INSTITUTE OF AERONAUTICAL ENGINEERING
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ENGINEERING GEOLOGY
(ACE003)
B.Tech II YEAR I SEM

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UNIT-I
INTRODUCTION

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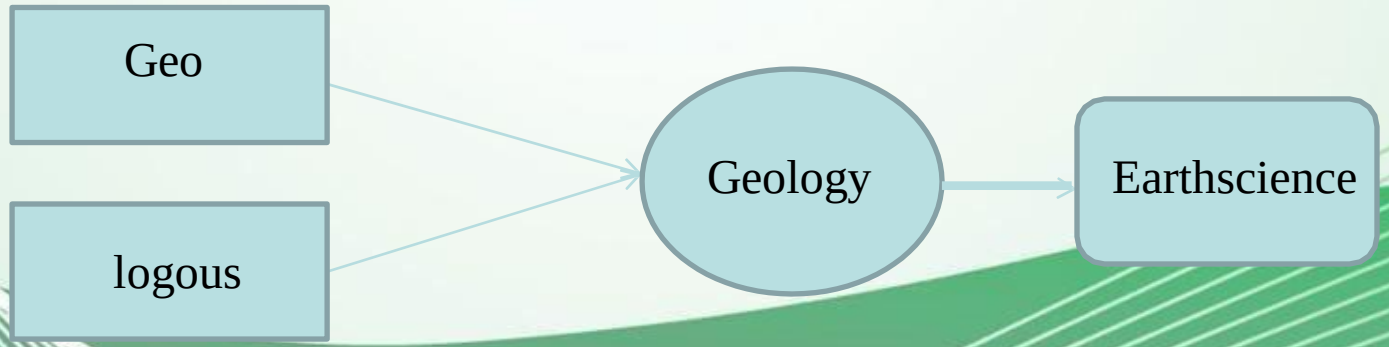
Definition:-

- The science which deals with the physical structure and substance of the earth, their history, and the processes which act onthem.
- The geological features of adistrict.
- The geological features of a planetarybody.



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The importance of geology in civil engineering may briefly as follows:

- Geology provides a systematic knowledge of construction material, its occurrence, composition, durability and other properties. Example of such construction materials isbuilding stones, road metal, clay, limestones andlaterite.

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- The knowledge of the geological work of natural agencies such as water, wind, ice and earthquakes helps in planningand carrying out major civil engineering works. For example the knowledge of erosion, transportation and deposition helps greatly in solving the expensive problems of river control, coastal and soilconservation.

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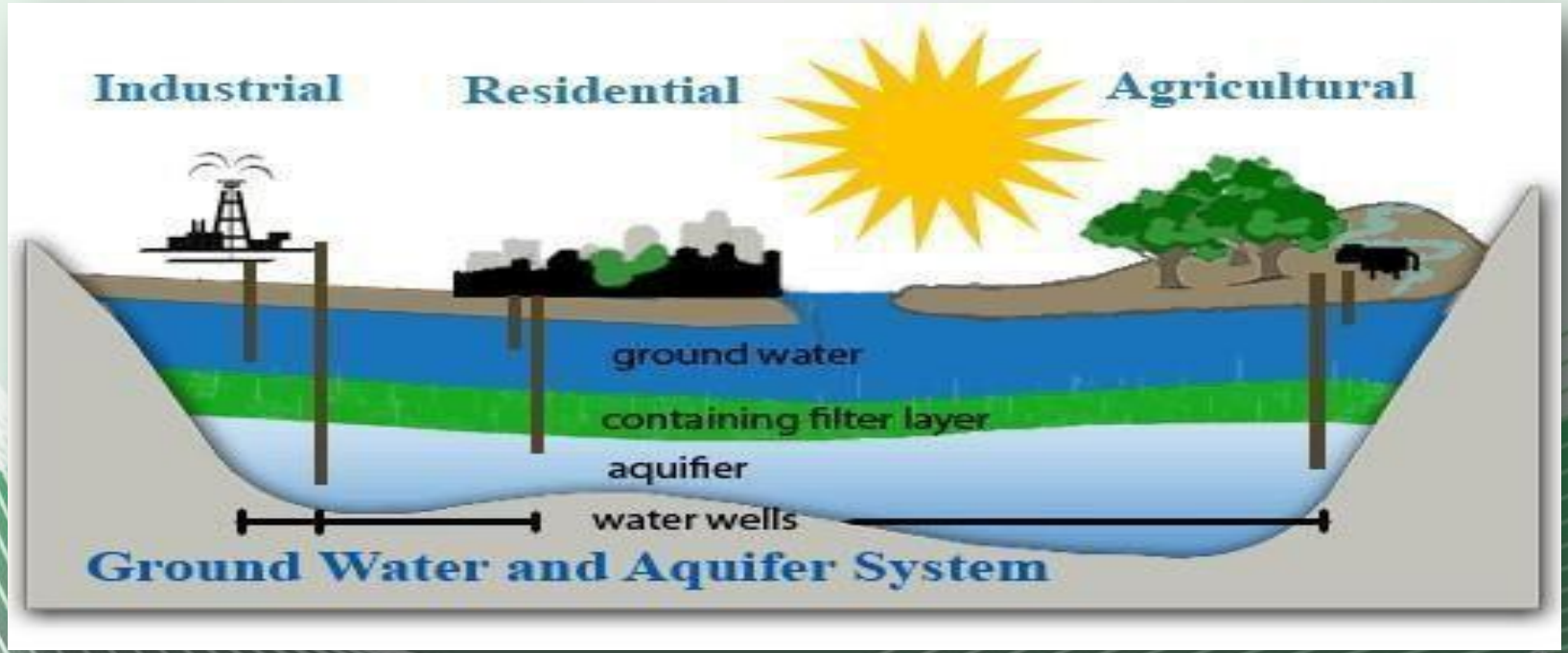
- Ground water is the water which occurs inthe subsurface rocks. The knowledge about its quantity and depth of occurrence is required in connection with water supply, irrigation, excavation and many other civil engineering works.



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- The foundation problems of dams, bridges and buildings are directly concerned with the geology of the area where they are to be built. In these works drilling is commonly undertaken to explore the ground conditions. Geology helps greatly in interpreting the drillingdata.

- In tunneling, constructing roads, canals, docks and in determining the stability of cuts and slopes, the knowledge about the nature and structure of rocks is verynecessary.

- Before staring a major engineering project at a place, a detailed geological report which is accompanied by geological maps and sections, is prepared. Such a report helps in planning and constructing theprojects.

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Physical Geology:

- Physical Geology uses the scientific method to explain natural aspects of the Earth - forexample, how mountains form or why oil resources are concentrated in some rocks and not inothers.

- This chapter briefly explains how and why Earth's surface, and its interior, are constantly changing. It relates this constant change to the majorgeological topics of interaction of the atmosphere, water and rock.

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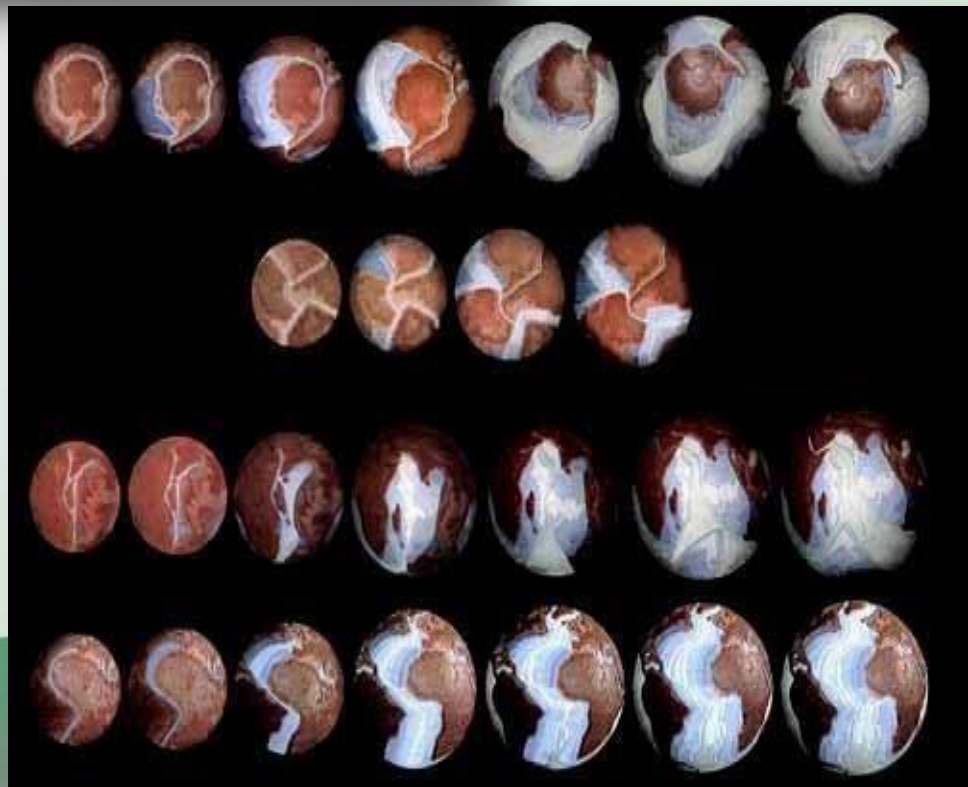

Petrology:-

- Petrology is the branch of geology that studiesthe origin, composition, distribution and structure of rocks.
- (from the Greek language : petra-"rock" andlogos-"study")
- “Lithology” was once approximately synonymous with petrography, but in current usage, lithology focuses on macroscopic hand-sample or outcrop-scale description of rocks while petrography is thespecialty that deals with microscopicdetails.

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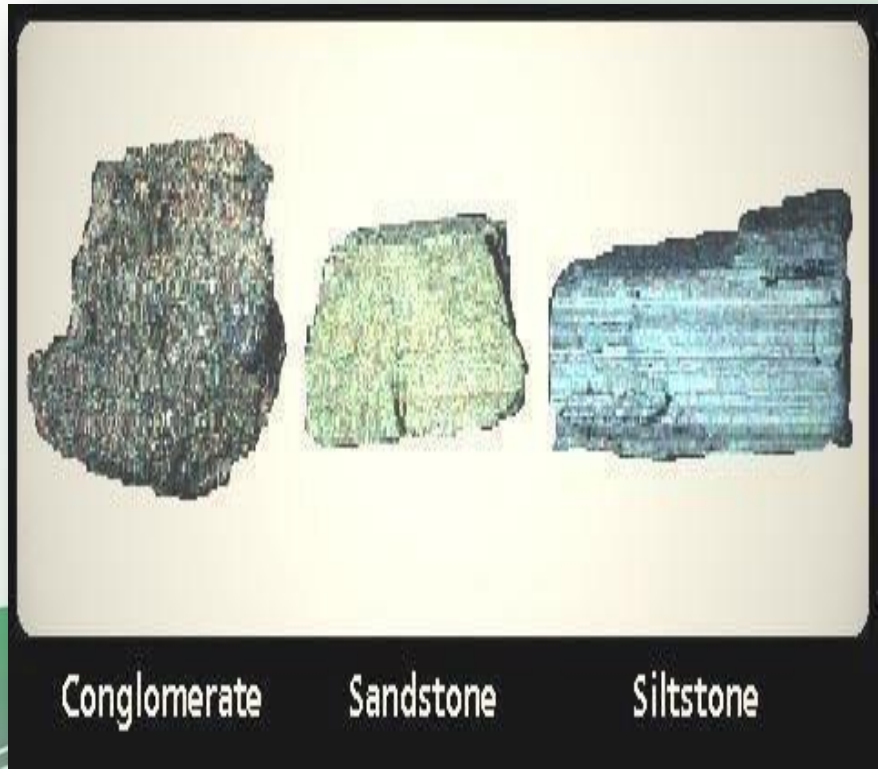
Branches:

- There are three branches of petrology,corresponding to the three types of rocks:

  Igneous, metamorphic, and sedimentary.

