Program : **B.Tech**

Subject Name: **Engineering Geology and Remote Sensing**

Subject Code: **CE-405**

Semester: **4th**

Unit 4

Structural geology: dip, strike, outcrops, classification and detailed studies of geological structures i.e. Folds, Faults, Joints, Unconformity and their importance in civil engineering.

Structural Geology

As a branch of geology, it deals with 'the study of systems located in rocks'. it's also referred to as tectonic geology or simply tectonics. Structural geology is an arrangement of rocks and performs an critical position in civil engineering in the selection of appropriate sites for all forms of initiatives consisting of dams, tunnels, multistoried homes, etc. Structural geology is the look at of the three dimensional distribution of rock units with respect to their deformational histories. The number one intention of structural geology is to use measurements of gift-day rock geometries to find information approximately the history of deformation (strain) inside the rocks, and ultimately, to recognize the strain area that resulted inside the determined strain and geometries.

Structural Functions/ Attitude of beds:

a) Out crop -: The rock exposure at the floor of the earth. Outcrops permit direct remark and sampling of the bedrock in situ for geologic analysis and developing geologic maps. In situ measurements are important for correct evaluation of geological records and outcrops are therefore extremely vital for know-how the geologic time scale of earth history.

b) Contour:- a contour line (often just called a "contour") joins points of equal elevation (height) above a given level, such as mean sea level. A contour map is a map illustrated with contour lines, for example a topographic map, which thus shows valleys and hills, and the steepness or gentleness of slopes.

Types of contour lines:-

1. Index Contour Lines:- Index contour lines are accented with a heavier mark, so that these lines will be the first thing to catch your eye when you look at a topographical map. Like all contour lines, they form in concentric circles or shapes and each index contour line is evenly spaced from one line to the next. Typical intervals between contour lines might be 100 or 200 feet although greater or lesser numbers are possible. Index contour lines are marked with the elevation above sea level and they are usually figured in intervals, such as every 100 or 200 feet.

2. Intermediate Contour Lines:- Between each pair of contour lines, there exists a set of intermediate contour lines. The intermediate contour lines usually come in sets and each intermediate contour line represents an equal amount of elevation change between each line. Also important is the fact that the elevation change between one index contour line and an adjacent intermediate contour line will also be the same value as the change between two intermediate contour lines that are located next to each other.

For example, if on a map, you have your index lines placed 100 feet apart, the likely scenario is that there will be four intermediate contour lines placed between each pair of index lines. Four lines would create five spaces and to make the change equal, the gap between each line would have to represent 20 feet of elevation change. It is important to remember that intermediate and supplementary contour lines are not marked with their elevation above sea level.

3. Supplementary Contour Lines:- Supplementary contour lines are expressed as a dashed line. These lines are drawn at all one elevation, but they differ from the previous two types of lines in that their spacing or change in elevation that they represent is different. They almost always represent half the elevation change that is found between intermediate and index contour lines. Therefore, these lines are only used on topographic maps where the overall change in elevation is very gradual or slight.

c) Strike-: The fashion of the rock bed on the floor surface is strike. Strike, in geology, direction of the line formed by the intersection of a fault, mattress, or different planar function and a horizontal plane. Strike indicates the mind-set or function of linear structural features consisting of faults, beds, joints, and folds.

d) Dip-: The attitude of inclination of a rock mattress with the horizontal aircraft is called dip. It measured in a aircraft perpendicular to the stripe line.

There are kinds of dip.

1. True dip: it's far a perpendicular aircraft to the strike line.

2. Apparent dip: it's far a dip measured in some other course than the true dip is known as apparent dip.

Fold

Fold may be described because the curve or zigzag shape proven via rock beds. In other wordsWavy undulation in rock beds are called folds.

Or

A geological fold occurs whilst one or a stack of originally flat and planar surfaces, together with sedimentary strata, are bent or curved because of permanent deformation. Synsedimentary folds are the ones due to slumping of sedimentary fabric before it's miles lithified.

Terms associated with FOLDING:

a) Limbs
b) Axial line
c) Axis of folds
d) Crest
e) Trough

1. **Limbs:-**

The sloping facets of folds from crest to trough are known as the limbs. An character fold could have no less than two limbs.

2. **Axial Line:-**

It's miles an imaginary plane or a floor which divides a fold into two equal halves.

3. **Axis of Folds:-**

An axis of fold is described as the line of intersection among the axial aircraft and the surface of any of the constituent rocks mattress.

