UNIT - IV

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.

Modern regional structure (macrostructures) is being investigated using seismic tomography and seismic reflection in three dimensions, providing unrivaled 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.

- Fault
- Fold
- Joint
- Shear

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.

STRATIGRAPHY

Stratigraphy, a branch of geology, studies rock layers and layering (stratification). It is primarily used in the study of sedimentary and layered volcanic rocks. Stratigraphy includes two related subfields: lithologic stratigraphy or litho-stratigraphy and, biologic stratigraphy or bio-stratigraphy.

One of stratigraphy's basic concepts is codified in the Law of Superposition, which simply states that, in an undeformed stratigraphic sequence, the oldest strata occur at the base of the sequence.

Chemostratigraphy is based on the changes in the relative proportions of trace elements andisotopes within and between lithologic units. Carbon and oxygen isotope ratios vary with time and are used to map subtle changes in the paleoenvironment. This has led to the specialized field ofisotopic stratigraphy.

Cyclostratigraphy documents the often cyclic changes in the relative proportions of minerals, particularly carbonates, and fossil diversity with time, related to changes in palaeoclimates.

DIVISIONS IN STRATIGRAPHY:

1. Biostratigraphy
2. Chronostratigraphy
3. Magnetostratigraphy
4. Archaeological stratigraphy

Biostratigraphy

Biostratigraphy or paleontologic stratigraphy is based on fossil evidence in the rock layers. Strata from widespread locations containing the same fossil fauna and flora are correlatable in time. Biologic stratigraphy was based on William Smith's principle of faunal succession, which predated, and was one of the first and most powerful lines of evidence for, biological evolution. It provides strong evidence for formation (speciation) of and the extinction of species. The geologic time scale was developed during the 19th century based on the evidence of biologic stratigraphy and faunal succession. This timescale remained a relative scale until the development of radiometric dating, which gave it and the stratigraphy it was based on an absolute time framework, leading to the development of chronostratigraphy.

Chronostratigraphy

Chronostratigraphy is the branch of stratigraphy that studies the absolute, not relative, age of rock strata.

Chronostratigraphy is based upon deriving geochronological data for rock units, both directly and by inference, so that a sequence of time relative events of rocks within a region can be derived. In essence, chronostratigraphy seeks to understand the geologic history of rocks and regions.

Magnetostratigraphy

Magnetostratigraphy is a chronostratigraphic technique used to date sedimentary and volcanic sequences. The method works by collecting oriented samples at measured intervals throughout the section.Oriented paleomagnetic core samples are collected in the field; mudstones, siltstones, and very fine-grained sandstones are the preferred lithologies because the magnetic grains are finer and more likely to orient with the ambient field during deposition.

Archaeological stratigraphy

In the field of archaeology, soil stratigraphy is used to better understand the processes that form and protect archaeological sites. The law of superposition holds true, and this can help date finds or features from each context, as they can be placed in sequence and the dates interpolated. Phases of activity can also often be seen through stratigraphy.

FAULT:

Definition: A **fault** is a planar fracture or discontinuity in a volume of rock, across which there has been significant displacement. These forms within the Earth's crust result from the action of tectonic forces.

Rocks are very slowly, but continuously moving and changing shape. Under high temperature and pressure conditions common deep within Earth, rocks can bend and flow. In the cooler parts of Earth, rocks are colder and brittle and respond to large stresses by fracturing. Earthquakes are the agents of brittle rock failure.

SIZES OF FAULTS:

They range in size from micrometers to thousands of kilometers in length and tens of kilometers in depth, but they are generally much thinner than they are long or deep.

FAULT CLASSIFICATIONS

Classifiification of faults based on their actions and displacements;

1. **Active**
2. **Inactive, and**
3. **Reactivated Faults**

1. Active faults are structure along which we expect displacement to occur. By definition, since a shallow earthquake is a process that produces displacement across a fault, all shallow earthquakes occur on active faults.

2. Inactive faults are structures that we can identify, but which do no have earthquakes. As you can imagine, because of the complexity of earthquake activity, judging a fault to be inactive can be tricky, but often we can measure the last time substantial offset occurred across a fault. If a fault has been inactive for millions of years, it's certainly safe to call it inactive.