- Igneous petrology focuses on the compositionand texture of igneous rocks (rocks such as granite or basalt which have crystallized from molten rock or magma). Igneous rocks include volcanic and plutonic rocks.

- Sedimentary petrology focuses on the compositionand texture of sedimentary rocks (rocks such as sandstone, shale, or limestone which consist of pieces or particles derived from other rocks or biological or chemical deposits, and are usually bound together in a matrix of finer material)



- Metamorphic petrology focuses on the composition and texture of metamorphic rocks (rocks such as slate, marble, gneiss, or schist which started out as sedimentary or igneous rocks but which have undergone chemical, mineralogical or textural changes due to extremes of pressure, temperature orboth).

- **Metamorphic rocks** arise from the transformation of existing rock types, in a process called metamorphism, which means "change in form". The original rock (protolith) is subjected to heat (temperatures greater than150to 200°C) causing profoundphysicaland/orchemicalchange.

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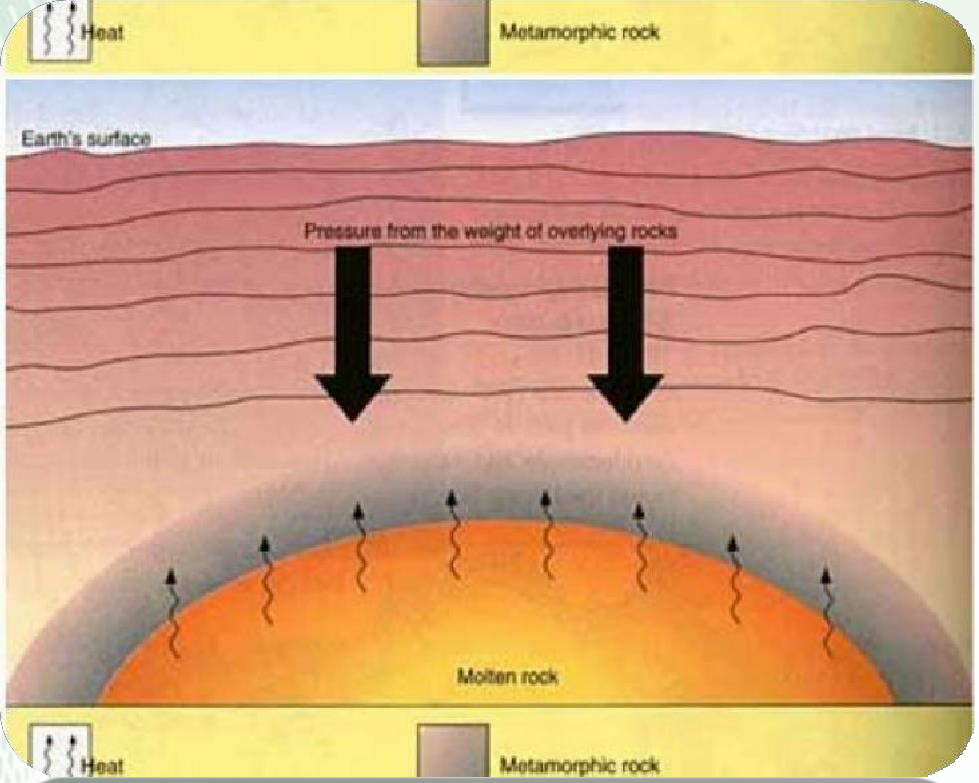
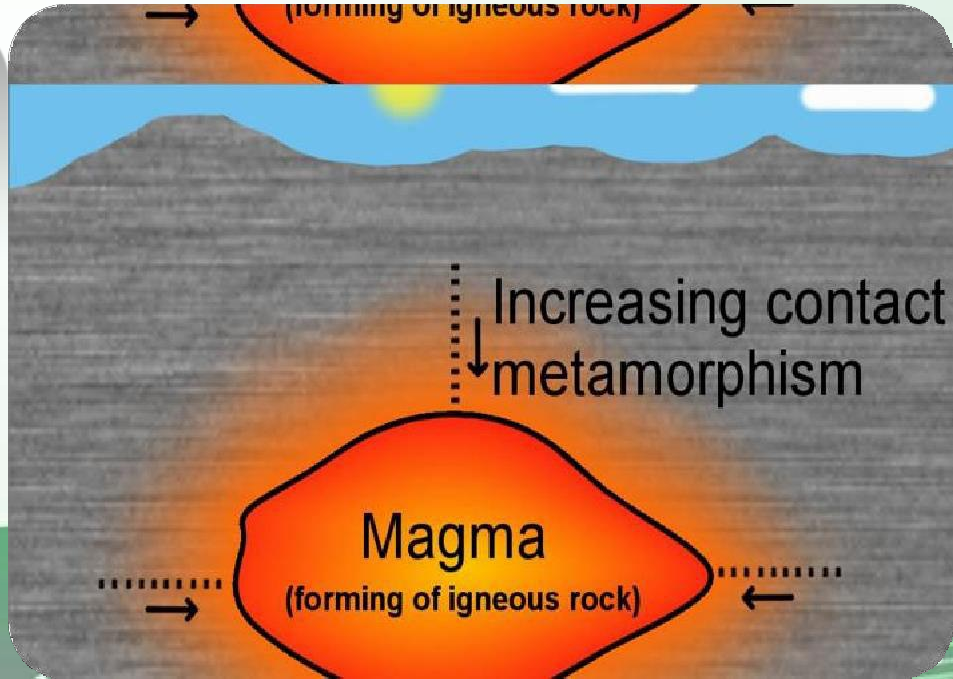

Heat
Metamorphic rock
Earth's surface
Pressure from the weight of overlying rocks
Molten rock
Heat
Metamorphic rock


Increasing contact metamorphism
Magma
(forming of igneous rock)

Structural geology:

- **Structural geology** is the study of the three-dimensional distribution of rock units with respect to their deformationalhistories.

- 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.

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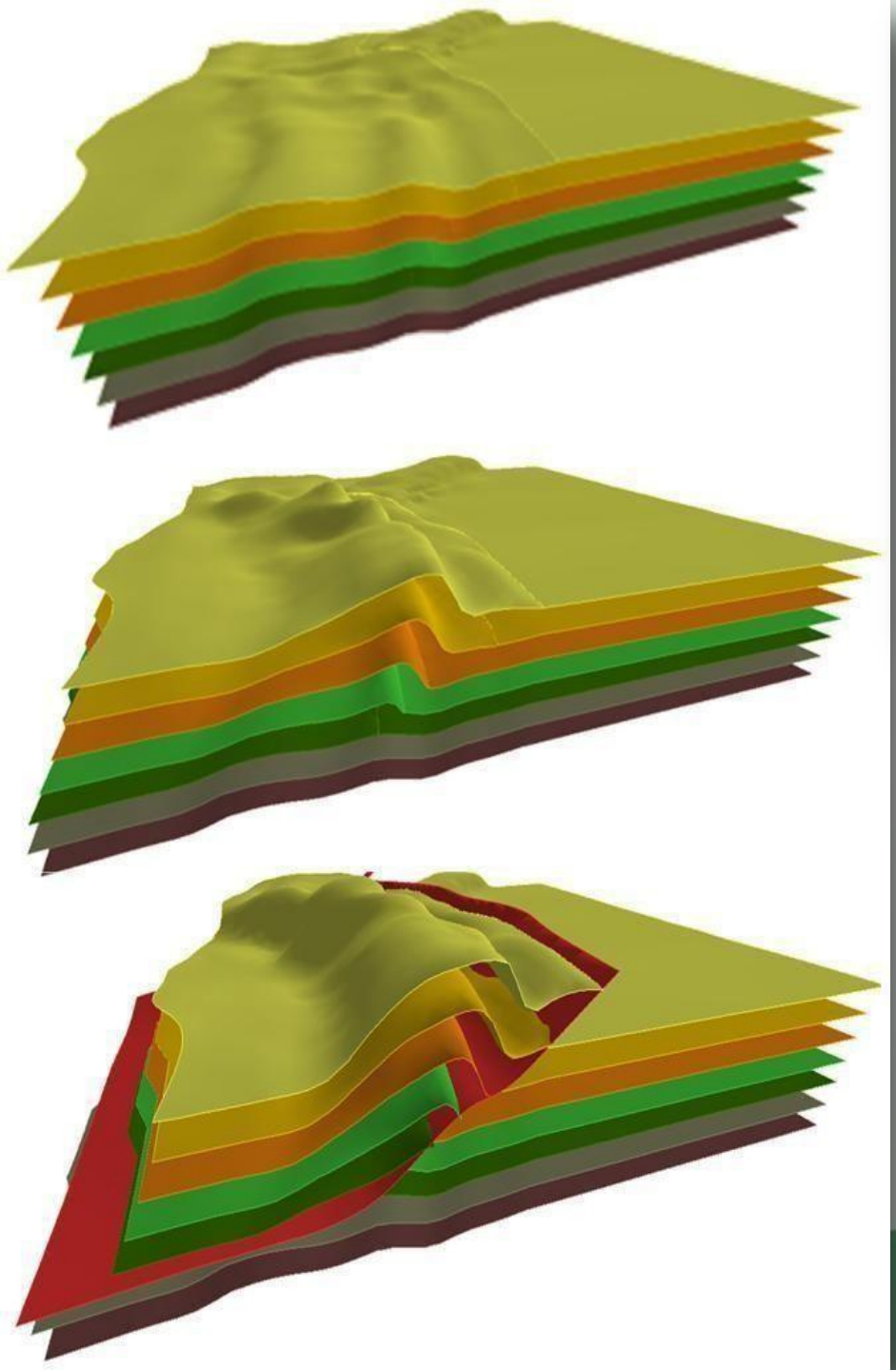