4. **Hinge Line:-**

Crest is the area in which the curvature is greatest, and the limbs are the edges of the fold that dip faraway from the hinge.

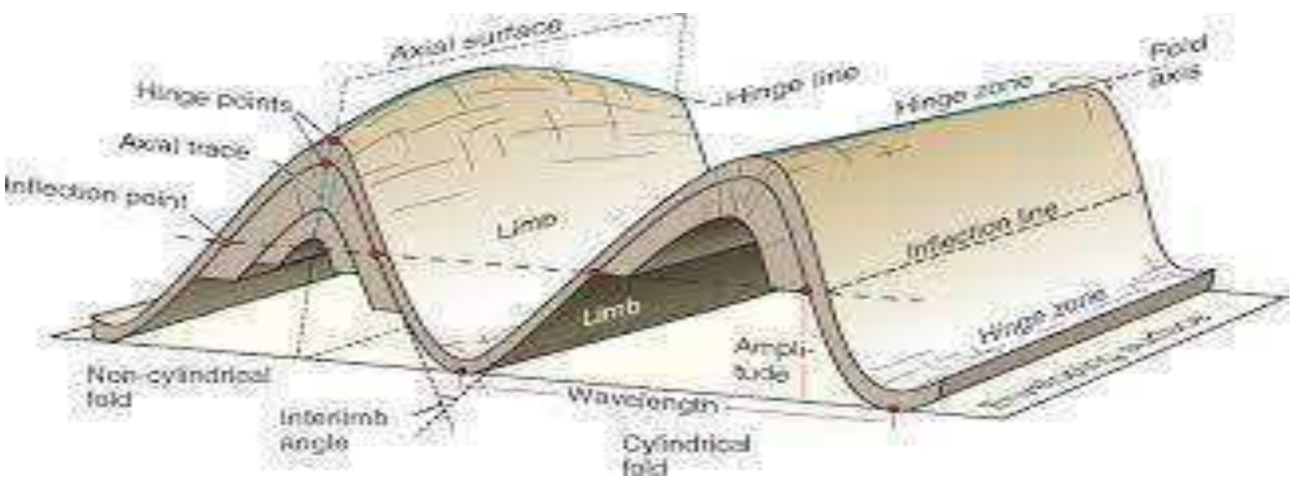
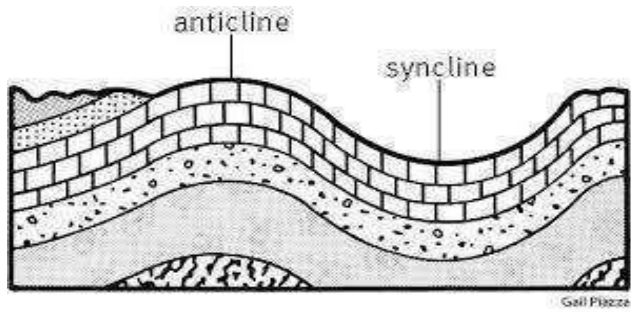


Fig. 9 Structure of Fold

Classification of Folds

1. **Fundamental category**
2. **Unique classification**
3. **Fundamental category**
    a) **Syncline: - Anticlines are folds in which every 1/2 of the fold dips away from the crest.**
    b) **Anticline: - Synclines are folds wherein every half of the fold dips towards the trough of the fold.**



Unique classification

1. **Based On The Position Of Axial Plane:**
   a) Symmetrical fold
   b) Asymmetrical fold
   c) Overturned fold
   d) Recumbent fold
   e) Isoclinal fold
2. **Primarily Based On Degree Of Compression:**
   a) Open folds
   b) Closed folds
3. **Based Totally On Mode Of Foundation:**
   a) Basin
   b) Dome
   c) Anticlinorium
   d) Synclinorium
   e) Geosyncinorium
   f) Geoanticlinorium

Folds are created in rock once they enjoy compression pressure this is when the rock is being driven inward from each facet that is like in case you placed a spring among your fingers and push them together. As you push, you're compressing the spring, and rock can be compressed inside the equal manner over long periods of time. There are exceptional types of folds created via compression pressure relying on which way the rock bends.

a) A monocline is a fold in which the rock layers shape an S-form as the perimeters of the rock are compressed. you can don't forget this sort of fold because all of the layers of rock are nonetheless horizontal, entering into one direction in preference to bending vertically upward or downward like anticlines and synclines. And seeing that 'mono' method 'one,' monoclines are layers in simplest 'one course.'

