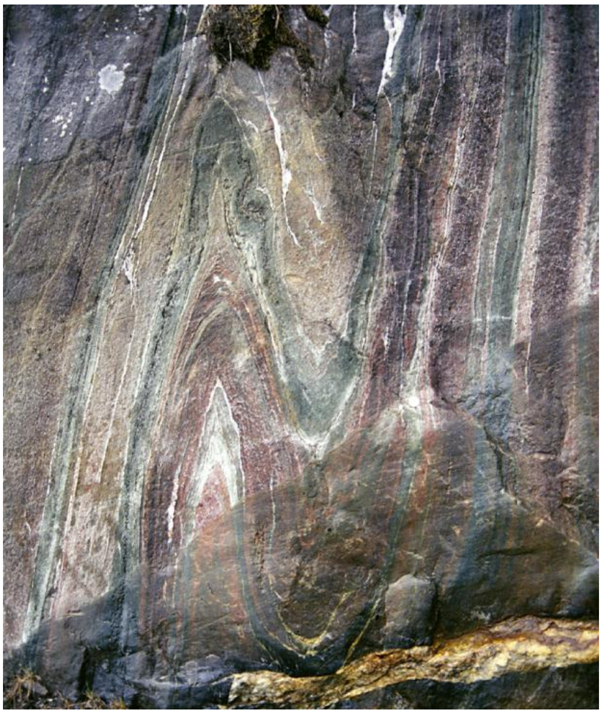
Folds:

The term fold is used in geology when one or a stack of originally flat and planar surfaces, such as sedimentary strata, are bent or curved as a result of permanent deformation.



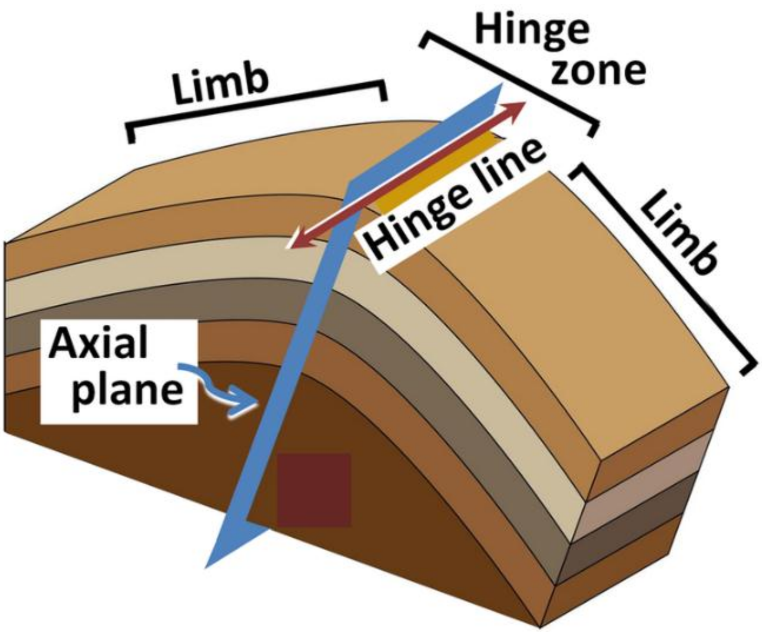
Synsedimentary folds are those due to slumping of sedimentary material before it is lithified. Folds in rocks vary in size from microscopic crinkles to mountain-sized folds. They occur singly as isolated folds and in extensive fold trains of different sizes, on a variety of scales. Folds form under varied conditions of stress, hydrostatic pressure, pore pressure, and temperature - hydrothermal gradient, as evidenced by their presence in soft sediments, the full spectrum of metamorphic rocks, and even as primary flow structures in some igneous rocks. A set of folds distributed on a regional scale constitutes a fold belt, a common feature of orogenic zones. Folds are commonly formed by shortening of existing layers, but may also be formed as a result of displacement on a non-planar fault (fault bend fold), at the tip of a propagating fault (fault propagation fold), by differential compaction or due to the effects of a high-level igneous intrusion e.g. above a laccolith.





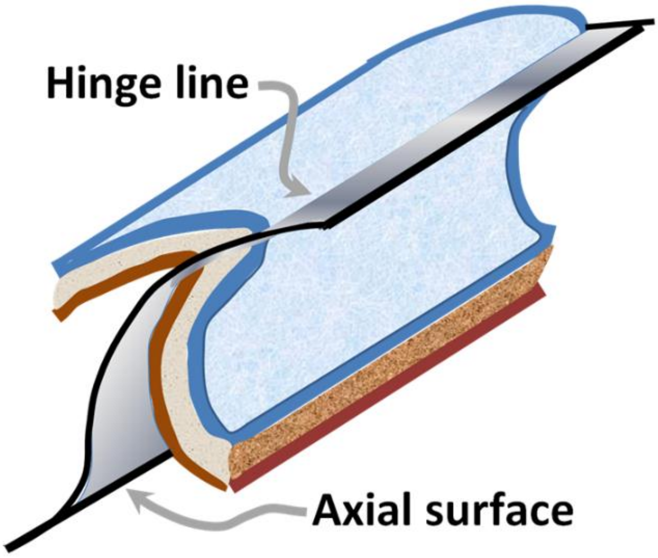
Description of folds:
Folds are classified by their size, fold shape, tightness, dip of the axial plane.

Fold terminology in two dimensions
Looking at a fold surface in profile the fold can be divided into hinge and limb portions. The limbs are the flanks of the fold and the hinge is where the flanks join together. The hinge point is the point of maximum radius of curvature for a fold. The crest of the fold is the highest point of the fold surface, and the trough is the lowest point. The inflection point of a fold is the point on a limb at which the concavity reverses; on regular folds, this is the midpoint of the limb.



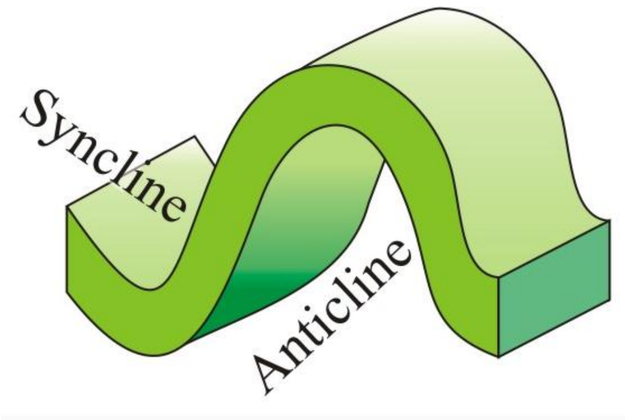
Fold terminology in three dimensions

The hinge points along an entire folded surface form a hinge line, which can be either a crest line or a trough line. The trend and plunge of a linear hinge line gives you information about the orientation of the fold. To more completely describe the orientation of a fold, one must describe the axial surface. The axial surface is the surface defined by connecting all the hinge lines of stacked folding surfaces. If the axial surface is a planar surface then it is called the axial plane and can be described by the strike and dip of the plane. An axial trace is the line of intersection of the axial surface with any other surface (ground, side of mountain, geological cross-section).



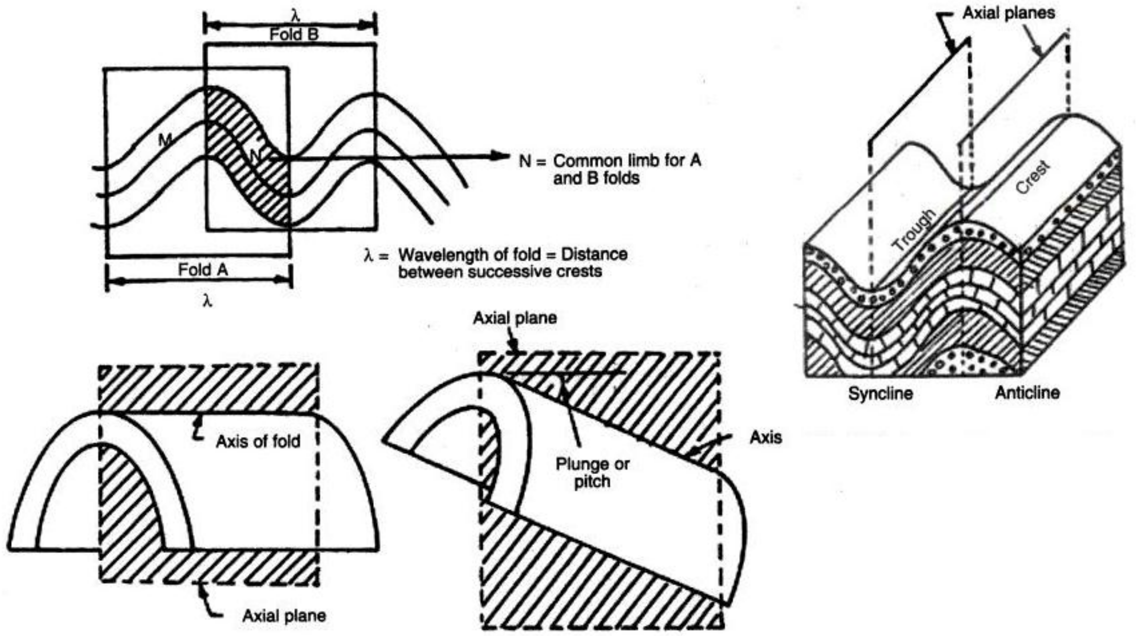
Crest and Trough:

The curved protion of the fold at the top is called crest and the bottom is called trough. In general the crest and trough are smoothly bent, but in chevron folds, these are sharp and angular. Some geologists' reefer to these as hinges.