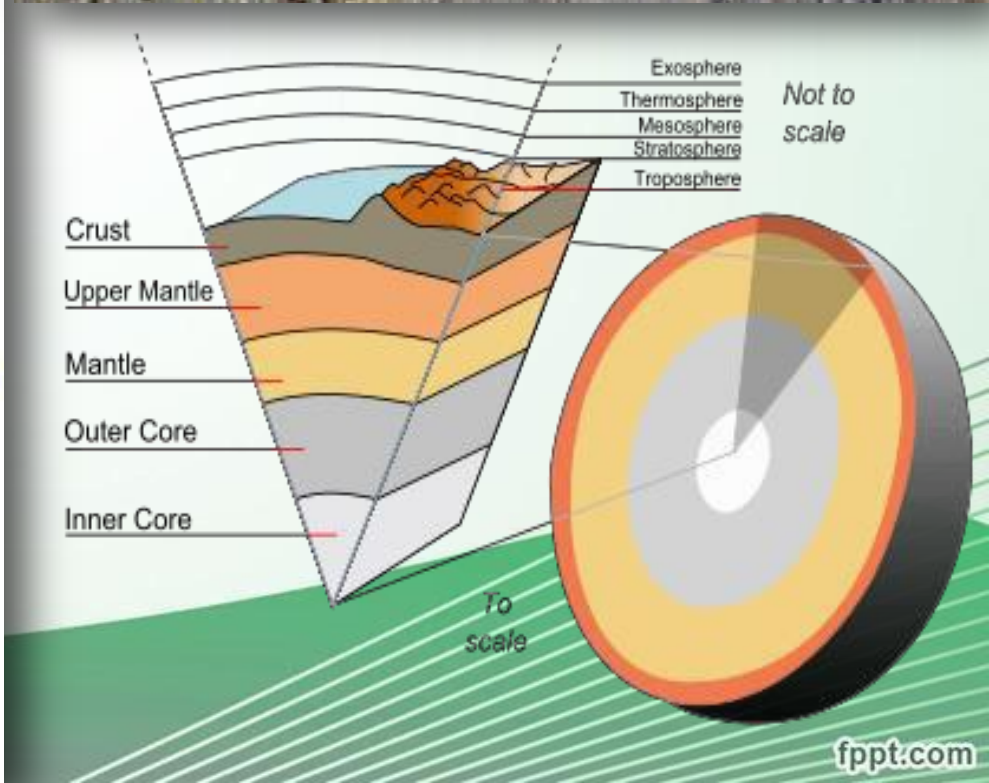
Exosphere
Thermosphere
Mesosphere
Stratosphere
Troposphere
Not to scale
Crust
Upper Mantle
Mantle
Outer Core
Inner Core
To scale
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Weathering of Rocks:

- **Weathering** breaks down and loosens the surface minerals of rock so they can be transported away by agents oferosion such as water, wind andice.
- There are two types of weathering: mechanical and chemical.
- Mechanical or physical weathering involves the breakdown of rocks and soils through direct contact with atmospheric conditions, such as heat, water, ice andpressure.
- The second classification, chemical weathering involves the direct effect of atmospheric chemicals or biologically produced chemicals also known as biological weathering in the breakdown of rocks, soils andminerals.

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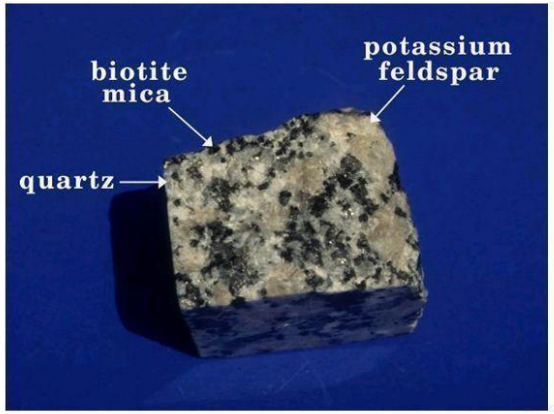
Chemical weathering of granite forms the minerals feldspar and quartz. The feldspar reacts with the carbonic acid forming clay. The quartz is resistant to weathering and remains unchanged.



Different Minerals weather at different rates and in different ways.

e.g. Granite

Quartz – hard – physical weathering – sands

Feldspar and Mica – 'softer' – chemical weathering - clays

UNIT-II
MINERALOGY

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Excavation:

- The section reviews standard excavation practices used to construct and modify rock slopes and provides current design and construction guidelines for theiruse.

- The most commonare

1. Blasting (which includes drilling the holes to be filled withexplosives)
2. Ripping
3. Drilling

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1. BLASTING: controlled use of explosives

- Blasting—the controlled use of explosives to excavate rock—has been part of construction engineering for hundreds ofyears.
- In any blasting situation, the geologic structure of the rock mass will be the most important consideration.
- It is practiced most often in mining, quarrying and civil engineering such as dam or road construction. The result of rock blasting is often known as a rockcut.
- Blasting is used for rock excavation on both small- andlarge-scale projects. There are two generaltypes:

1. productionblasting
2. Controlledblasting.

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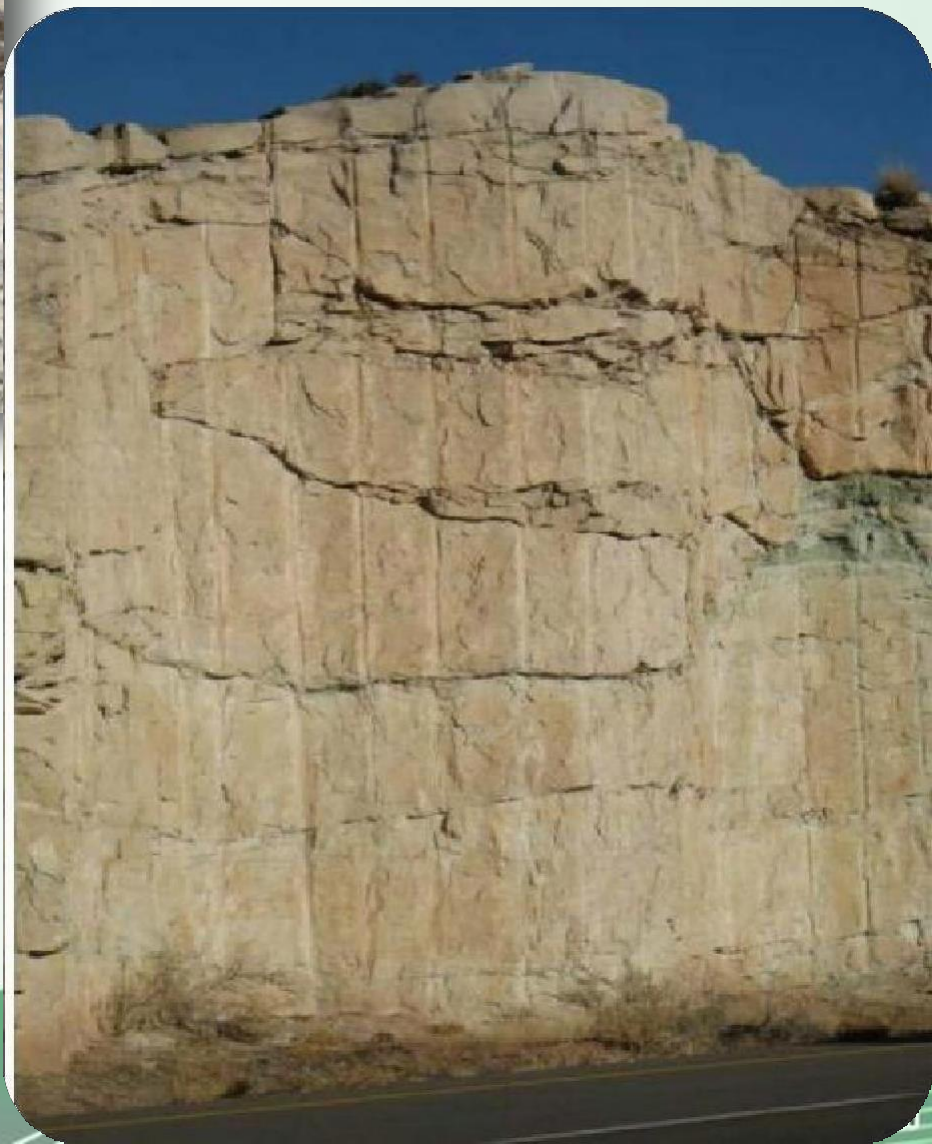

2. RIPPING:

- Uses a tractor with an attached tooth or teeth that is lowered into the rock and dragged to break up material forexcavation.
- The tooth of the ripper can leave scars on the rock surface. The tractor cannot be used on steep slopes because of risk of overturning. Ripping is limited to relatively low densityrocks.

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3. DRILLING:

- Blast holes are drilled at various orientations, fromvertical throughhorizontal.
- To create vertical holes, which are used almost exclusivelyin production blasting, rock slope excavation uses two types of drilling:

1. Downhole
2. Step drilling

- *Horizontal drilling* is used for both production and controlled blasting because of limited drill rig access or geometry requirements.
- *Angled drilling* can be performed as determined by slope face anglerequirements.

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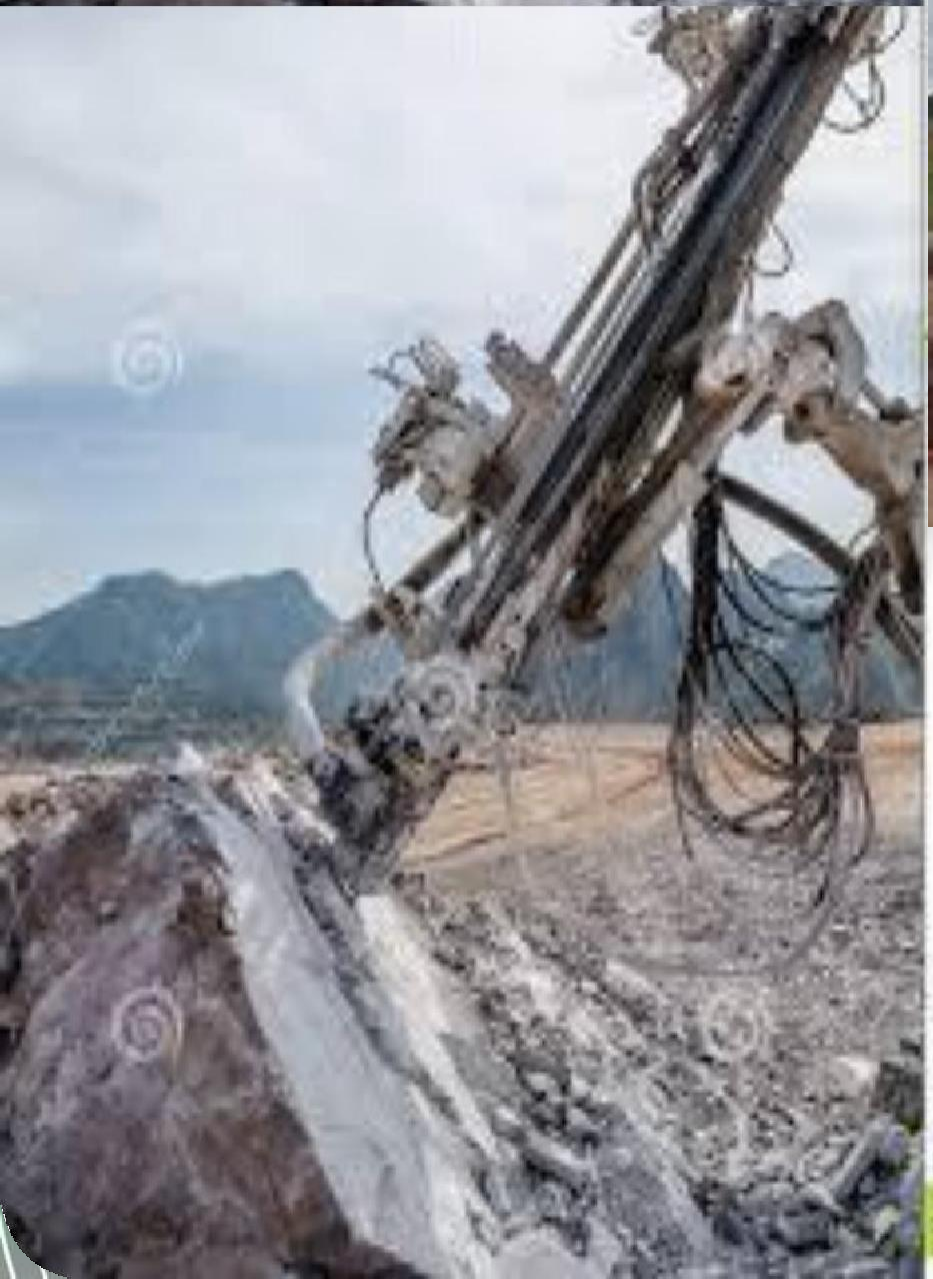