b) Domes, which can be like anticlines however instead of an arch, the fold is in a dome form, like an inverted bowl. Similarly, there also are basins, which can be like synclines but once more, as opposed to a sinking arch, the fold is within the form of a bowl sinking down into the ground.

c) Symmetrical folds are folds with the same angle. This makes sense on account that symmetry approaches the identical on each facet. We can also have the opposite of symmetrical, which takes place in asymmetrical folds, or folds with one of kind angles.

d) Isoclinal folds are just like symmetrical folds; however those folds each have the identical attitude and are parallel to every other. 'Iso' means 'the identical' (symmetrical), and 'cline' way 'angle,' so this calls literally method 'same angle.' So, Isoclinal folds are both symmetrical and aligned in a parallel style.

e) Overturned folds occur when the folding is so severe that the fold appears to have turned over on itself. Further, we can have recumbent folds, which might be even more intense than overturned folds these are folds which might be almost horizontal. 'Recumbent' way 'mendacity down,' so you could think about this fold as mendacity down sideways.

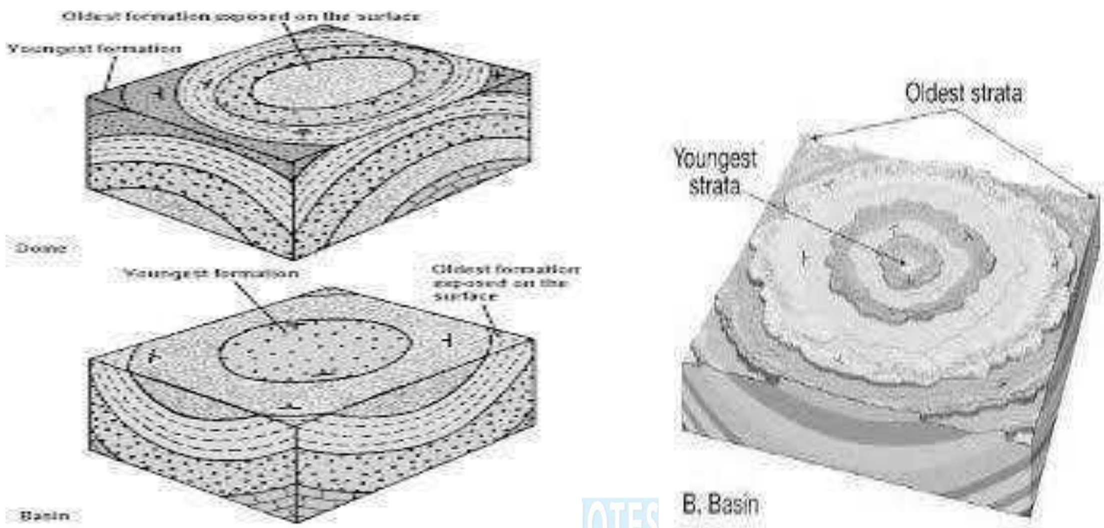


Fig. 10 Dome and Basin

Causes of Folding:

The folds arise as a result of the tectonic pressure and stress in the rocks and rather than fracture, they fold. They are easily visualized by the loss of horizontality of the strata. When tectonic forces acting on sedimentary rocks are a number of characteristic forms. Sedimentary rocks are more flexible than the metamorphic, and when the thrust is not intense enough to move them fold as if they were a piece of paper.

A fold is a bending of the rocks of the earth's crust. It is structured in the form of waves, successive. As such some of the features of the folds correspond to a wave either.

Rock layers in Folds

The rock layers in folds can be folded in two ways: as a result of transverse bending and by longitudinal bending.

Transversal flexure

The layer is bent under the action of forces applied perpendicular to the layer plane direction. For this slouch, various forces must exist. The folds that arise in this case are caused by the transverse bending folds. The most characteristic among them arise as a result of the action of vertical forces applied to the horizontal layers.

For example, the bending folds transversal firm layers that cover the crystalline basement, elevated above the block bounded by the fractures. The forces that form pairs are directed from the bottom up to meet the latter and are caused by the gravitational force, which holds the layers in its original level outside the boundaries of the block that rises.