Axial Plane:

This is the imaginary plane which divides the fold into equal (or nearly equal) halves. It passes through either the crest or the trough, i.e, in between the limbs. Depending upon the nature of the fold, the axial plane may be vertical, horizontal or inclined. In case of symmetrical folds, the axial plane divides the fold into exactly two equal halves. But in asymmetrical folds, the two halves will be only nearly equal.



Axis:

This is the trace of the intersection between the axial plane and the crest (or trough) of the fold. Depending the nature of the fold, it may be inclined or horizontal or vertical. When is inclined, the angle between the axis and the horizontal plane is called the plunge or pitch. In general an axis is undulatory (wavy) and its height changes along the trend of the fold.

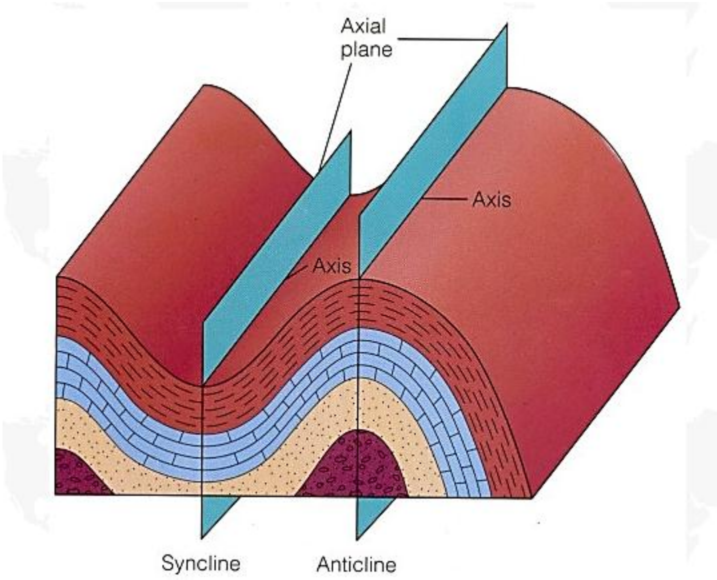
Wavelength:

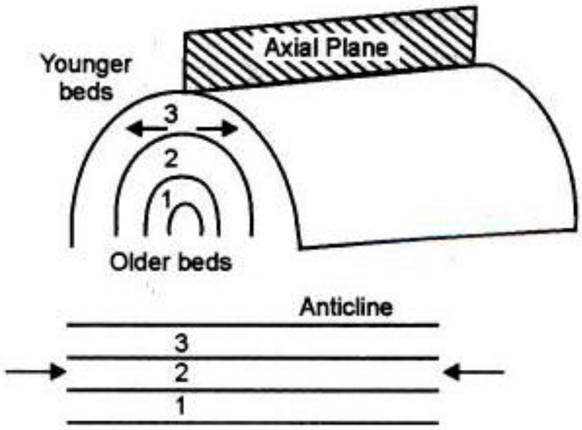
The distance between the successive crests or troughs is called wavelength.

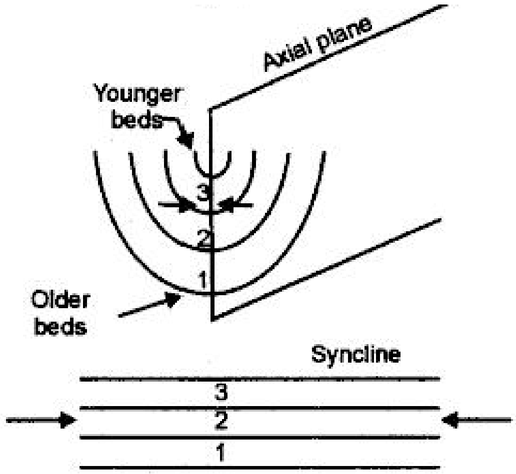
Anticline & Syncline:

When the beds are bent upwards, the resulting fold is called anticline. When the beds are bent downwards, the resulting fold is syncline.

In the anticline, the fold will be convex upwards and the younger beds occur towards convex side. In the syncline, the fold will be convex downwards and the younger beds occur towards the concave side.

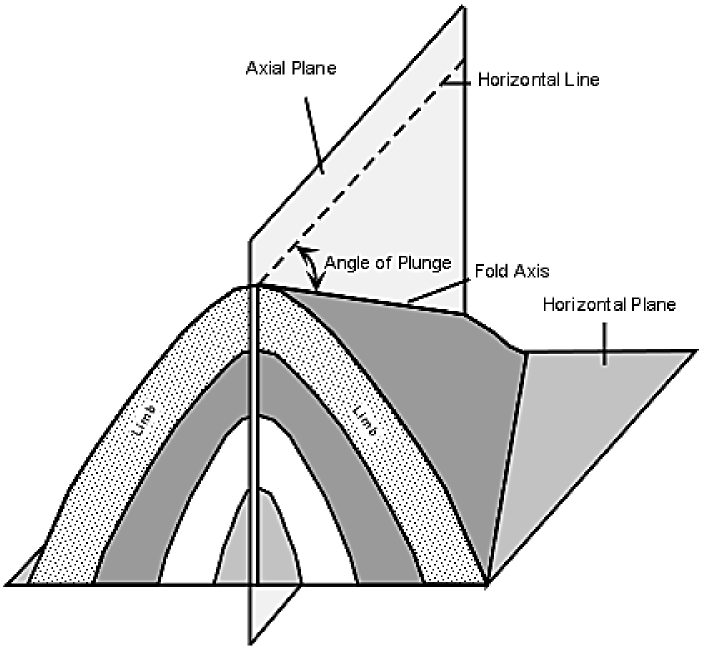






Plunge:

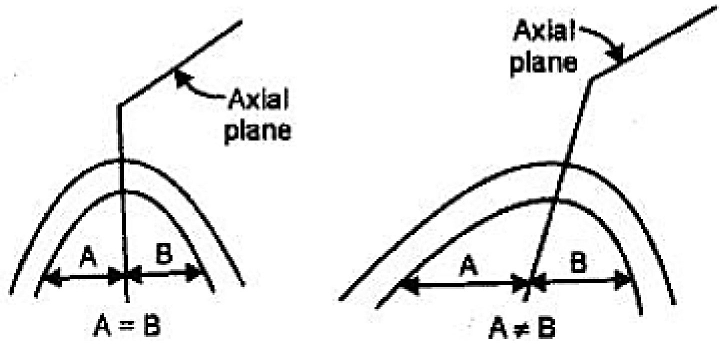
The inclination of fold axis to the horizontal plane is called plunge.



Types of Folds:

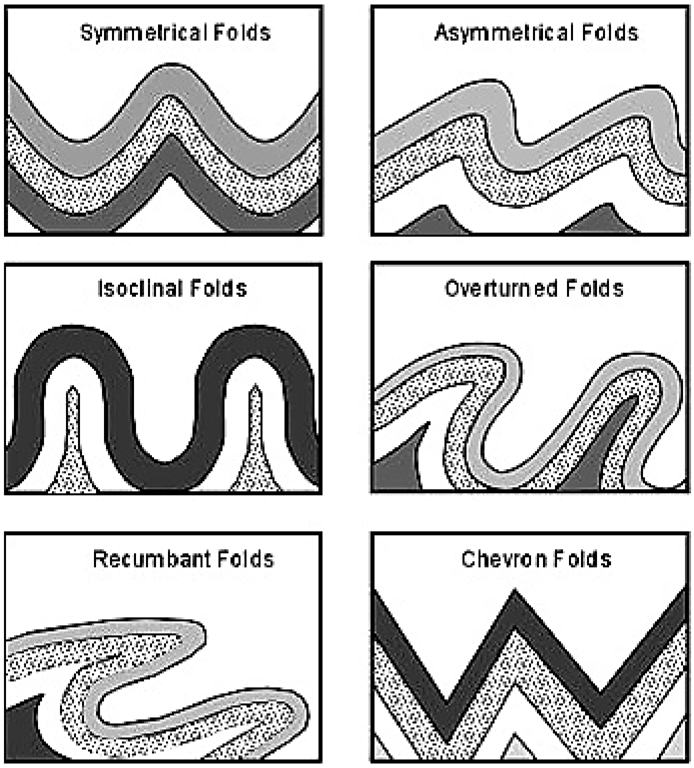
Symmetrical and Asymmetrical Folds:

When the axial plane divides a fold into two equal halves in such a way that one half is the mirror image of another, then such a fold (whether anticline or syncline) is called a symmetrical fold. If the two halves are not mirror images, then the fold is called asymmetrical fold.