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- The modes of failure can be groupedinto four primarymechanisms:

1.Planar Failure (A)

2.Wedge Failure (B)

3.Circular Failure (C)

4.Toppling Failure(D)

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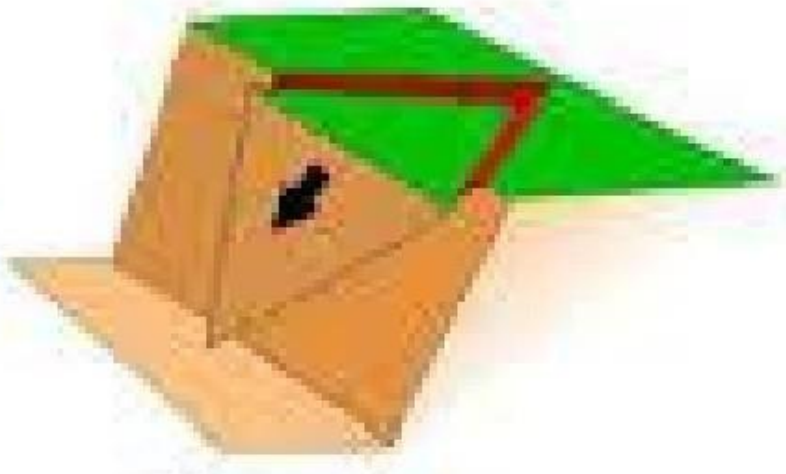
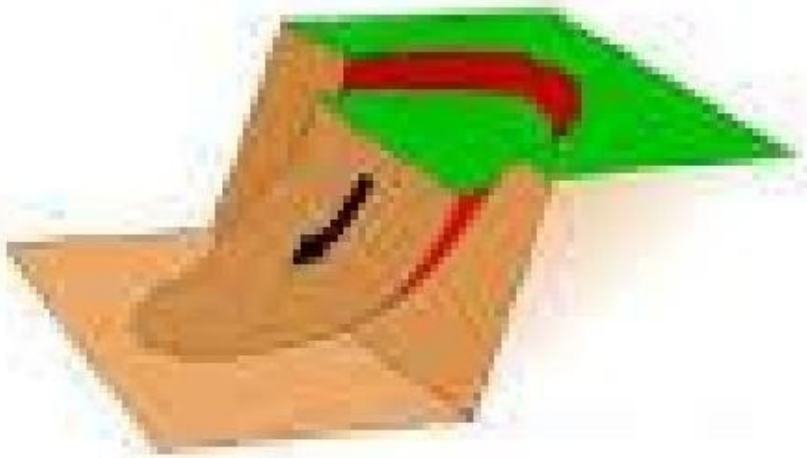
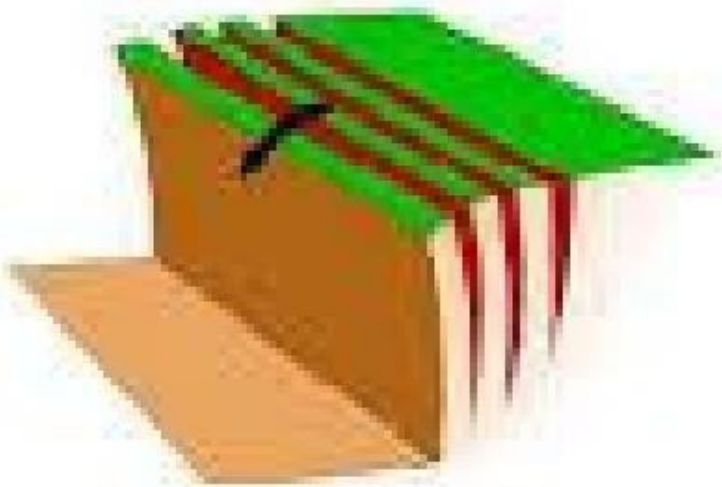
Plane failure



Wedge failure



Circular failure



Toppling failure

UNIT-III
STRUCTURAL GEOLOGY

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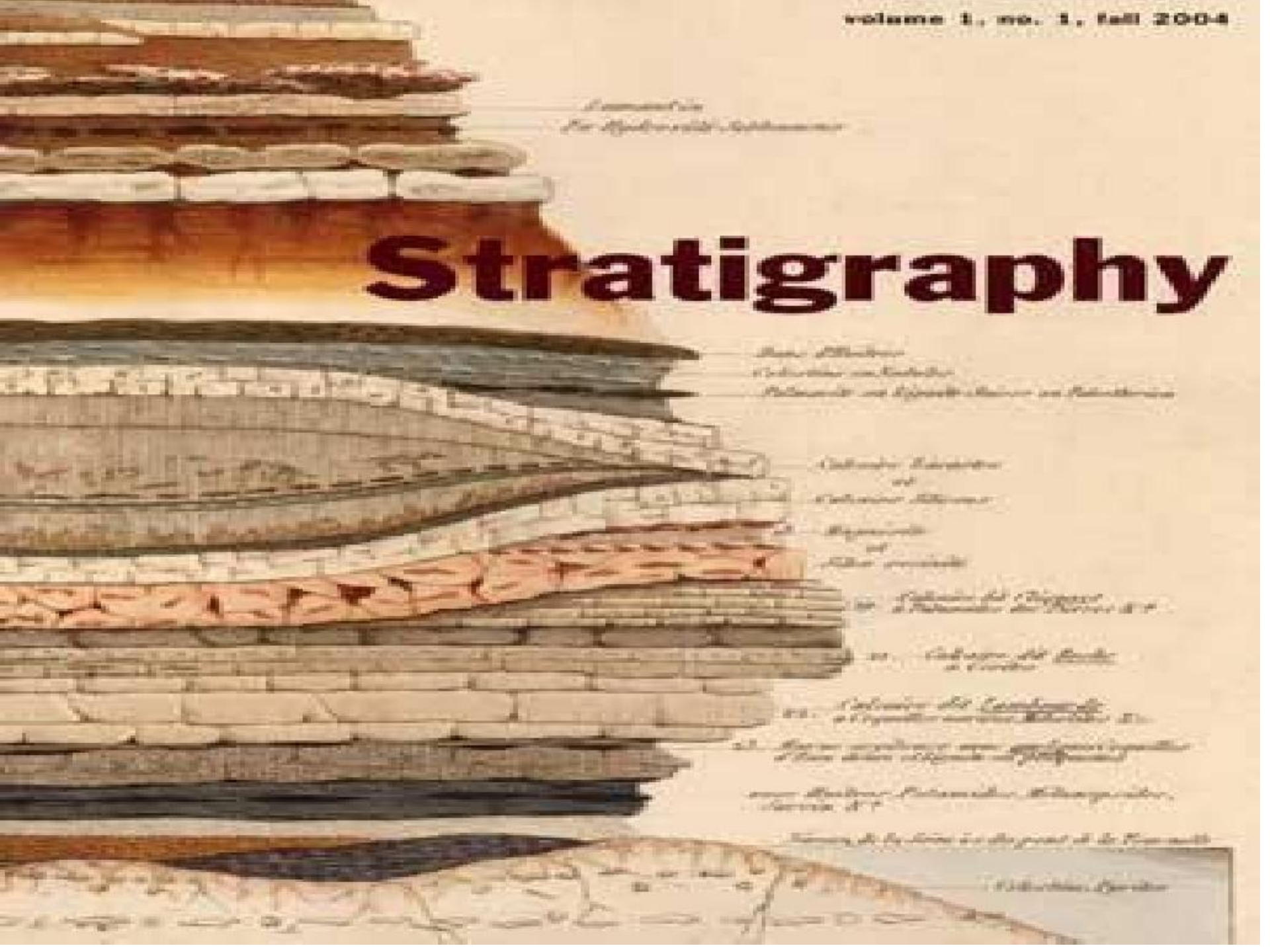

Stratigraphy

STRATIGRAPHY:

- **Stratigraphy** is a branch of geology which studiesrock layers (strata) and layering(stratification).

- It is primarily used in the study of sedimentaryand layered volcanicrocks.