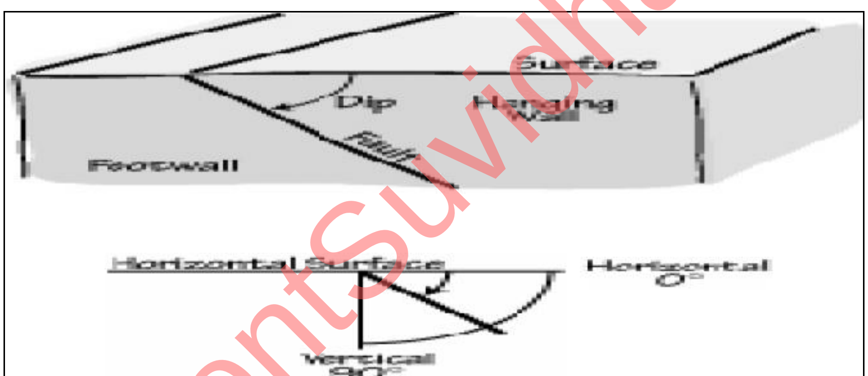
3. Reactivated faults form when movement along formerly inactive faults can help to alleviate (relief) strain within the crust or upper mantle. Deformation in the New Madrid seismic zone in the central United States is a good example of fault reactivation.

SPECIAL FAULT NAMES: Geologists use many different names for special types of faults. These names have complex and far-reaching implications that depend to some extent on the user. When in doubt, use a simple name. Some important types of specialized fault names:

1. **Wrench vs. strike-slip fault.** These terms are synonyms and indicate a fault with a slip-vector closely parallel to the fault strike. Some geologists reserve the term **wrench** for large, regional strike-slip faults, steeply-dipping regional strike-slip faults or as a synonym for **tear** fault.
2. **Thrust fault.** This name once meant any reverse fault with a dip-angle of 30° or less. Now the term indicates faults with an originally low dip-angle that formed during regional compressional deformation. A single thrust fault may change its orientation as it crosscuts different lithologies. Folding can reorient thrusts so that they may have a variety of angles today.
3. **Detachment fault.** A regional, low-angle, listric normal fault formed during crustal extension.
4. **Tear fault.** Often used to indicate a steeply-dipping wrench fault that bounds or cuts the hanging wall of a thrust or normal fault, also used for mode III faults.

FAULTING GEOMETRY:

In general fault classification based on the geometry of faulting, which we describe by specifying three angular measurements: dip, strike, and slip.



DIP : Dip is defined as the inclination of the bed caused by the faulting or folding

Slip: True relative displacement of originally neighboring point

STRIKE: The strike is an angle used to specify the orientation of the fault and measured clockwise from north. For example, a strike of 0° or 180° indicates a fault that is oriented in a north-south direction, 90° or 270° indicates east-west oriented structure.

FAULT TERMINOLOGY

- Faults occur on all scales (scale independent: fractal geometry)
- Hangingwall – upper block
- Footwall- lower block
- Allochton – rocks have moved (e.g. hangingwall)
- Autochthon – rocks in place (e.g. footwall)
- Fault zone – deformation mechanism is cataclasis (low T)
- Shear zone – deformation mechanism is ductile (not necessarily high. Temp)

- Fault splay – secondary fault off main fault
- Listric fault – dip decreases with depth
- Dip slip – offset parallel to dip (up or down)
- Displacement up dip – thrust
- Displacement down dip- normal fault
- Oblique slip – offset oblique to fault dip
- Strike slip – offset parallel to fault strike
- Low-angle fault – dip 10-30 deg.
- Steep fault – high angle dip (60 – 80)
- Normal: offset down dip
- Strike slip – left or right lateral
- Reverse – high angle thrust– offset up dip
- Thrust – often low angle – offset up dip