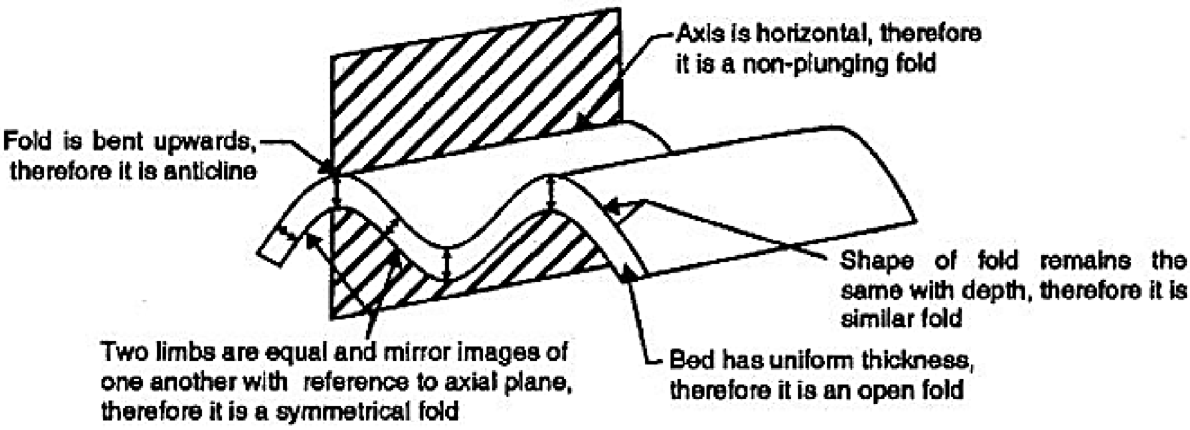
Symmetrical anticline   Asymmetrical anticline

Symmetrical folds occur when the compressive forces responsible for folding are of same magnitude and when the compressive forces are not of same magnitude, asymmetrical fold occur.



Plunging & Non-Plunging Folds:

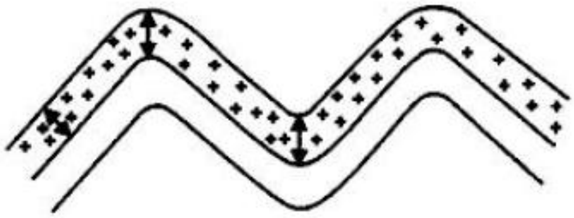
If the axis of a fold is inclined to horizontal i.e., without a plunge, fold is said to be plunging. If the axis of fold is horizontal, the fold is said to be Non-plunging.



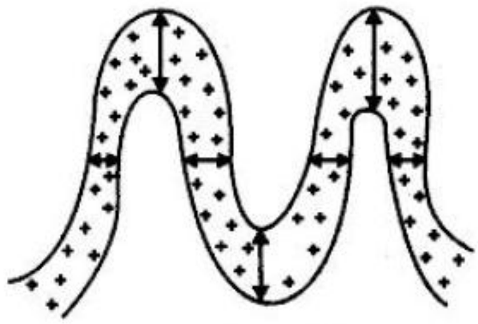
A non-plunging, similar, symmetrical and open anticiline

Open and closed folds:

Depending on the intensity of deformation, the beds of the fold may or may not have uniform thickness. If the thickness of the bids is uniform throughout the fold, it is called an open fold. On the other hand if the beds are thinner in the limb portions and thicker at crests and troughs, such a fold is called closed fold.



Open anticlinal fold

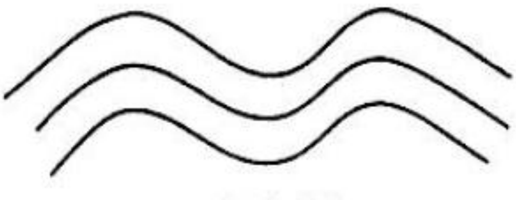


Closed anticlinal fold

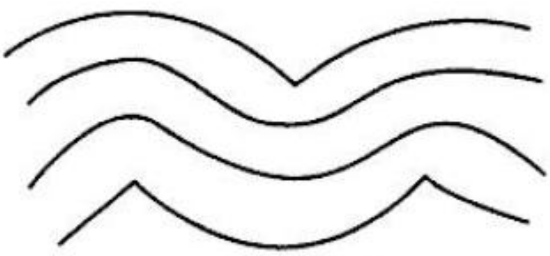
The plastic movement (irreversible movement under heavy stress) of the materials from the limbs to the crest and troughs results in the formation of closed folds.

Similar and Parallel Folds:

If the shape or pattern of folds remains the same from surface to depth, the folds are similar folds. If the shape or patter of folds changes from surface to depth, the crest and trough become pointed or angular give rise to parallel folds.



Similar fold

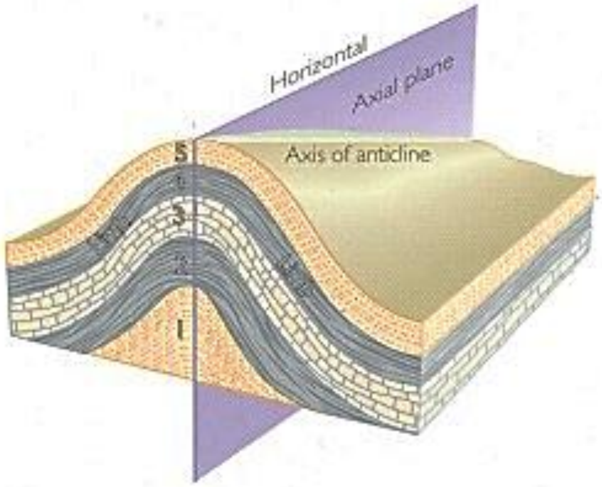


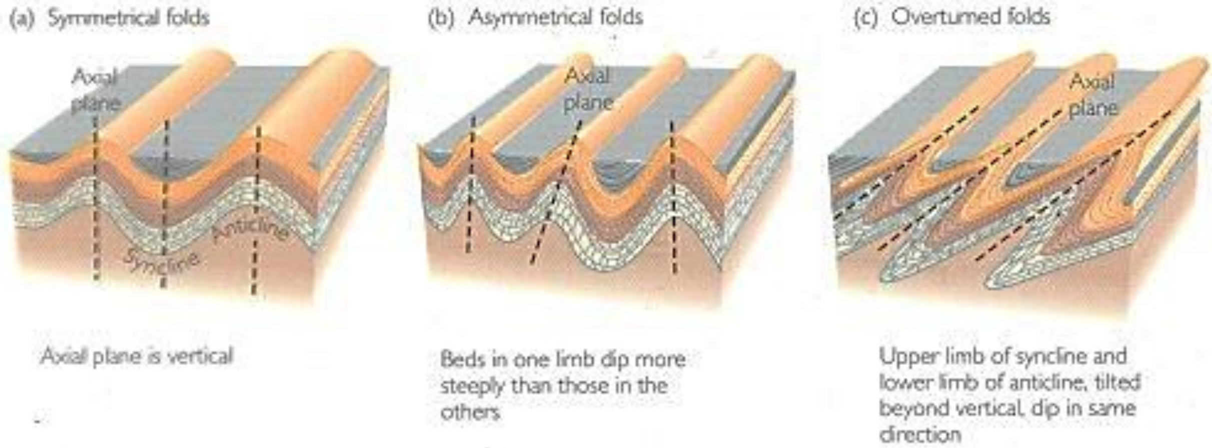
Parallel fold

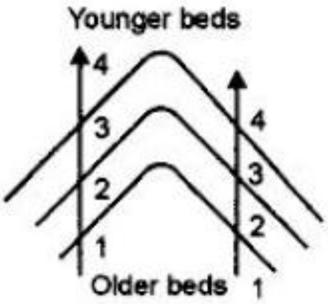
Apart from the regular types of folds, a few types of folds are also visible in the real world with some peculiarities.

Overturned Fold:

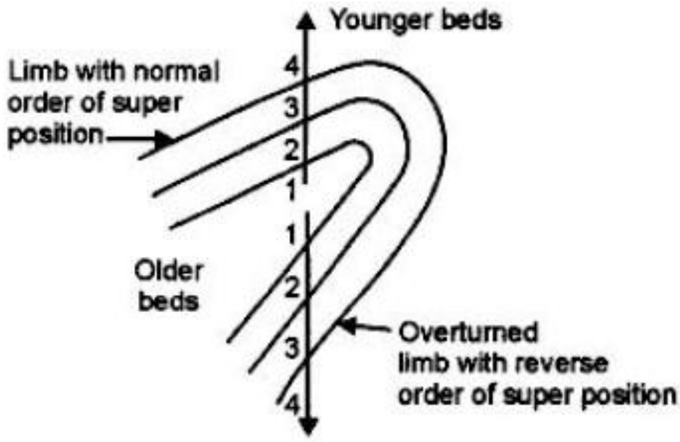
If the upper limb of syncline and the lower limb of anticline, tilt beyond vertical and dip in the same direction, then the fold is said to be over turned fold.