- Stratigraphy includes two relatedsubfields:

1. Lithologic stratigraphy orlithostratigraphy,
2. Biologic stratigraphy orbiostratigraphy.

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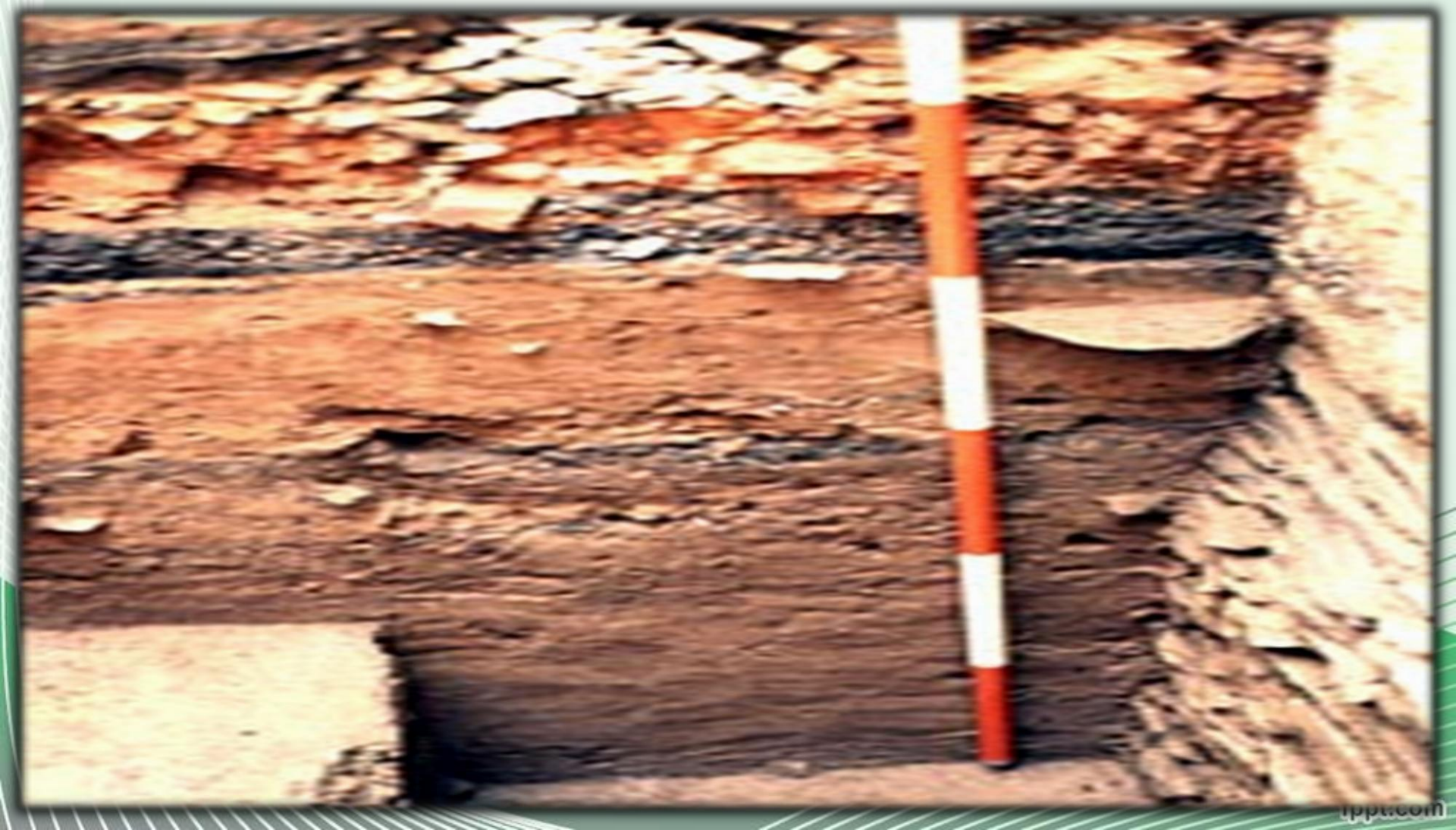
- Application of stratigraphy was by William Smith in the 1790s and early 1800s. Smith, known as the "Father of Englishgeology“.



1) Lithostratigraphy:

Lithostratigraphy is the geological scienceassociated with the study of strata or rock layers.

Litho logy:

The **litho logy** of a rock unit is a description of its physical characteristics visible at outcrop, in hand or core samples or with low magnification microscopy, such as color, texture, grain size, or composition.

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Strata:

Strata are layers of rock, or sometimes soil. Innature, strata come in many layers. It is a term in sedimentary and historical geology; the singular is stratum. These layers are laid down as sediment, often in the sea, and are slowly changed by pressure, heat and chemical action into rocks.

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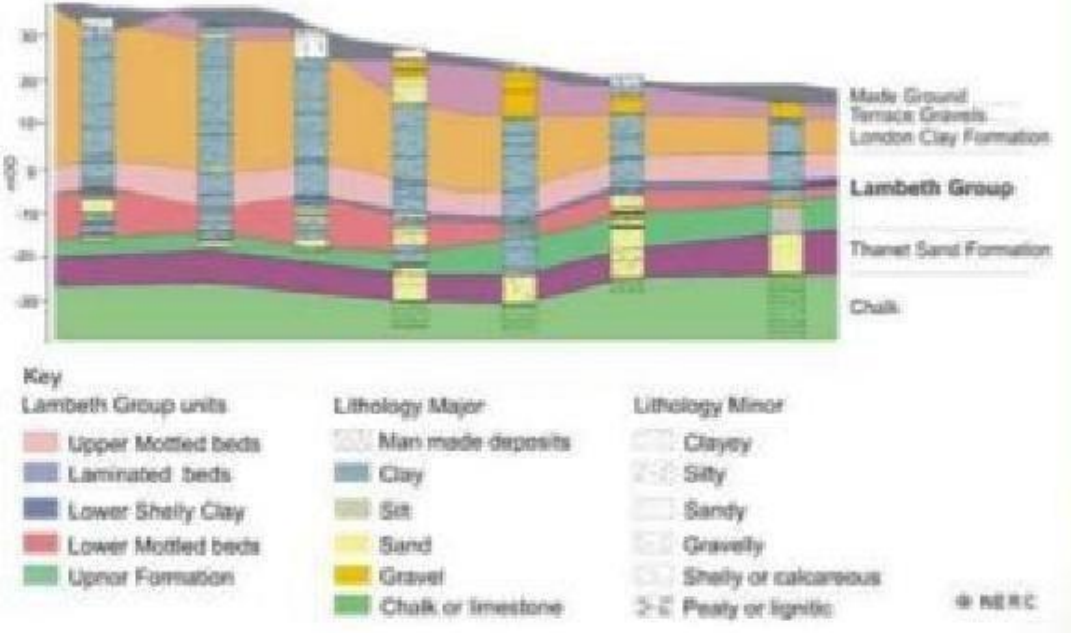
LITHOSTRATIGRAPHY

- Subdivision of rock successions into units on the basis of lithology or rock type
- Lithostratigraphical standard units:
  - Supergroup
  - Group
  - Formation
  - Member
  - Bed



2) Biostratigraphy:

- **Bio stratigraphy** is the branch of stratigraphy which focuses on correlating and assigning relative ages of rock strata by using the fossil assemblages contained within them.

- 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, biologicalevolution.

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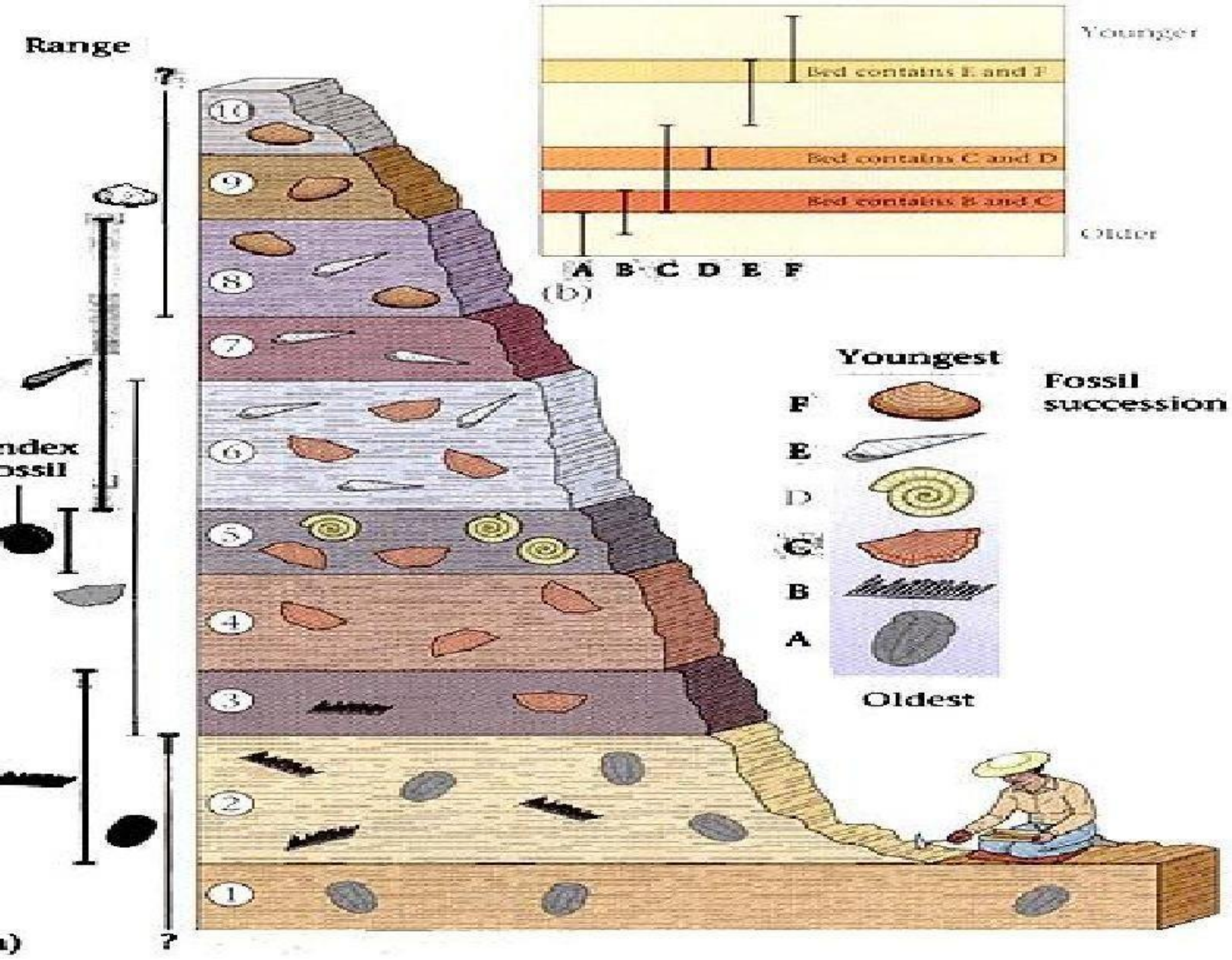
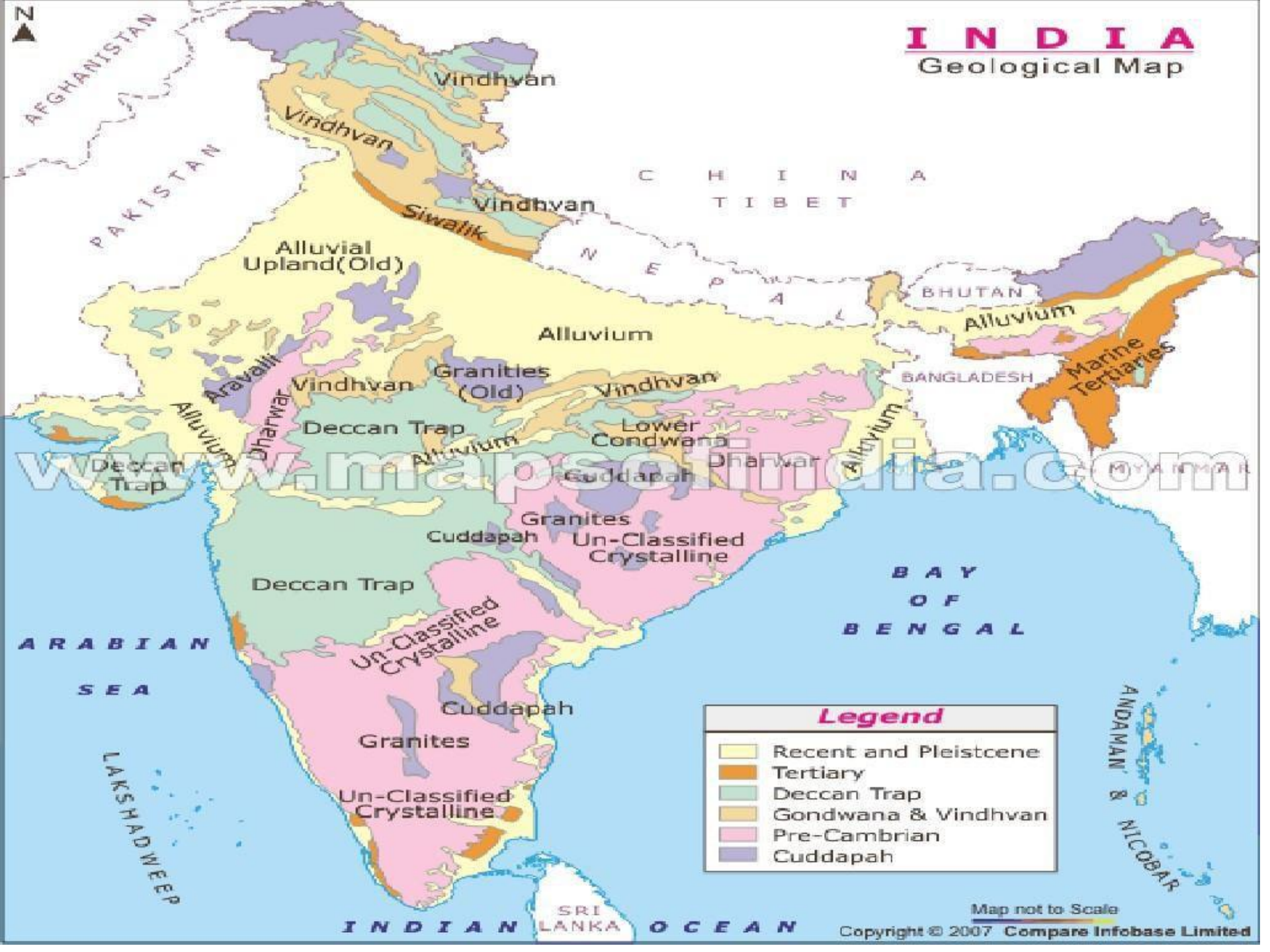