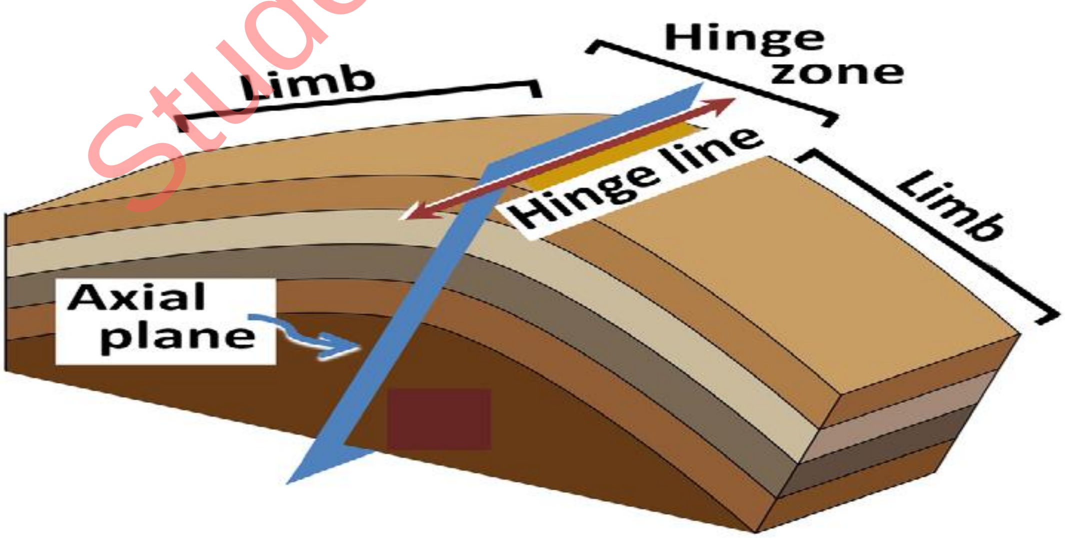
FOLDS

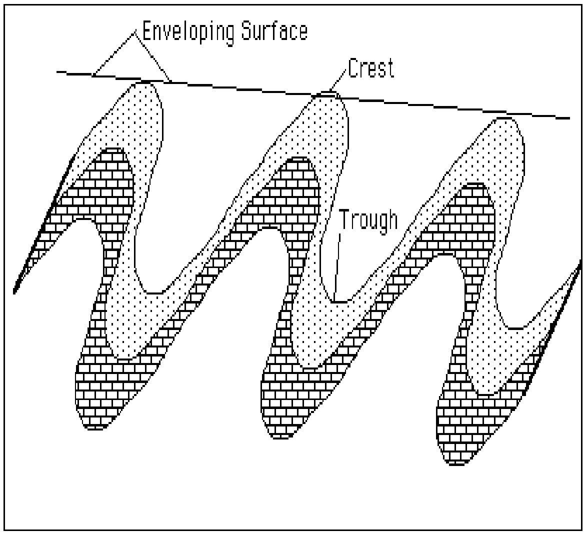
Fold is defined as the bent or deformed arrangement of stratified rocks. These rocks may be of sedimentary or volcanic origin. Although stratified rocks are normally deposited on the earth's surface in horizontal layers (stratification).

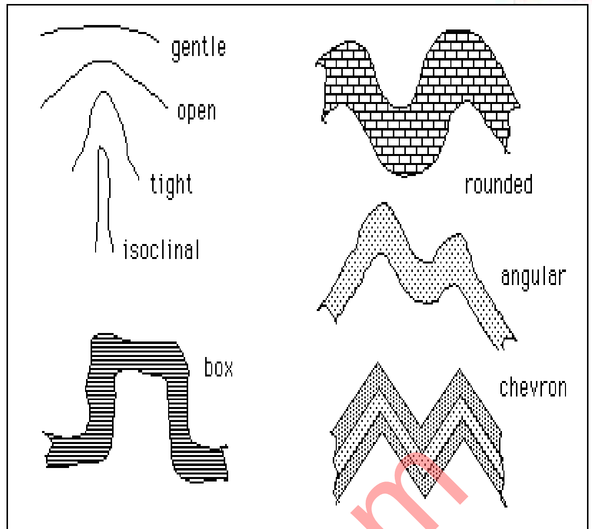
In simple words fold is a bend in stratified rocks that results from movements within the earth's crust and produces such structures as anticlines and synclines.

SIZE & SHAPE OF FOLDS

Folds in rocks vary in size from microscopic crinkles to mountain-sized folds. It is necessary to convey a sense of the shape of the fold. A fold can be shaped as a chevron, with planar limbs meeting at an angular axis, as **cuspate** with curved limbs, as circular with a curved axis, or as elliptical with unequal wavelength.







MECHANICS OF FOLDING

Folds in rock are formed in relation to the stress field in which the rocks are located and the Rheology (The branch of physics that studies the deformation and flow of matter), or method of response to stress, of the rock at the time at which the stress is applied.

Folding of rocks must balance the deformation of layers with the conservation of volume in a rock mass. This occurs by several mechanisms.