Longitudinal flexure

It arises under the action of the compressive force parallel to the direction layers. The latter, during the longitudinal compression, loses its stability and deforms rather than uniformly thickening, they are curved. The role of the layered structure of the rocks during the transverse and longitudinal deflections is not the same.

During transverse bending, even if there is no mechanical dividing determined by stratification, the deformation end with the formation of a fold. For example, if the layers are drawn simply in the side wall of a plastic test tube and, therefore, they cannot play any mechanical role. A result of the first deformation will turn out to be in a curved fold transverse bending.

The longitudinal bending plays different stratification geological folds in principle without the latter in any way that may form folds, since one of the conditions for their formation necessary during bending is longitudinal slip between possible layers. The slouching packet divided by folds of strata slips relieved surfaces, all sliding layer to the underlying, towards the dome and anticline respect to the overlying, towards the hook syncline. Due to friction, to bend the strata, all inside layer is under the action of a pair of forces, one of which (on the roof of the layer) is directed towards the anticline dome. The other (in the wall layer) is directed to the hook of the syncline. This torque tends to cause a deformation in the displacement layer.

Faults

In geology, a fault is a planar fracture or discontinuity in a quantity of rock, throughout which there has been substantial displacement due to rock-mass motion. large faults within the Earth's crust end result from the movement of plate tectonic forces, with the largest forming the boundaries between the plates, including subduction zones or remodel faults energy release associated with fast motion on energetic faults is the reason of most earthquakes.

Types of Faults

On the basis of slip

1. Dip slip fault
2. Strike slip fault
3. Oblique slip fault

a) Dip slip fault:- The faults in which the slip takes area along the direction of the slip is referred to as dip slip fault inside the dip slip fault net slip is parallel to the dip of fault

b) Strike slip fault:- The faults wherein the slip takes vicinity alongside the path of the strike is called dip slip fault .inside the dip slip fault net slip is parallel to the strike fault

c) Oblique strike fault:- while the net slip is neither parallel to strike nor parallel to the dip of fault is known as oblique strike fault.

On the basis of movement:

1. Normal fault
2. Reverse fault

a) Normal fault: - A dip-slip fault in which the block above the fault has moved downward relative to the block below. This type of faulting occurs in response to extension. “Occurs when the “hanging wall” moves down relative to the “foot wall”

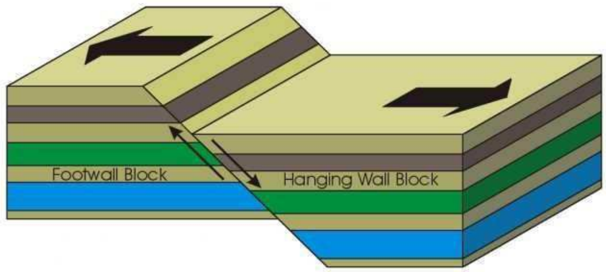


Fig. 11 Normal Fault

b) Reverse fault

A dip-slip fault in which the upper block, above the fault plane, moves up and over the lower block. This type of faulting is common in areas of compression, when the dip angle is shallow, a reverse fault is often described as a thrust fault. “Occurs where the “hanging wall” moves up or is thrust over the “foot wall”

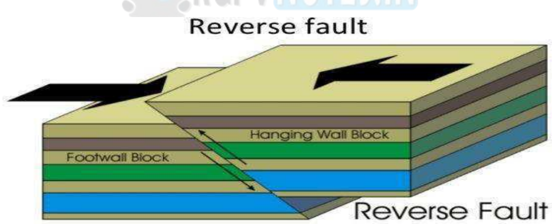


Fig. 11 Reverse Fault

On the basis of angle:-

1. High angle fault :- A high attitude fault is one that dips at angle more than 45°
2. Low angle fault:- A low perspective fault is one which dips at angle smaller than 45°

On the basis of formation:-

1. Parallel faults
2. Step faults
3. Graben or rift fault
4. Horst
5. Radial fault

6. Peripheral faults
7. Enechelon faults

a) Parallel fault

A chain of faults strolling greater or less parallel to one another and all handing in the same route, are called "parallel faults"

b) Step fault

It's far consists of those parallel faults in which down throw of all are in the same course and it offers a step like association

c) Graben or Rift fault

Whilst regular faults fade in the direction of every other and the beds between them are thrown down within the form of a wedge, the shape is known as graben or rift fault

d) Horst

A horst includes a important block on the both aspects of which adjacent beds seem to were faulted down