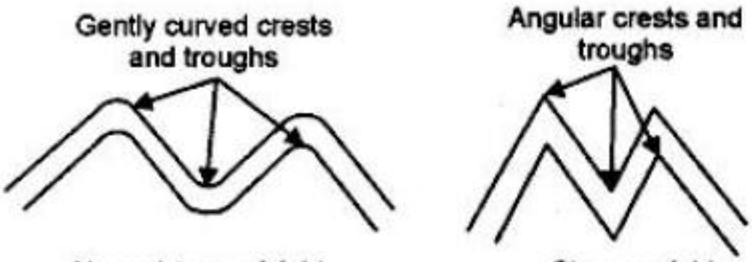
Normal type of fold



Overturned fold

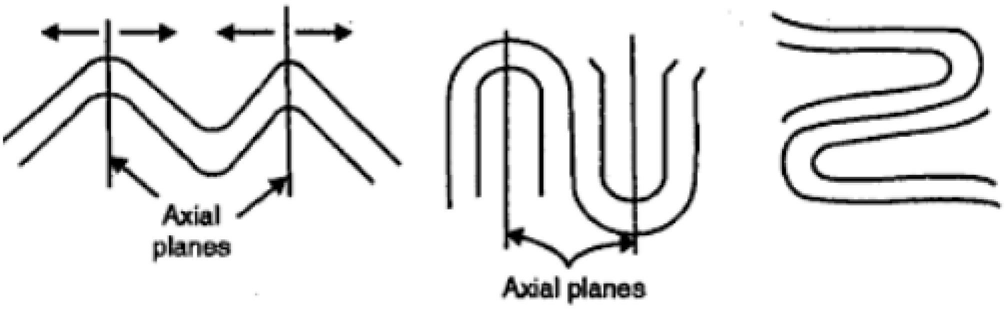
Chevron folds:

The folds that are curved sharply, resulting with angular crest and troughs are called as chevron folds.

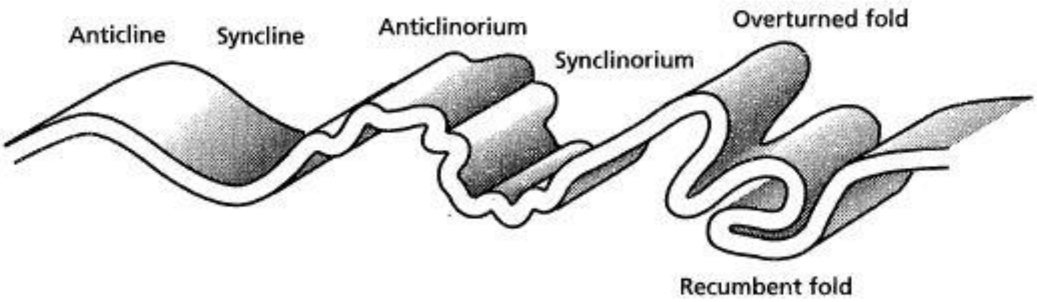


Normal type of fold Chevron fold

Isoclinal folds: usually, the folds have inclined limbs, i.e., the limbs will be mutually diverging or converging with reference to axial planes. But in some folds, the limbs will be mutually parallel to a great extent. Such folds are isoclinal folds. These folds may be vertical, inclined or horizontal. The horizontal isoclinal folds are called recumbent folds. The inclined and recumbent isoclinal folds are naturally overturned folds.



Normal type of fold Isoclinal folds Recumbent folds



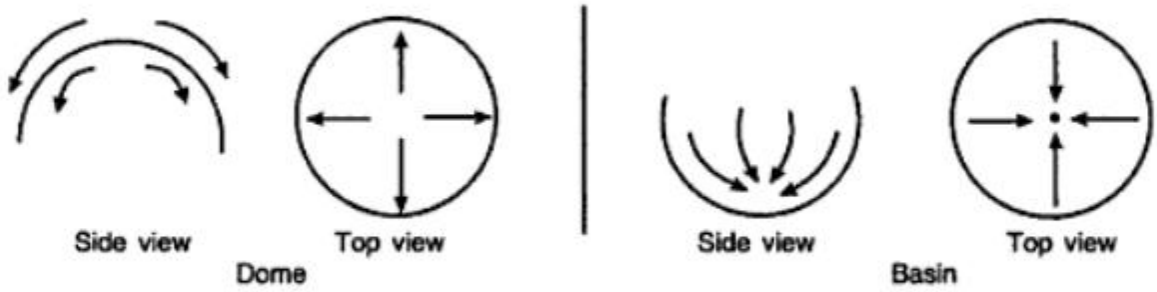
Fan folds:

Folds with limbs dipping away from each other with the reference to their axial plane, are called fan folds.

Normal type of fold Fan fold

Domes and basins:

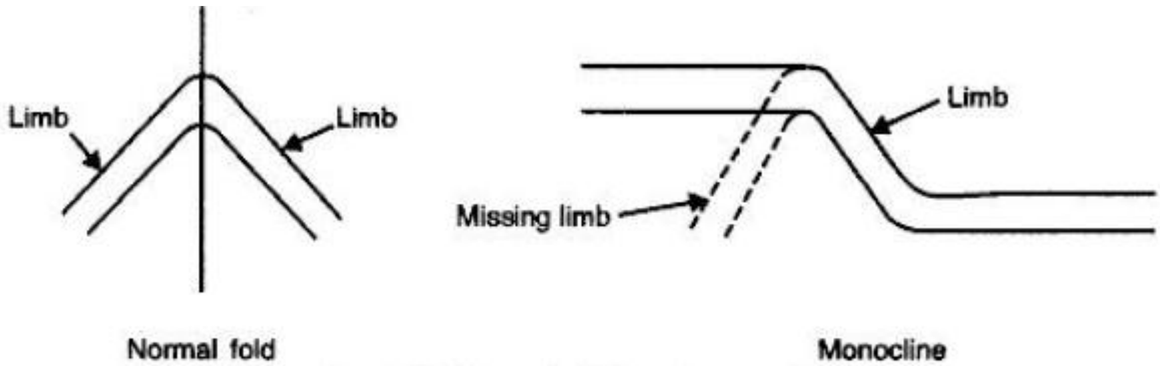
In general, the folds will have two distinct limbs. But some folds do not have any such specific limbs and appear as beds locally pushed up and down. i.e, their shapes appear as domes or basins.



In a dome, the fold resembles as an upper hemisphere and the dips are found in all the sides form the common central top point. This is a type of anticline. In basin, the fold appears like bowl, the slopes are just opposite, i.e, the dips are found towards a common central bottom point from all sides. This is a type of syncline.

Monocline:

It is the fold usually one fold missing. It occurs when beds show a simple bend with similar attitude on either side.



Geanticlines and Geosynclines:

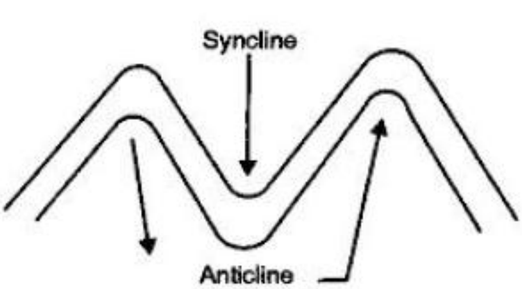
The anticlines and synclines with a normal shape but of very large magnitude are called geanticlines (giant anticlines).

Geosyncline is a term used for a subsiding linear trough that was caused by the accumulation of sedimentary rock strata deposited in a basin and subsequently compressed, deformed, and uplifted into a mountain range, with attendant volcanism and plutonism.

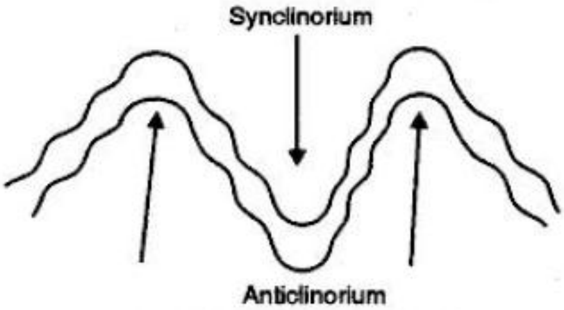
Ex: the Himalayan geosyncline, the Appalachian geosyncline, the Cordilleran geosyncline etc.

Anticlinoriums and synclinoriums:

When the limbs of folds are not plain but characterized by the appearance of other minor folds on them, the major folds are called anticlinorium and synclinoriums.

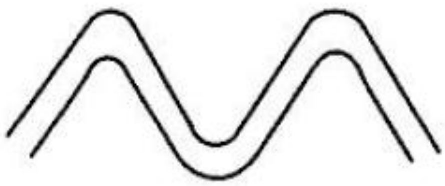


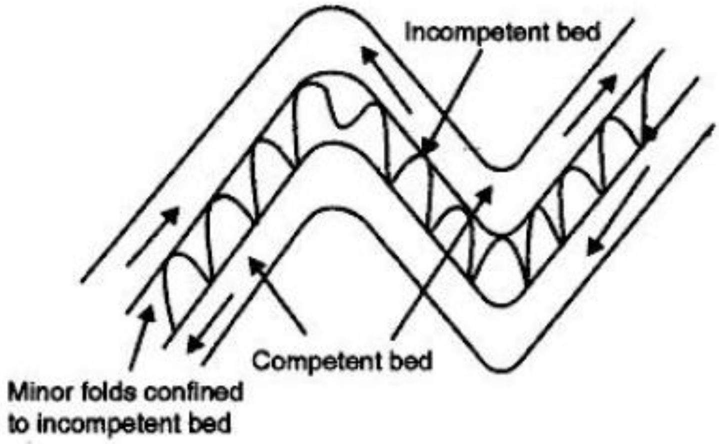
Normal folds



Anticlinorium and synclinorium

Drag Folds: These are the minor asymmetrical folds within major folds but confined only to incompetent beds, which are sandwiched between competent formation. These develop because of the shearing/ dragging effect.