Flexural slip: Flexural slip allows folding by creating layer-parallel slip between the layers of the folded strata, which, altogether, result in deformation. The best analogy is bending a phone book, where volume preservation is accommodated by slip between the pages of the book.

Buckling: Typically, folding is thought to occur by simple buckling of a planar surface and its confining volume. The volume change is accommodated by layer parallel shortening the volume, which grows in thickness. Folding under this mechanism is typically of the similar fold style, as thinned limbs are shortened horizontally and thickened hinges do so vertically.

Mass displacement: If the folding deformation cannot be accommodated by flexural slip or volume-change shortening (buckling), the rocks are generally removed from the path of the stress.

FOLD TYPES

Folds will be classified based on their structure and mode of appearance; name as follows

- Anticline: linear, strata normally dip away from axial center, oldest strata in center.
- Syncline: linear, strata normally dip toward axial center, youngest strata in center.

- Antiform: linear, strata dip away from axial center, age unknown, or inverted.
- Synform: linear, strata dip toward axial centre, age unknown, or inverted.
- Dome: nonlinear, strata dip away from center in all directions, oldest strata in center.
- Basin: nonlinear, strata dip toward center in all directions, youngest strata in center.
- Monocline: linear, strata dip in one direction between horizontal layers on each side.
- Chevron: angular fold with straight limbs and small hinges
- Recumbent: linear, fold axial plane oriented at low angle resulting in overturned strata in one limb of the fold.

CAUSES OF FOLDING

Folds appear on all scales, in all rock types, at all levels in the crust and arise from a variety of causes.

1.Fault-related folding

Many folds are directly related to faults, associate with their propagation, displacement and the accommodation of strains between neighbouring faults.

2.Compaction

Folds can be generated in a younger sequence by differential compaction over older structures such as fault blocks and reefs

3.Sedimentary folding

Recently deposited sediments are normally mechanically weak and prone to remobilisation.

4.Slump folding

When slumps form in poorly consolidated sediments they commonly undergo folding, particularly at their leading edges, during their emplacement. The asymmetry of the slump folds can be used to determine paleoslope directions in sequences of sedimentary rocks

5.Dewatering

Rapid dewatering of sandy sediments, possibly triggered by seismic activity can cause convolute bedding

6.Igneous intrusion

The emplacement of igneous intrusions tends to deform the surrounding country rock. In the case of high-level intrusions, near the Earth's surface, this deformation is concentrated above the intrusion and often takes the form of folding, as with the upper surface of a laccolith.

UNCONFORMITIES

An **unconformity** is a contact between two rock units in which the upper unit is usually much younger than the lower unit. Unconformities are typically buried erosional surfaces that can represent a break in the geologic record of hundreds of millions of years or more.

In general words An **unconformity** is a buried erosion surface separating two rock masses or strata of different ages, indicating that sediment deposition was not continuous.

Rocks below the unconformity are tilted and sheared off, and rocks above it are level. The unconformity tells a clear story:

1. First a set of rocks was laid down.
2. Then these rocks were tilted, then eroded down to a level surface.
3. Then a younger set of rocks was laid down on top.

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 subaerial 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.

Nonconformity

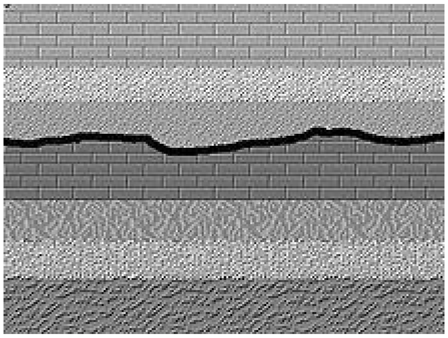
A nonconformity exists between sedimentary rocks andmetamorphic or igneous rocks when the sedimentary rock lies above and was deposited on the pre-existing and eroded metamorphic or igneous rock. Namely, if the rock below the break is igneous or has lost its bedding by metamorphism, the plane of juncture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

Angular unconformity

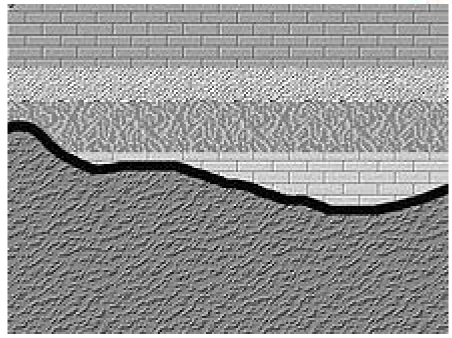
An angular unconformity is an unconformity where horizontally parallel strata of sedimentary rock are deposited on tilted and eroded layers, producing an angular discordance with the overlying horizontal layers. The whole sequence may later be deformed and tilted by further orogenic activity.