e) Radial faults

Some of faults exhibiting a radial pattern are described as radial faults

f) Peripheral faults

Curved faults of extra or much less round, or are like outcrops on stage surface are referred to as peripheral faults

g) Enechelon Faults

Enechelon fault are relatively quick faults which overlap each different

On the basis of altitude:-

1. Dip fault
2. Strike fault
3. Bedding fault
4. Oblique fault
5. Tear fault or transcurrent fault

a) Dip fault

A dip fault is one shore strike is parallel to the dip of strata and also referred to as transverse faults whilst it runs across the overall shape of the region

b) Strike Fault

A strike fault is one shore strike is parallel to the strike of strata and also called longitudinal faults while it runs throughout the general structure o the area

c) Bedding fault

When strike of the fault aircraft is oblique to the strike of dip of strata, its miles called an oblique fault

e) Oblique fault

While the strike of the fault plane is oblique to the strike and dip of strata, it's far referred to as an indirect Fault.

f) Tear fault or transcurrent fault

It generally moves transverse to the strike of united states rocks .the fault aircraft is more or less vertical and often enlarge from an extended distances it's also referred to as a wrench fault.

Causes of faults:-

Geological faults happen when stress occurs and determines the fault's type after the event. There are three main categories of stress:

a) Compression stress:- Occurs at convergent plate boundaries. The plates move and crash toward each other. This is what like when two cars crash into each other.

b) Tension stress: - Occurs at divergent plate boundaries. The plates are drifting away from each other.

c) Shear stress:- Occurs majorly at transform boundaries. The plates slide past each other horizontally in opposite directions.

Joints:-

A brittle-fracture surface in rocks along which little or no displacement has occurred

Types of Joints:

Joints are classified based on (a) forces causing the joints and (b) the position of the joint relative to the dip and strike of the rock bed.

Joints of the former type are said to be of Genetic type and the latter of Geometric type.

1. Genetic Types of Joints:- These joints are of two types, namely tension joints and shear joints. Tension joints are large as well as wide. These joints are formed by tensile forces which are induced due to change in volume of rocks due to drying shrinkage in the process of cooling or dehydration and stretching of the fold limbs of strata. The tension joints appear rough, irregular with jagged surfaces. Rocks easily yield to tensile forces and the rock joints are mostly tension joints.

Tension Joints in Igneous Rocks: - As magma undergoes cooling and solidifies or as lava gradually cools and becomes rigid, cracks or ruptures occur forming tension joints.

These joints may be mural joints or sheet joints or columnar joints.

Mural Joints:- These joints are common in granites and related plutonic rocks and some hypabyssal rocks. These joints appear in a three dimensional network, the joint sets being mutually perpendicular to each other. The joints break the rock into separate somewhat cubical blocks. Such block separation permits easy quarrying of the rock. The joints may be attacked by weathering agents due to whose actions the separated cubical blocks may get rounded.

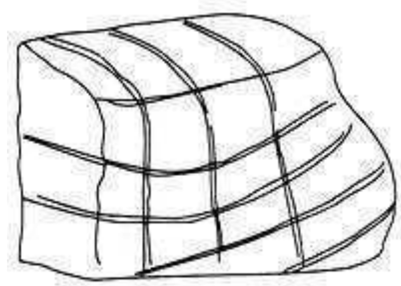


Fig. 17.46 Mural joints in granite

(b) Sheet Joints:- These joints also are seen in granites and other plutonic rocks. In this case there is one set of prominent joints parallel to the ground surface whose spacings generally increase with depth and a second set running at right angles. The joints in this case separate the rock body into sheet like blocks.

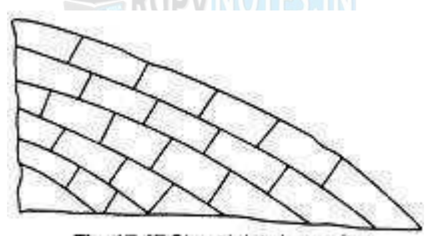


Fig. 17.47 Sheet joints in granite

(c) Columnar Joints:- These joints are seen in basalts and some other volcanic igneous rocks. They consist of vertical and horizontal joints separating the rock body into a number of vertical polygonal (quite often hexagonal prismatic columns). When the horizontal lavas cool weak planes are developed by radial contraction causing these joints.