Normal folds

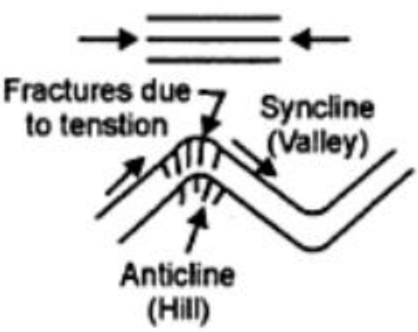


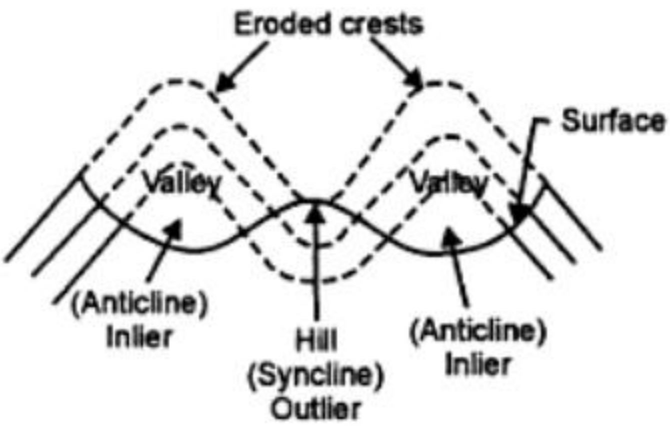
Drag folds in incompetent beds

Effects of folding:

When a folded area is affected by weathering and erosion, interesting topographic features are produced as follows:

- Immediately after folding, anticlines by virtue of their upward bending appear as hills and synclines due to downward wrapping appear as valleys.





- During folding in crest portions, the geological formation is subjected to tensional forces and hence numerous fractures appear there. Because of the fractures, crest portions are eroded quickly leading to conspicuous degradations locally. On the other hand trough portions are highly compressed and hence offer a greater resistance to erosion.

Fault:

A fault is a planar fracture or discontinuity in a volume of rock, across which there has been significant displacement along the fractures as a result of earth movement. Large faults within the Earth's crust result from the action of plate tectonic forces. Energy release associated with rapid movement on active faults is the cause of most earthquakes

A fault line is the surface trace of a fault, the line of intersection between the fault plane and the Earth's surface. Since faults do not usually consist of a single, clean fracture, geologists use the term fault zone when referring to the zone of complex deformation associated with the fault plane.

Causes of Fault:

The relative motion of rocks on either side of the fault surface controls the origin and behaviour of faults, in both an individual small fault and within larger fault zones which define the tectonic plates.

Because of friction and the rigidity of the rock, the rocks cannot glide or flow past each other. Rather, stress builds up in rocks and when it reaches a level that exceeds the strain threshold, the accumulated potential energy is dissipated by the release of strain, which is focused into a plane along which relative motion is accommodated—the fault.

Strain is both accumulative and instantaneous depending on the rheology of the rock; the ductile lower crust and mantle accumulates deformation gradually via shearing, whereas the brittle upper crust reacts by fracture - instantaneous stress release - to cause motion along the fault. A fault in ductile rocks can also release instantaneously when the strain rate is too great. The energy released by instantaneous strain release causes earthquakes, a common phenomenon along transform boundaries.

Microfracturing & AMR (Theory):

Microfracturing, or microseismicity, is often thought of as a symptom caused by rocks under strain, where small-scale failures, perhaps on areas the size of a dinner plate or a smaller area, release stress under high strain conditions. Only when sufficient microfractures link up into a large slip surface can a large seismic event or earthquake occur.

According to this theory, after a large earthquake, the majority of the stress is released and the frequency of microfracturing is exponentially lower. A connected theory, accelerating moment release (AMR), claims that the seismicity rate accelerates in a well-behaved way prior to major earthquakes, and that it might provide a helpful tool for earthquake prediction on the scale of days to years.

AMR is being increasingly used to predict rock failures within mines, and applications are being attempted for the portions of faults within brittle rheological conditions. Researchers observe like behaviour in tremors preceding volcanic eruptions.

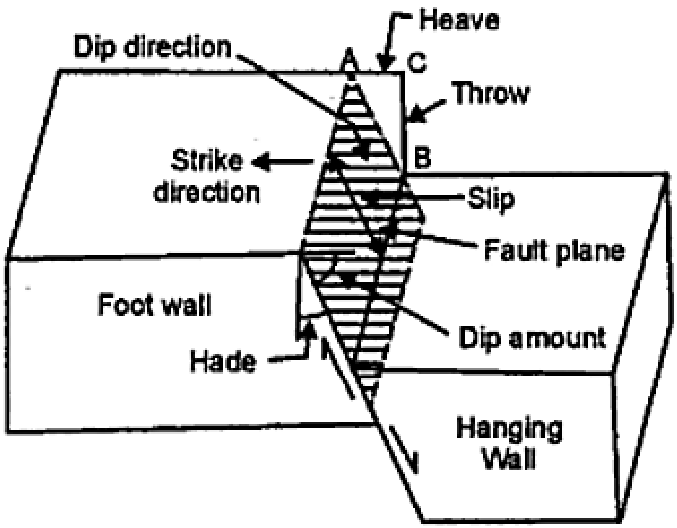
Few technical words:

Slip:

Slip is defined as the relative movement of geological features present on either side of a fault plane, and is a displacement vector.

Sense of slip:

Sense of slip is defined as the relative motion of the rock on each side of the fault with respect to the other side.



Throw:

Throw of the fault is the vertical component of the dip separation

Heave:

Heave of the fault is the horizontal component.

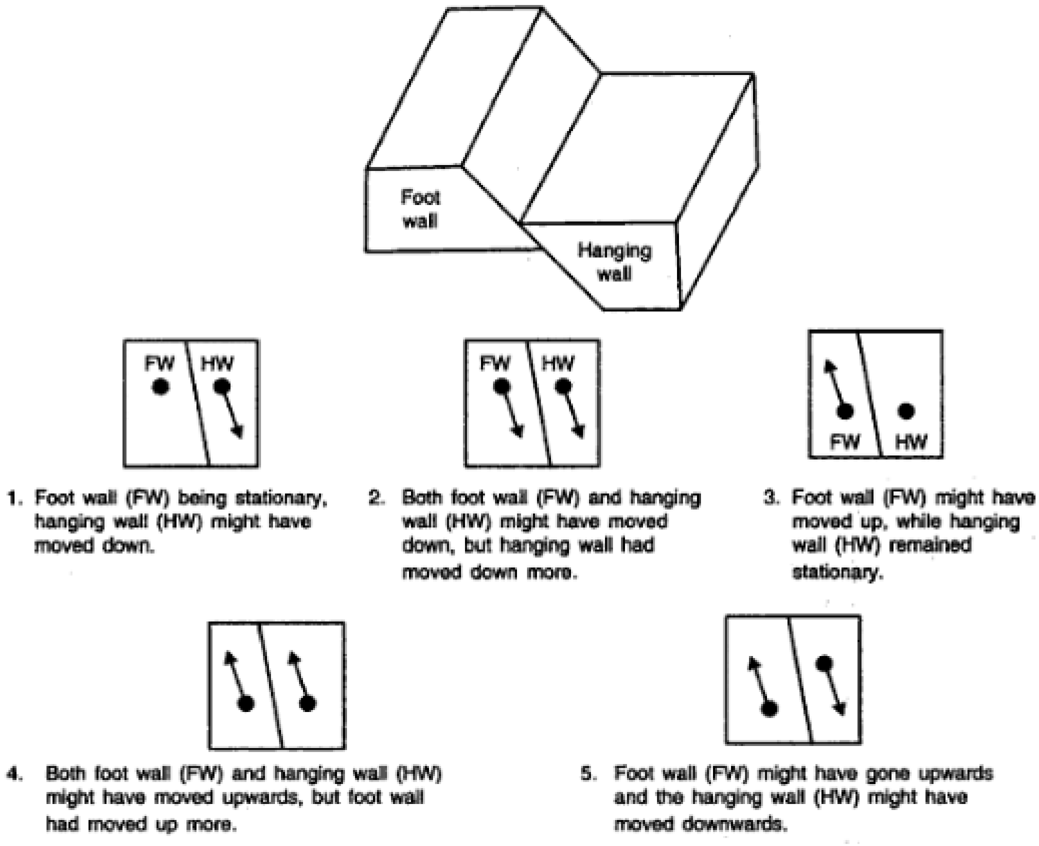
Fault Plane:

The plane along which the adjacent blocks are relatively displaced is fault plane.