Paraconformity

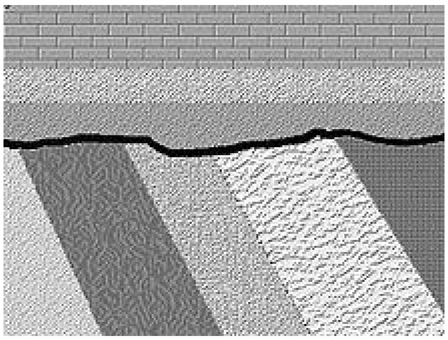
A paraconformity is a type of unconformity in which strata are parallel; there is little apparent erosion and the unconformity surface resembles a simple bedding plane. It is also known as non-depositional unconformity or pseudoconformity.



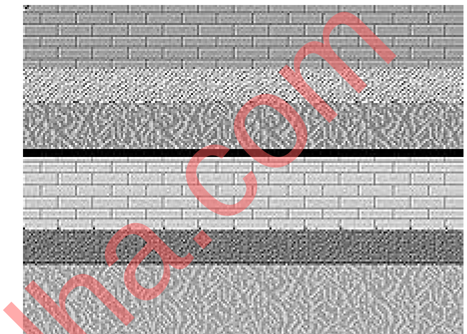
Disconformity



Nonconformity



Angular unconformity



Paraconformity

For example, the contact between a 400-million-year-old sandstone that was deposited by a rising sea on a weathered bedrock surface that is 600 million years old is an unconformity that represents a **time hiatus** of 200 million years. The sediment and/or rock that was deposited directly on the bedrock during that 200-million-year span was eroded away, leaving the "basement" surface exposed.

JOINT S

In geology the term **joint** refers to 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.

Influence factors for joints:

Stress, Strain And deformations are the main factors influences joint in rocks

Formation of joints in rocks

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.

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

TYPES OF JOINTS

Types with respect to formation

1. Tectonic joints

Tectonic joints are formed during deformation episodes whenever the differential stress is high enough to induce tensile failure of the rock, irrespective of the tectonic regime. They will often form at the same time as faults. Measurement of tectonic joint patterns can be useful in analyzing the tectonic history of an area because they give information on stress orientations at the time of formation.[2]

2.Unloading joints

Joints are most commonly formed when uplift and erosion removes the overlying rocks thereby reducing the compressive load and allowing the rock to expand laterally. Joints related to uplift and erosional unloading have orientations reflecting the principal stresses during the uplift.

Exfoliation joints are special cases of unloading joints formed at, and parallel to, the current land surface in rocks of high compressive strength.

3.Cooling joints

Joints can also form via cooling of hot rock masses, particularly lava, forming cooling joints, most commonly expressed as vertical columnar jointing. The joint systems associated with cooling typically are polygonal because the cooling introducing stresses that are isotropic in the plane of the layer.

Types with respect to attitude and geometry

Joints can be classified into three groups depending on their geometrical relationship with the country rock:

- Strike joints – Joints which run parallel to the direction of strike of country rocks are called "strike joints"
- Dip joints – Joints which run parallel to the direction of dip of country rocks are called "dip joints"
- Oblique joints – Joints which run oblique to the dip and strike directions of the country rocks are called "oblique joints".

Fractography

Joint propagation can be studied using the techniques of fractography in which characteristic marks such as hackles and plumose structures can be used to determine propagation directions and, in some cases, the principal stress orientations.

Importance joints with respect to soil and rock mass strength & in the production of geofluids:

In geotechnical engineering a joint forms a discontinuity that may have a large influence on the mechanical behavior (strength, deformation, etc.) of soil and rock masses in, for example, tunnel, foundation, or slope construction.

It is long been recognized that joints (fractures) play a major role in the subsurface fluid flow of water in aquifers and petroleum in oil fields. Major industry research projects have been dedicated during the last decades to the study of faulted and fractured reservoirs.