Range
?
ndex
ossil
?
a)
Younger
Bed contains E and F
Bed contains C and D
Bed contains B and C
Older
A B C D E F
(b)
10
9
8
7
6
5
4
3
2
1
Youngest
F
E
D
C
B
A
Oldest
Fossil succession



www.mapsofindia.com


PALEONTOLOGY

DEFINITION:

- Paleontology is the study of what fossils tell us aboutthe ecologies of the past, about evolution, and about our place, as humans, in theworld.
- Paleontology incorporates knowledge from biology, geology, ecology, anthropology, archaeology, andeven computer science to understand the processes that have led to the origination and eventual destruction of the different types of organisms since lifearose.

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- It includes the study of fossils to determine organisms' evolution and interactions with eachother and theirenvironments.
- The simplest definition is "the study of ancientlife”.
- Paleontology seeks information about severalaspects of past organisms: "their identity and origin, their environment and evolution, and what they can tell us about the Earth's organic and inorganicpast".

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GEOLOGICAL TIME SCALE:

- The geological time scale (GTS) is a system of chronological measurement that relates stratigraphy to time, and is used by geologists, paleontologists, and other Earth scientists to describe the timing and relationships between events that have occurred throughout Earth's history.

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OUTCROP:

- An outcrop or rocky outcrop is a visible exposure of bedrock or ancient superficial deposits on the surface of the Earth.
- However, in places where the overlying cover is removed through erosion or tectonic uplift, the rock may be exposed, or *cropout*.
- It may also exposed at the Earth's surface due to human excavations such as quarrying and building of transportroutes.

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Outcrop

- Any Geological formation exposed on the surface is called an outcrop.

STRIKE AND 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.
- On a geologic map, this is represented with a short straight line segment.
- *Strike* (or strike angle) can be given as either a quadrant compass bearing of the strike line or in terms of east or west of true north or south oriented parallel to the strike line.

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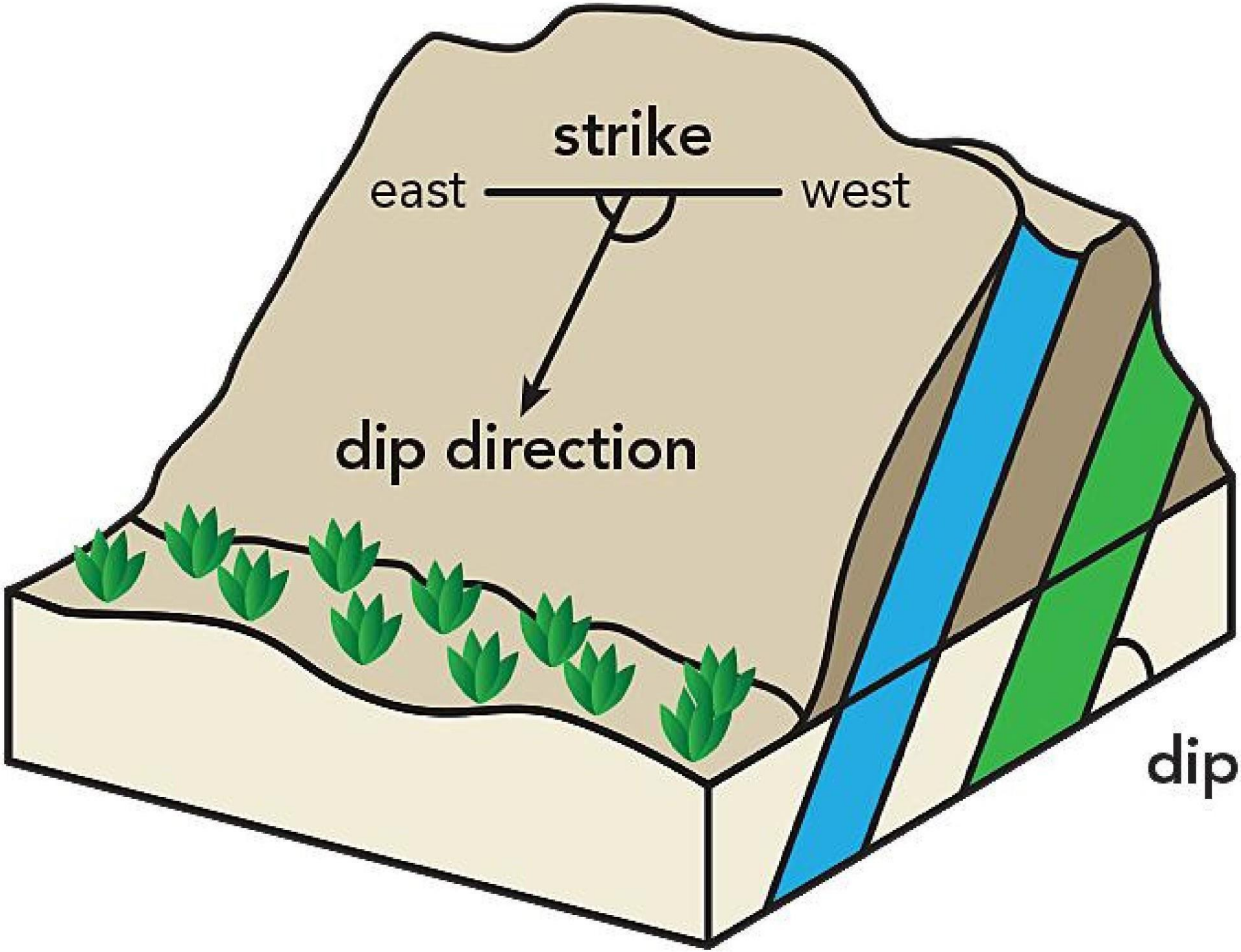
strike
east
west
dip direction
dip

DIP:

- Thedipgivesthesteepestangleofdescentofatiltedbedor feature relative to a horizontal plane.
- One technique is to always take the strike so the dip is 90° to the right of thestrike.
- The angle of dip is generally included on a geologic map without the degree sign.

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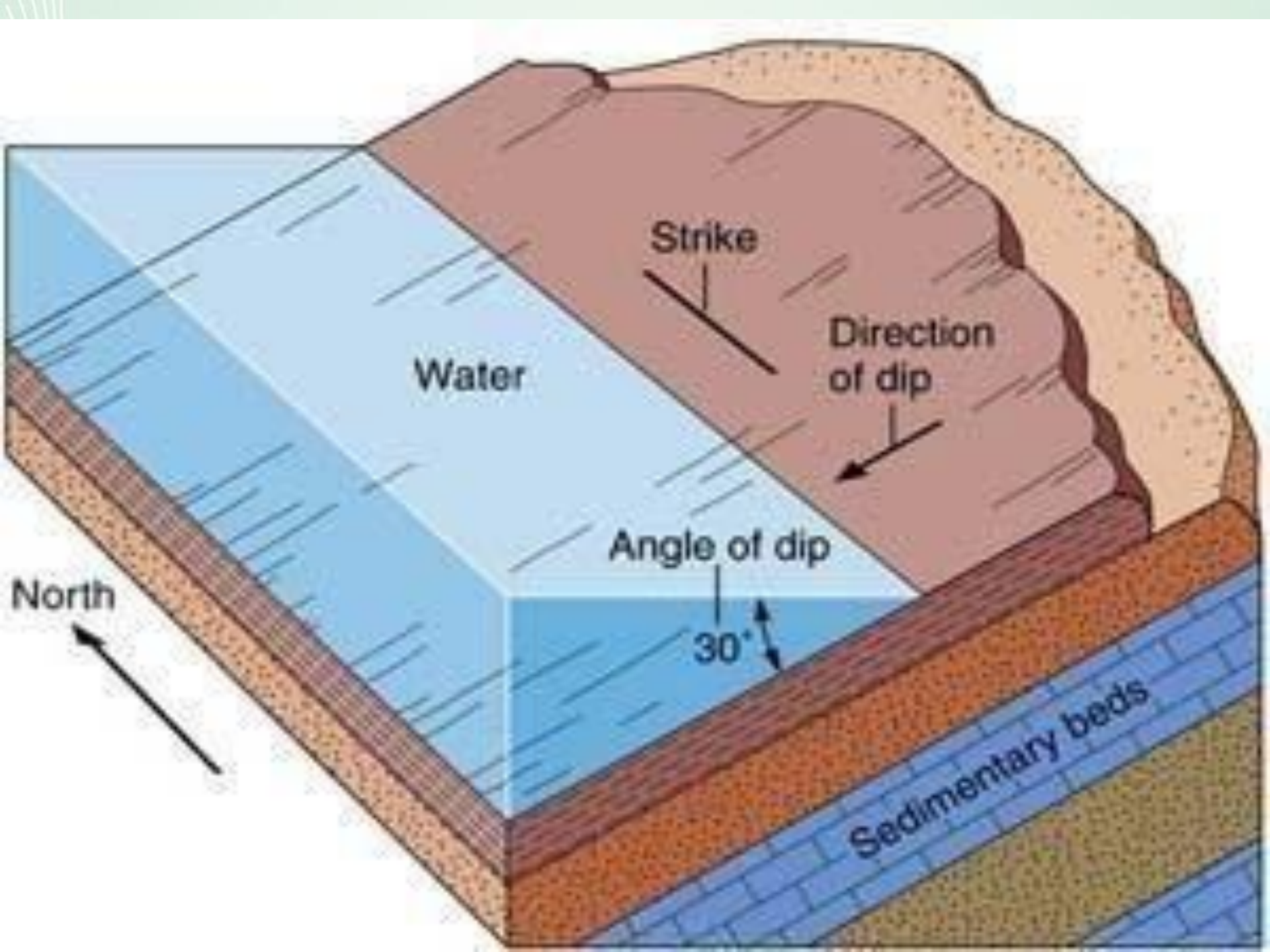
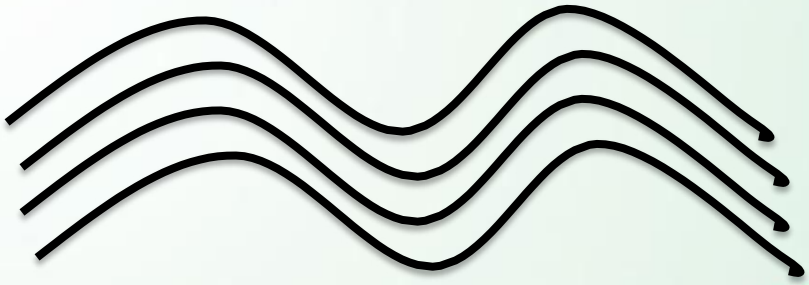