Foot wall & Hanging Wall:

The two sides of a non-vertical fault are known as the hanging wall and footwall. By definition, the hanging wall occurs above the fault plane and the footwall occurs below the fault. This terminology comes from mining: when working a tabular ore body, the miner stood with the footwall under his feet and with the hanging wall hanging above him.

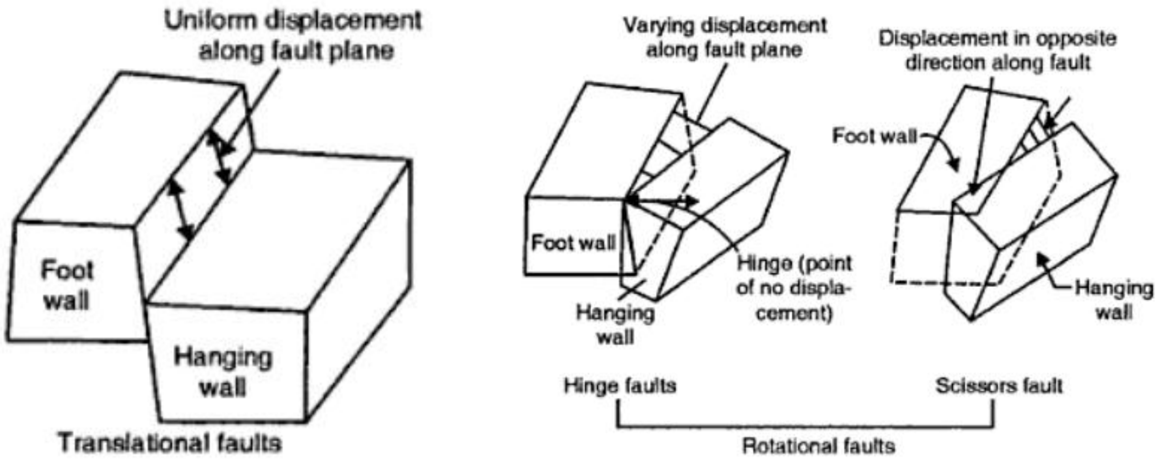
Possible movements causing faults:



Types of faults:

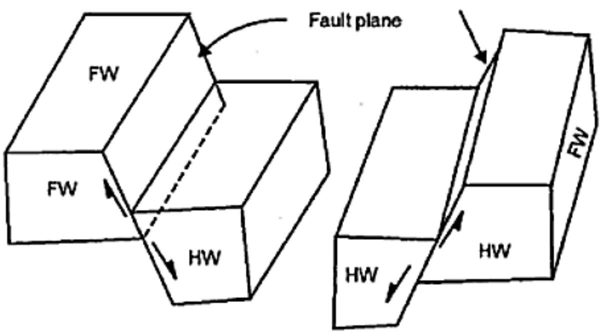
Translational fault:
If the displacement of the footwall with reference to the hanging wall is uniform along the fault plane, it is translational fault.

Rotational fault:
If the displacement of footwall gradually increases or decreases with reference to hanging wall, it is said to be rotational fault.

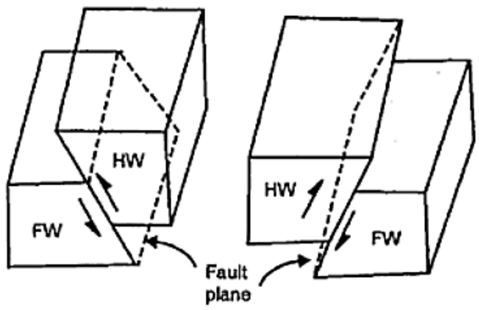


Normal fault:
If the hanging wall goes down with reference to the foot wall, it is called normal fault or gravity fault.

Reverse fault:
If the relative displacement of the hanging wall is upwards with reference to the foot wall, it is reverse fault or thrust fault.

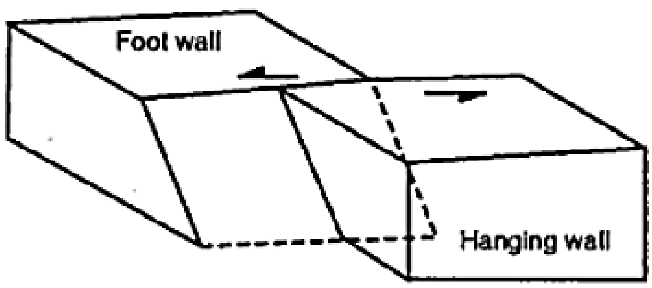


Normal faults

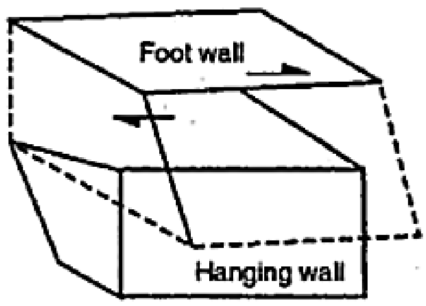


Reverse faults

Dextral faults:
If the relative displacement of the hanging wall is neither upwards nor downwards with the reference to the inclined fault plane, but side wards, then the faults are described as dextral faults. These are also called sinistral faults. If the relative displacement is towards right hand side, it is dextral and if it is towards left hand side, it is sinistral.



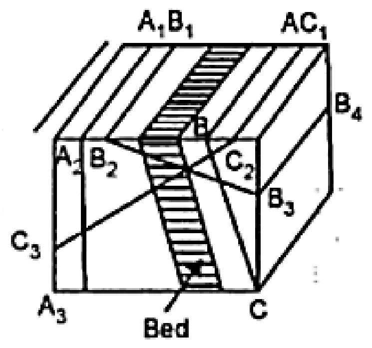
Dextral fault



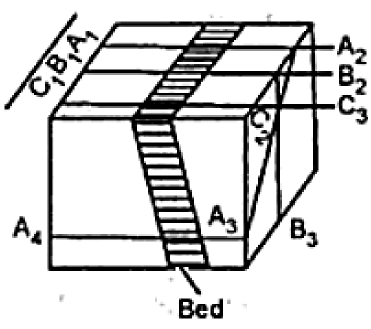
Sinistral fault

Faults basing on the attitudes (Strike & Dip):

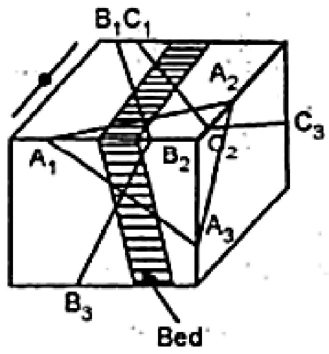
- If the strike direction of the fault plane and that of the adjacent bets are the same the fault is said to be *Strike Fault*.
- If the strike direction of the fault plane is parallel to true dip direction of the adjacent strata, such fault is called *Dip Fault*.
- If the strike direction of the fault plane is parallel to neither the strike direction nor the dip direction of adjacent beds, it is an *Oblique Fault*.
- If the fault plane is parallel to the bedding plane, i.e., when strike direction, true dip direction and true dip amount coincide with the adjacent beds, the fault is called *Bedding Fault*.



Strike Faults



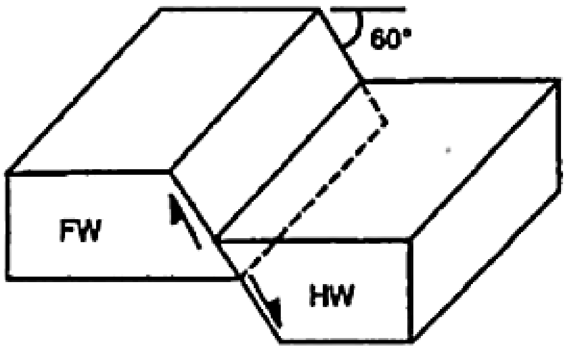
Dip Faults



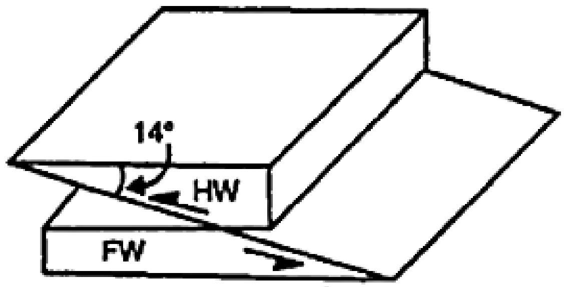
Oblique Faults

High Angle Faults and Low angle Faults:

If the dip amount of the fault plane is steep, i.e., more than 45^{o}C, it is called a high angle fault and if it is a gentle slope (i.e., less than 45^{o}C), it is low angle fault. Generally normal faults or gravity faults are high angle faults while thrust faults are low angle faults.



High angle fault



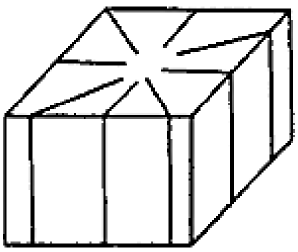
Low angle fault

Faults basing on mode of occurrence:

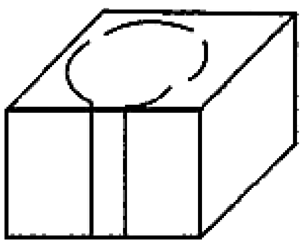
Radial Faults: When a set of faults occur on the surface and appear to be radiating from a common point, they are called radial faults.