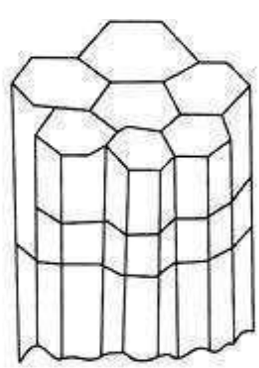


Fig. 17.48 Columnar joints in basalt

Tension Joints in Sedimentary Rocks:- When many layers of sediments are deposited, during their consolidation under high pressure ruptures occur breaking them into smaller volumes. These joints appear at right angles to each other in more or less regular intervals. These are common in massive and also the bedded sedimentary rocks. The most common tension joints of sedimentary rocks are called master joints.

Master Joints:- These joints are mostly seen in sandstones and limestone's. These joints consist of three sets of mutually perpendicular joints. One set of joints is parallel to the bedding planes. The other two sets are perpendicular to the bedding planes and occur in staggered pattern. These joints continue for long distance maintaining regularity in spacing and width and are therefore named as master joints.

Extension and Release Joints:- These joints are seen in folded rock strata. These joints are formed in the crustal region of the fold and they extend parallel or at right angles to the axial plane or in both these directions. The joints running parallel are called release joints (they run along the strike of the folds) and the joints running at right angles to these are called extension joints.

Shear Joints:- These are joints associated with deformed rocks especially folded rocks. These joints occur as intersecting or crisscrossing sets at a high angle. These joints are referred to as conjugate joint system. These joints are produced by the action of shear stresses occurring in folding and faulting stages. They are narrowly spaced intersection joints.

Geometric Joints:- In this case the joints are classified based on their attitude relative to the dip and strike of the rock strata. In this case the joints are classified into dip joints, strike joints and oblique joints. Dip joints run in the direction of the dip of the strata. (Ex: Extension joints). Strike joints run in the direction of the strike of the strata (Ex: Release joints). Oblique joints are at some inclination to the dip and strike directions of the strata. These joints are also called diagonal joints. (Ex: Conjugate joints).

Unconformities

Unconformities are gaps in the geologic record that may indicate episodes of crustal deformation, erosion, and sea level variations. They are a feature of stratified rocks, and are therefore usually found in sediments (but may also occur in stratified volcanic). They are surfaces between two rock bodies that constitute a substantial break (hiatus) in the geologic record (sometimes people say inaccurately that "time" is missing). Unconformities represent times when deposition stopped, an interval of erosion removed some of the previously deposited rock, and finally deposition was resumed.

Commonly three types of unconformities are distinguished by geologists:

Angular Unconformities:- Angular Unconformities are those where an older package of sediments has been tilted, truncated by erosion, and then a younger package of sediments was deposited on this erosion surface. The sequence of events is summarized in the pictures at left. First: subsidence and sediment deposition occurs; Second: rocks are uplifted and tilted (deformation); Third: erosion removes the uplifted mountain range; Fourth: subsidence occurs, the sea covers the land surface, and new sediments deposition occurs on top the previous land surface. Then the cycle may repeat.

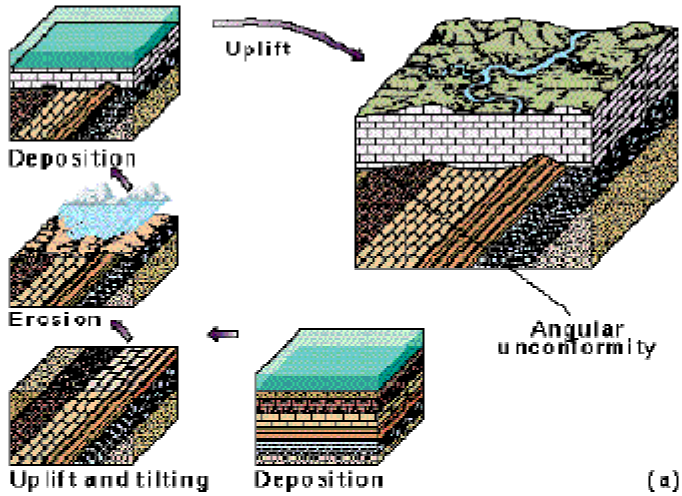


Fig 14 Process of Unconformity

Disconformities: - Disconformities are also an erosion surface between two packages of sediment, but the lower package of sediments was not tilted prior to deposition of the upper sediment package. The sequence of events is as follows: First: subsidence and sediment deposition; Second: uplift and erosion; Third: renewed subsidence and deposition. Because the beds below and above the disconformity are parallel, disconformities are more difficult to recognize in the sedimentary record. In the diagram at left, the disconformity is indicated by an irregular black line between the 3rd and 4th rock unit from the bottom.