En echelion faults: These refer to a series of minor faults which appear to be overlapping one another.

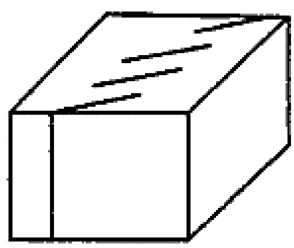
Accurate or peripheral faults: These also refer to a set of relatively minor faults which have curved outcrops and are arranged in a peripheral manner, enclosing more or less a circular area.



Radial faults



Arcuate faults

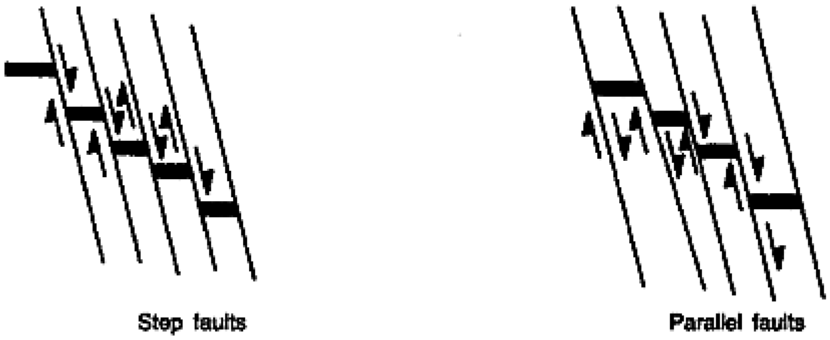


Enechelon faults

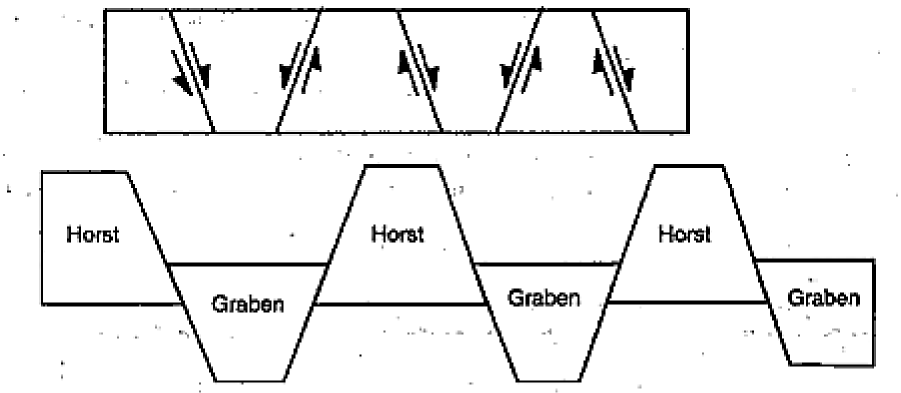
Miscellaneous faults:

Step faults: when a set of parallel normal faults occur at regular intervals, they give a step-lime appearance and are called step faults.

Parallel faults: These are the set of parallel normal faults with the same strike and dip. They are like step faults but may not have a regular interval.



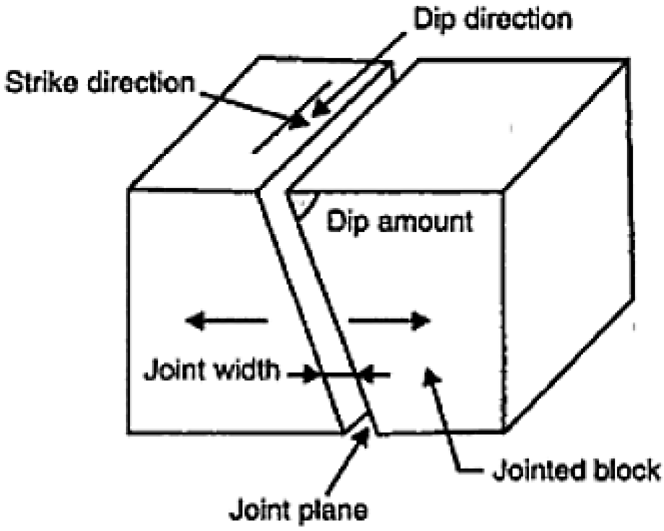
Horsts and grabens: When the normal faults mutually diverge or converge with fault planes, a few wedge-shaped blocks called “horsts” are displaced upwards and a few others (alternating raised blocks) called “grabens” displace downwards.



Large blocks of Horsts are called Block Mountains and large blocks of grabens are called Rift Valleys.

Joints:

Joint is a fracture in rock where the displacement associated with the opening of the fracture is greater than the displacement due to lateral movement in the plane of the fracture (up, down or sideways) of one side relative to the other. Typically, there is little to no lateral movement across joints. This makes joints different from a fault which is defined as a fracture in rock in which one side slides laterally past the other with a displacement that is greater than the separation between the blocks on either side of the fracture. Joints normally have a regular spacing related to either the mechanical properties of the individual rock or the thickness of the layer involved. Joints generally occur as sets, with each set consisting of joints sub-parallel to each other.



Formation:

Joints form in solid, hard rock that is stretched such that its brittle strength is exceeded (the point at which it breaks). When this happens the rock fractures in a plane parallel to the maximum principal stress and perpendicular to the minimum principal stress (the direction in which the rock is being stretched). This leads to the development of a single sub-parallel joint set. Continued deformation may lead to development of one or more additional joint sets. The presence of the first set strongly affects the stress orientation in the rock layer, often causing subsequent sets to form at a high angle to the first set.

Joint sets are commonly observed to have relatively constant spacing, which is roughly proportional to the thickness of the layer.

Effects of joints:

From the civil engineering point of view, joints are important because they split the rocks into a number of pieces which, in turn, reduce the competence of rock mass, increase the porosity and permeability and make them susceptible to quick decay and weathering. Joints become avenues for the leakage of water in case of reservoirs. If they are closely spaced in the upstream side, silting problems also arise in reservoirs. Joints may pose ground water problems in tunnelling. The incompetence, leakage and other effects introduced by joints in rocks may create foundation problems at dam sites. Depending on the relation of the dip of joints in rocks with reference to the surface slope, they may pose problems in laying roads and railways along hill slopes. But a few advantages that accompany joints are: their occurrence increases the ground water potentiality in any place. Suitably spaced joints not only facilitate the quarrying process or tunnelling process but also reduce the cost by decreasing the use of explosives.

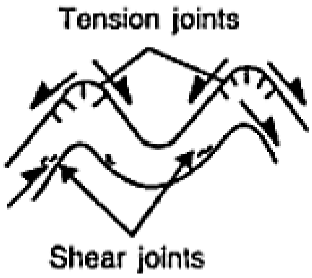
Types of Joints:

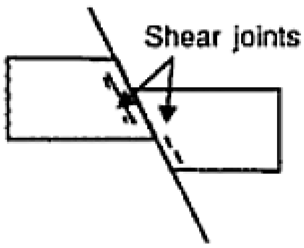
Strike joints or Dip joints: When the joints are parallel to the strike direction or dip direction of adjacent beds, they are called strike joints or dip joints.
If the strike or dip direction is not parallel to joints they are called *oblique joints*.

Bedding joints: If the attitude of joints (dip direction or amount, strike direction or amount) coincides completely with the attitude of adjacent beds, they are called bedding joints.

Tension joints: The columnar joints which occur normally in basalts due to the tensional forces are called tension joints.

Sheer joints: These develop in those contexts where shearing forces prevail. Faults and limbs of folds are the places where shearing forces occur and create shear joints.





Mural joints: The joints that occur in sets are called mural joints. Normally there will be three sets of joints, of which two are vertical sets and the other horizontal (resembling the cubic cleavage found in minerals). In granite all the joints will be mutually perpendicular. The mural joints are often accompanied by the sets of micro-factures, called *Rift and Grain*.
From the civil engineering point of view, the mural joints facilitate easy quarrying, while rift and grain are helpful in the dressing of rocks.

Sheet joints: The horizontal joints sheen in plutonic igneous rocks, are called sheet joints. These normally occur near the surfaces of the structures that too parallel. These mainly occur due to the release of overburden or thermal effect of plutonic rocks.

Joints in sedimentary rocks: Normally tension and shearing joints are seen in sedimentary rocks. Some lime stones and sand stones are characterized by set of parallel factures that enables them to be split into uniform thin sheets. These rocks are called flaggy sandstones or flaggy limestones. Cuddapah slabs and Shahabad stones.

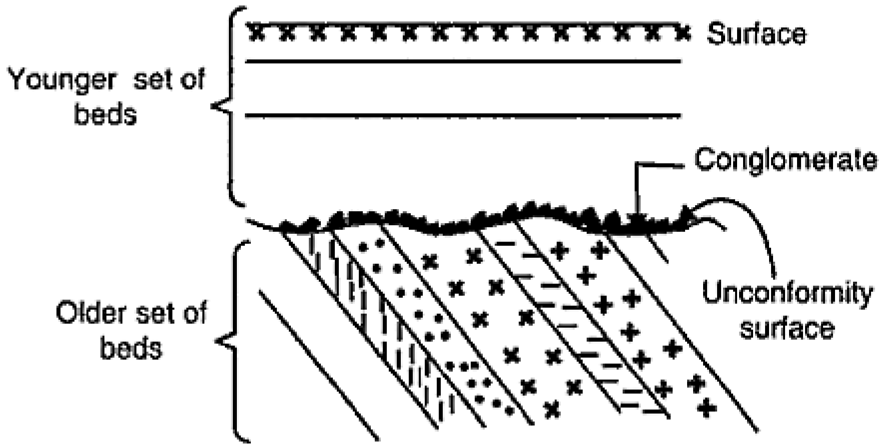
Joints in metamorphic rocks: Though joints are common in metamorphic rocks. These joints do not have any definite pattern.

Unconformity:

Unconformity is one of the common geological features found in the rocks that are different form fault, fold or joint.

An unconformity is a buried erosional or non-depositional surface separating two rock masses or strata of different ages, indicating that sediment deposition was not continuous. In general, the older layer was exposed to erosion for an interval of time before deposition of the younger, but the term is used to describe any break in the sedimentary geologic record.

"Unconformity is the major break that occurred in sedimentation processes".



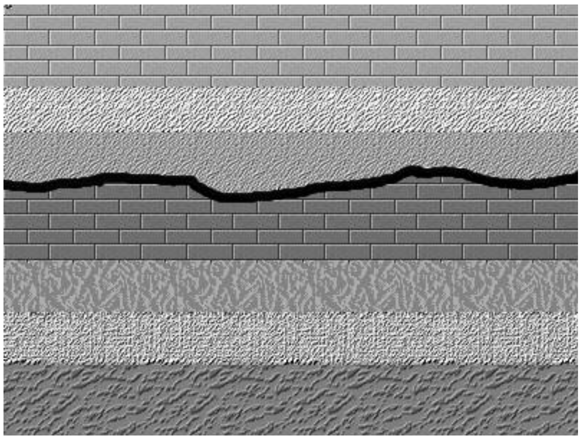
The rocks above an unconformity are younger than the rocks beneath (unless the sequence has been overturned). An unconformity represents time during which no sediments were preserved in a region. The local record for that time interval is missing and geologists must use other clues to discover that part of the geologic history of that area. The interval of geologic time not represented is called a *hiatus*.

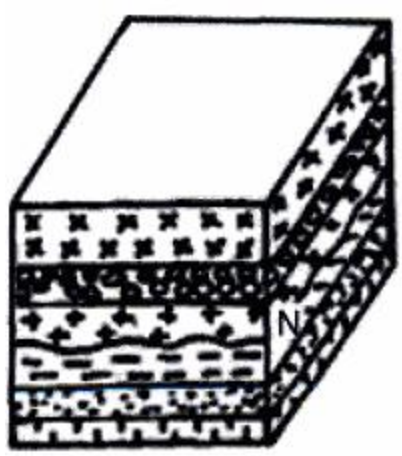
Types of unconformities:

DISCONFORMITY:

A disconformity is an unconformity between parallel layers of sedimentary rocks which represents a period of erosion or non-deposition. Disconformities are marked by features of sub-aerial erosion. This type of erosion can leave channels and paleosols in the rock record. A paraconformity is a type of disconformity in which the separation is a simple bedding plane with no obvious buried erosional surface. A blended unconformity is a type of disconformity or nonconformity with no distinct separation plane or contact, sometimes consisting of soils, paleosols, or beds of pebbles derived from the underlying rock.

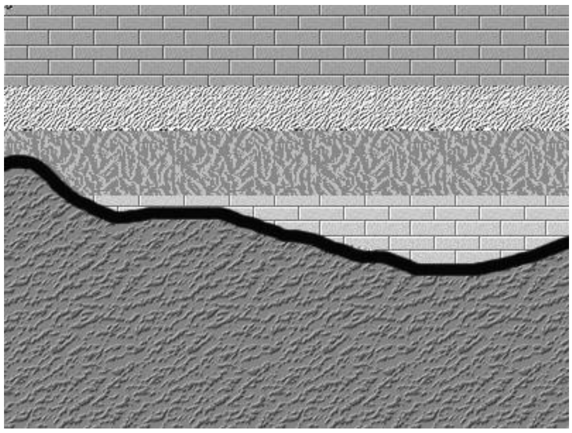
"If the beds of the younger and older sets are mutually parallel and the contact plane of two sets is only an erosion surface with conglomerate than the unconformity is called "disconformity"".

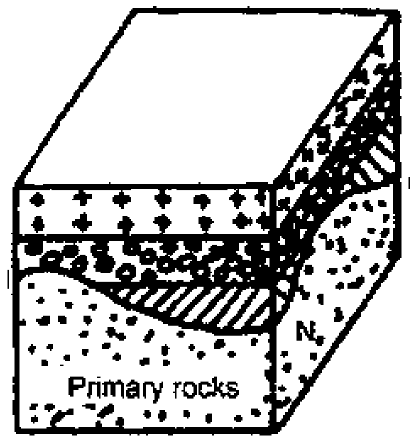




Nonconformity:

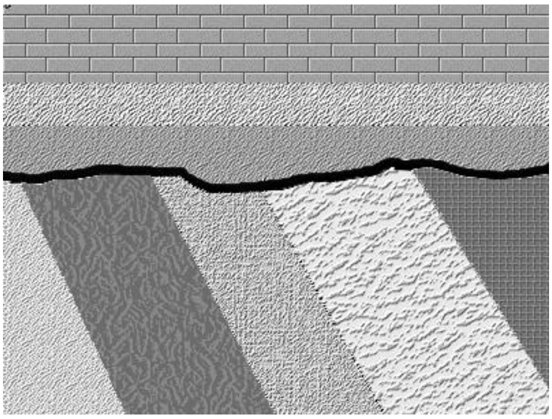
Nonconformity exists between sedimentary rocks and metamorphic or igneous rocks when the sedimentary rock lies above and was deposited on the pre-existing and eroded metamorphic or igneous rock. Namely, if the rock below the break is igneous or has lost its bedding by metamorphism, the plane of juncture is nonconformity.

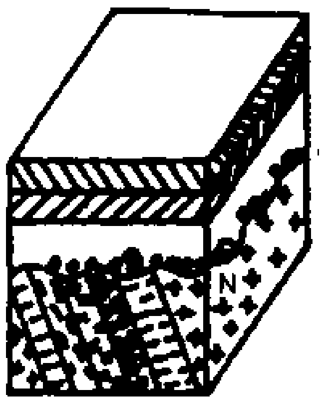




Angular unconformity:

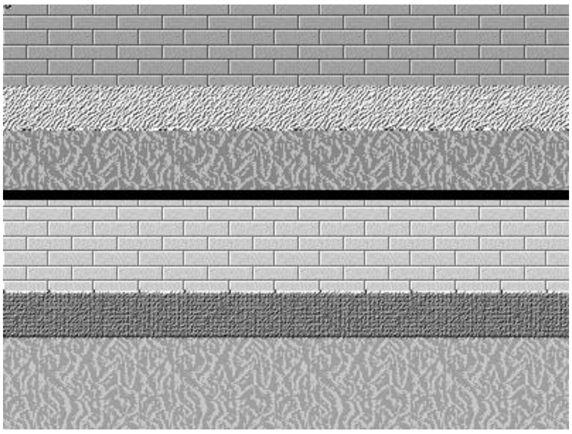
An angular unconformity is an unconformity where horizontally parallel strata of sedimentary rock are deposited on tilted and eroded layers, producing an angular discordance with the overlying horizontal layers. The whole sequence may later be deformed and tilted by further orogenic activity.

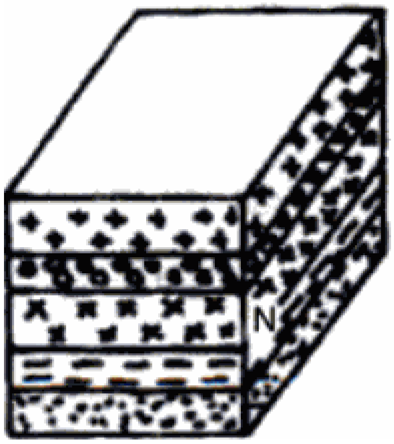




Paraconformity:

A paraconformity is a type of unconformity in which strata are parallel; there is little apparent erosion and the unconformity surface resembles a simple bedding plane. It is also known as nondepositional unconformity or pseudoconformity





Recognition of unconformities:

Unconformities can be identified by the following ways:

1. Difference in attitudes of two adjacent sets of beds (disconformity is an exception).
2. Remarkable difference in nature, age and types of fossils in adjacent sets of beds.
3. Occurrence of conglomerates along the unconformity plane.
4. Occurrence of residual soil/laterite/bauxite along the unconformity surface.
5. Considerable difference in the degree of metamorphism of two adjacent sets of beds.
6. Statigraphical correlation and lithological peculiarities.

Symbols indicating the geological structures.