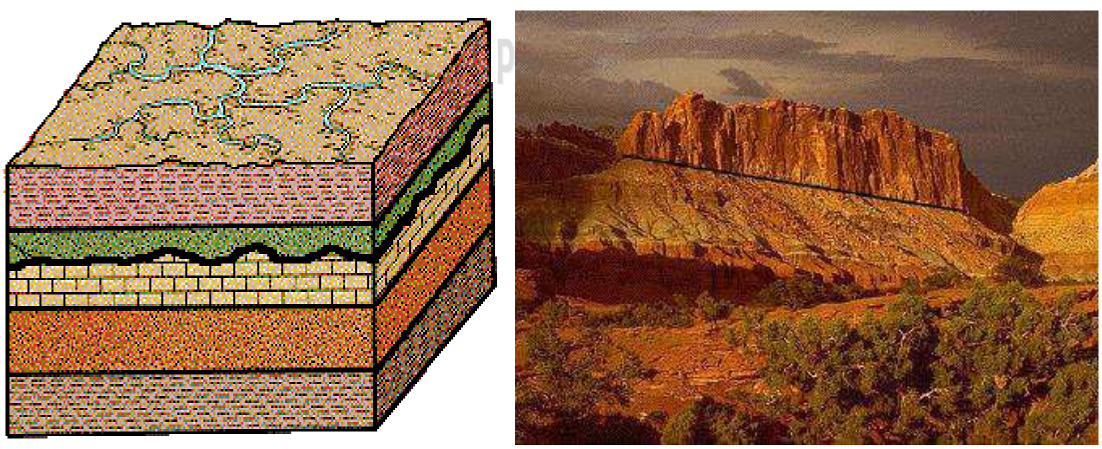


Fig. 15 Disconformities

Nonconformities:- Nonconformities are unconformities that separate igneous or metamorphic rocks from overlying sedimentary rocks. They usually indicate that a long period of erosion occurred prior to deposition of the sediments (several km of erosion necessary). In the diagram at left, the igneous/metamorphic rocks below the nonconformity are colored in red.

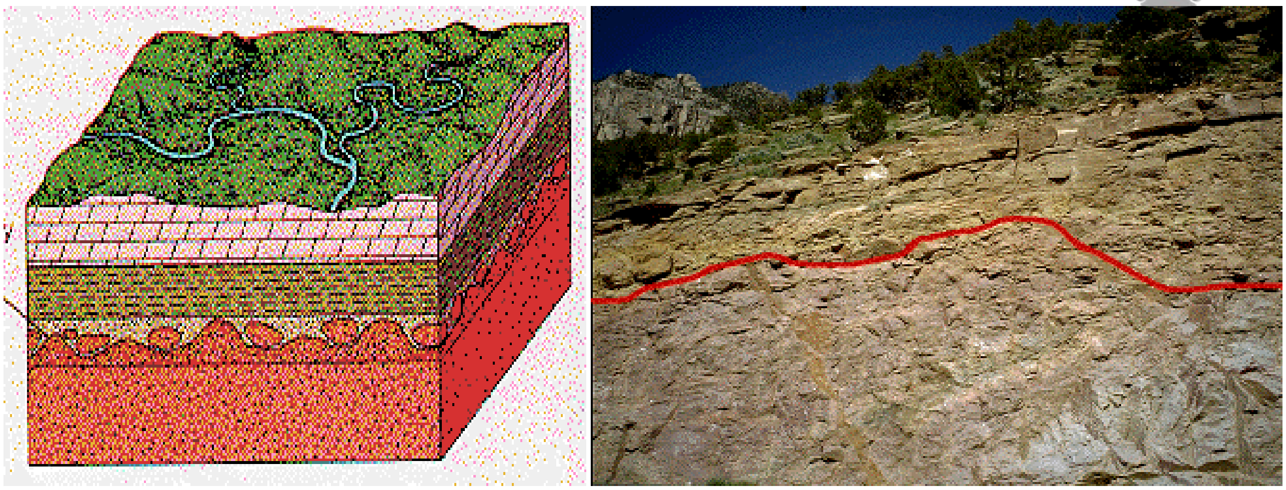


Fig. 16 nonconformities

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