Strike
Direction of dip
Water
Angle of dip
North
30°
Sedimentary beds

FOLDS:

- Folds are one of the most common geological structuresfound inrocks.
- When a set of horizontal layers are subjected tocompressive forces, they bend either upwards or downwards.



- The bends noticed in rocks are calledFolds.
- Folds are described variously as wavyor arch orcurvedor warping appearances found inrocks.

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Types of Folds:

Anticline:

- When the beds are bent upwards, the resulting fold iscalled anticline. This folds is convex upwards.

Anti = Opposite

Cline= Inclination

Syncline:

- Syncline is just opposite to anticline in its nature, when thebeds are bent downwards the resulting fold is called syncline.
- This fold is convexdownwards.

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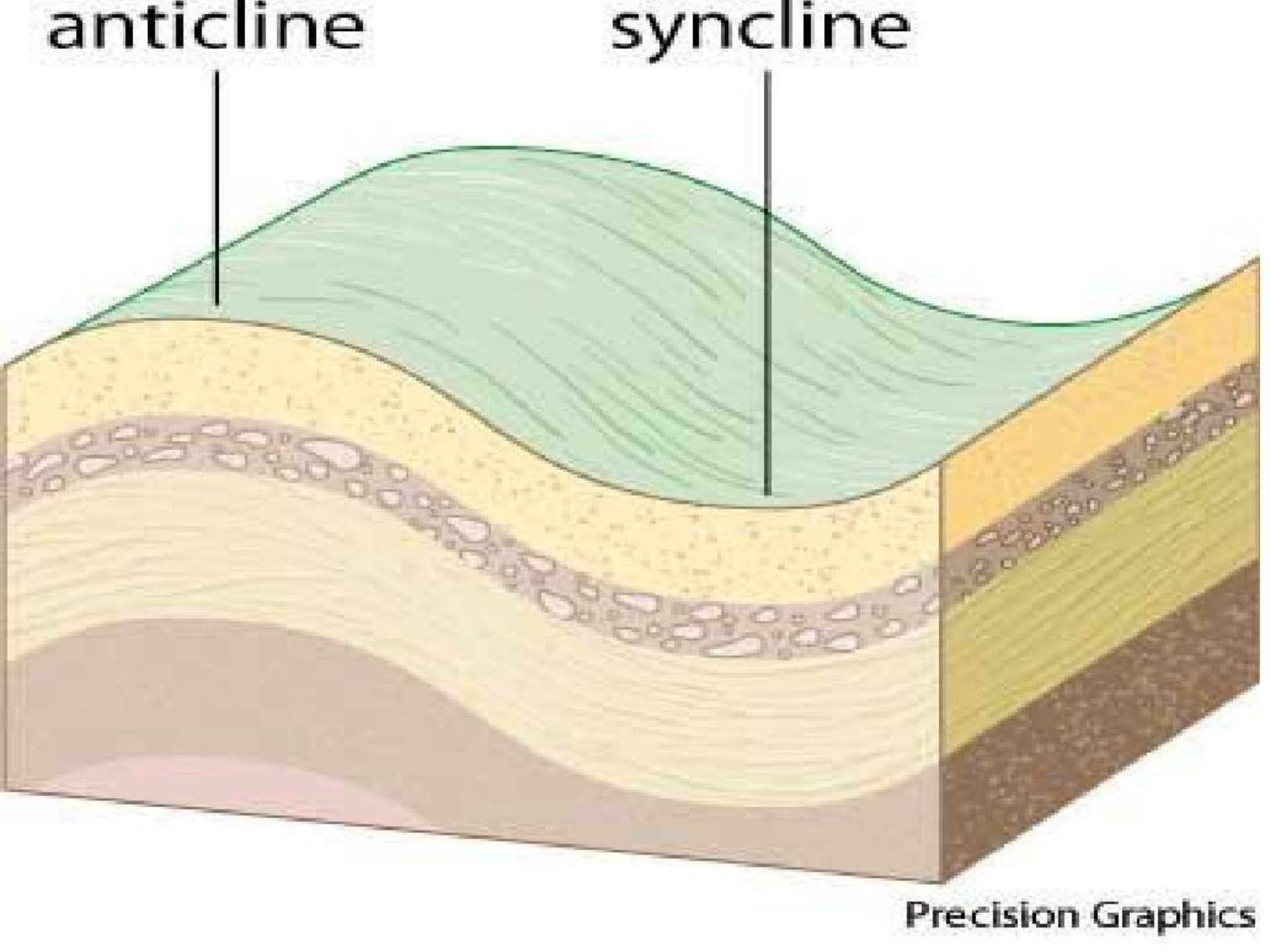
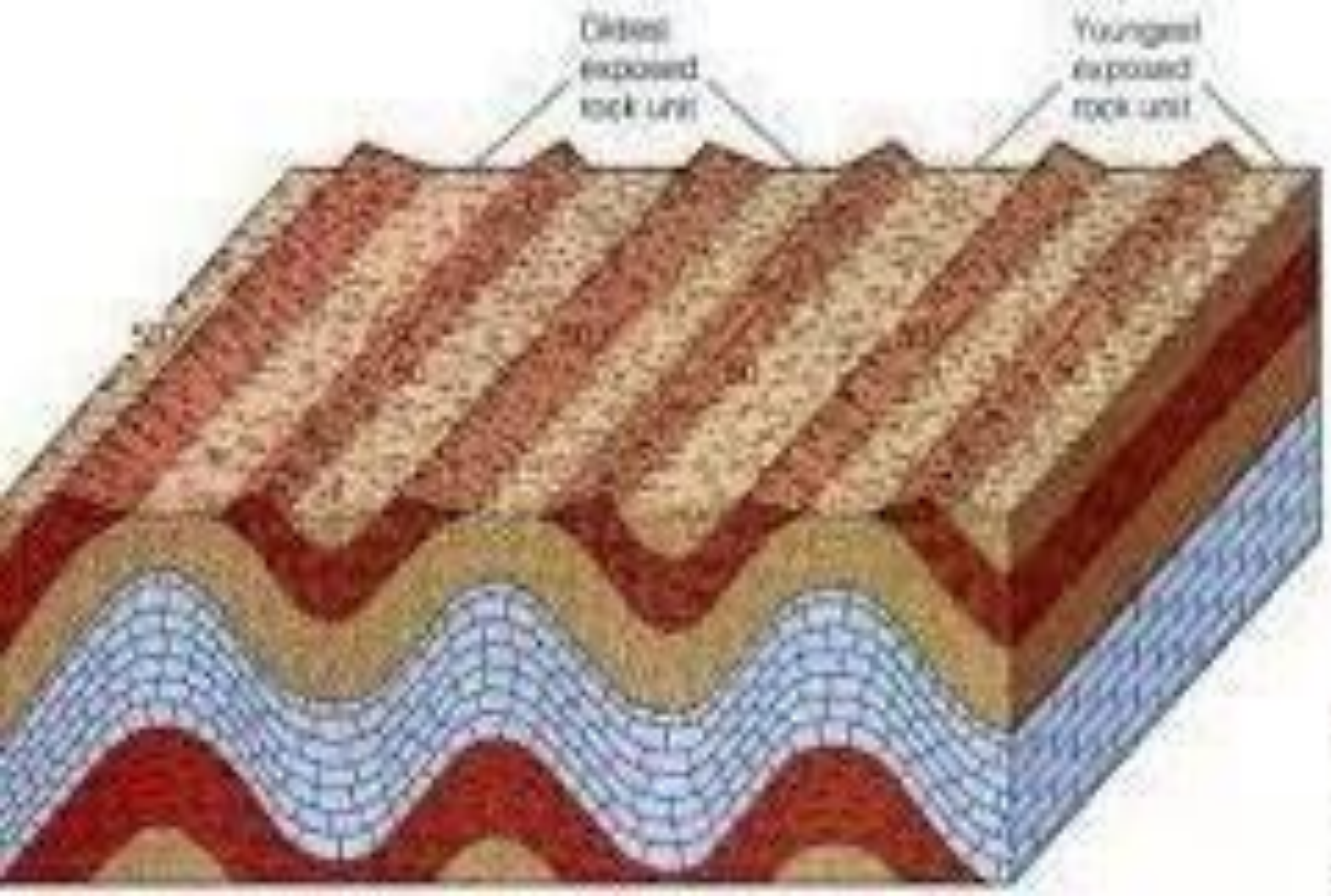

anticline
syncline
Precision Graphics

Symmetrical:

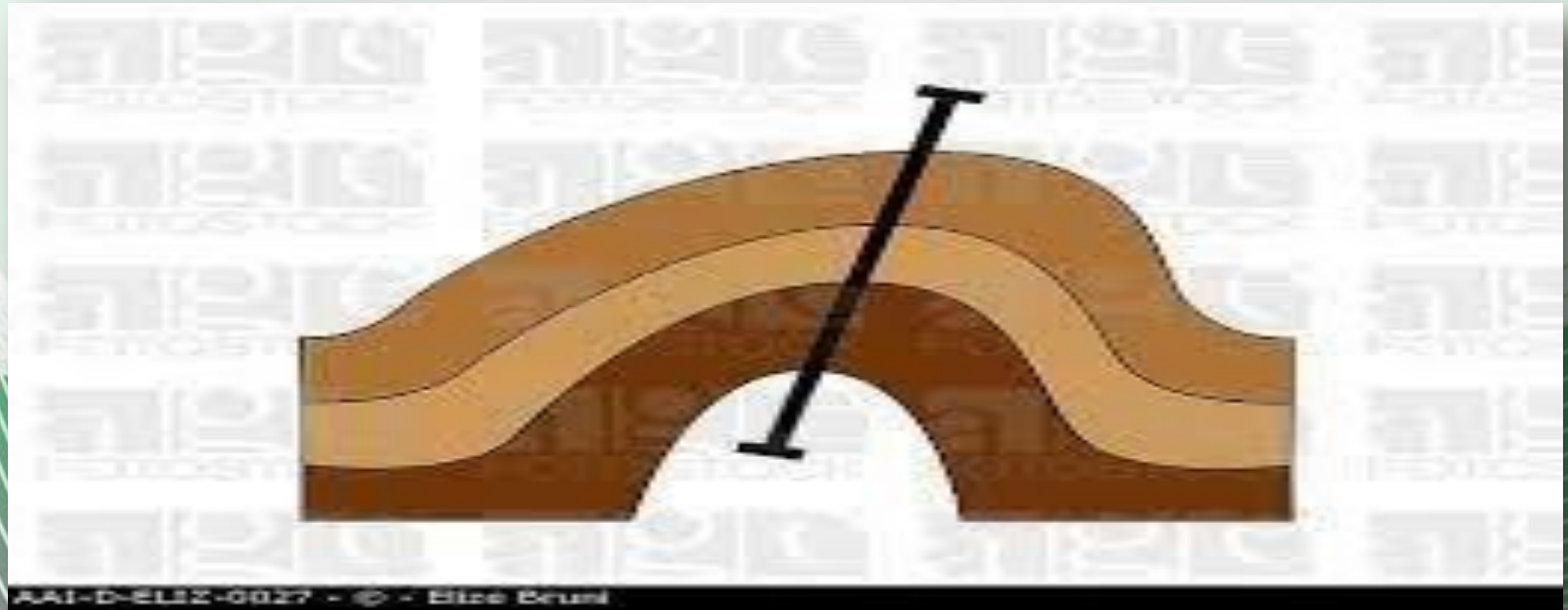
- When the axial plane divides a fold into two equal halves in such a way that one half is the nature image of another, then such fold is called Symmetricalfolds.



► FIGURE 13-15 Identifying eroded anticlines and synclines by strike and dip and the relative ages of the folded rock layers.

Asymmetrical:

- If the two halves are not mirror images, then the fold is called as asymmetrical fold.
- If the compressive forces responsible for folding are not of the same magnitude, asymmetrical folds areformed.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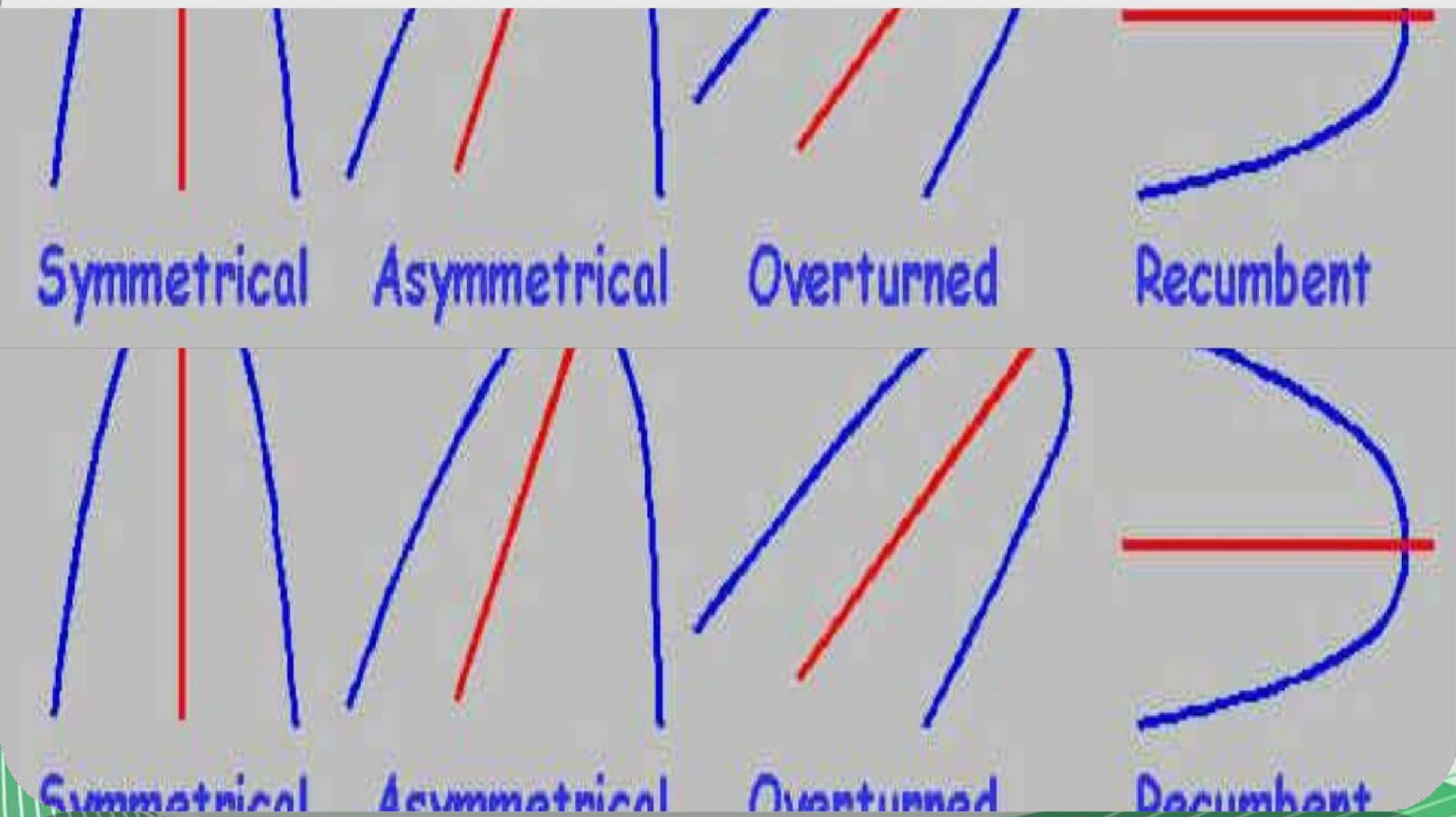
Symmetrical
Asymmetrical
Overturned
Recumbent
Symmetrical
Asymmetrical
Overturned
Recumbent

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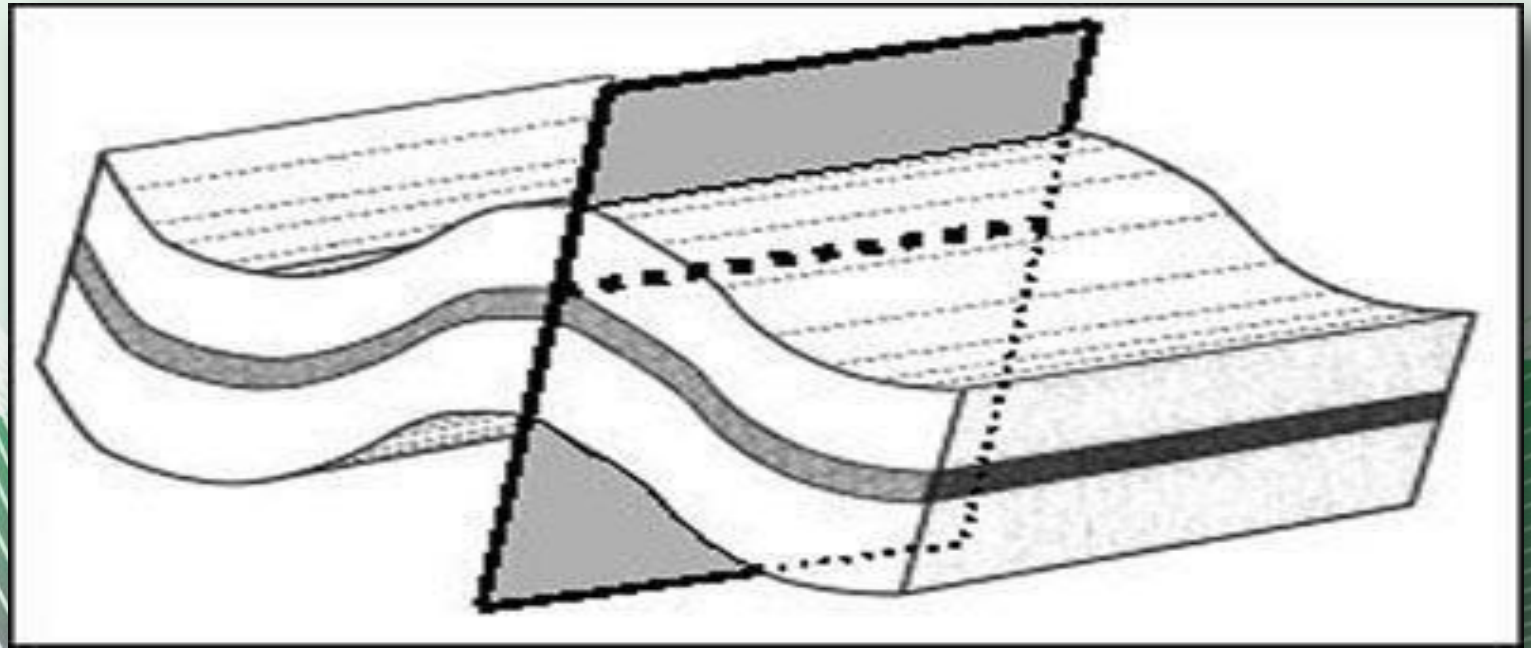
Open folds:

- Depending on the intensity of deformation, the beds of the folds may or may not have uniform thickness.
- If the thickness of bed is uniform throughout the fold it is called Openfold.



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Closed Folds:

- In a fold if the beds are thinner in the limb portions andthicker at crests and troughs, such fold is called a closed fold.

FAULTS:

- A fault isafracture or zoneoffractures betweentwo blocks of rock.
- Faults allow the blocks to move relative to eachother.
- This movement may occur rapidly, in the form of an earthquake - or may occur slowly, in the form ofcreep.
- Faults may range in length from a few millimeters to thousands of kilometers.
- During an earthquake, the rock on one side of the faultsuddenly slips with respect to the other.

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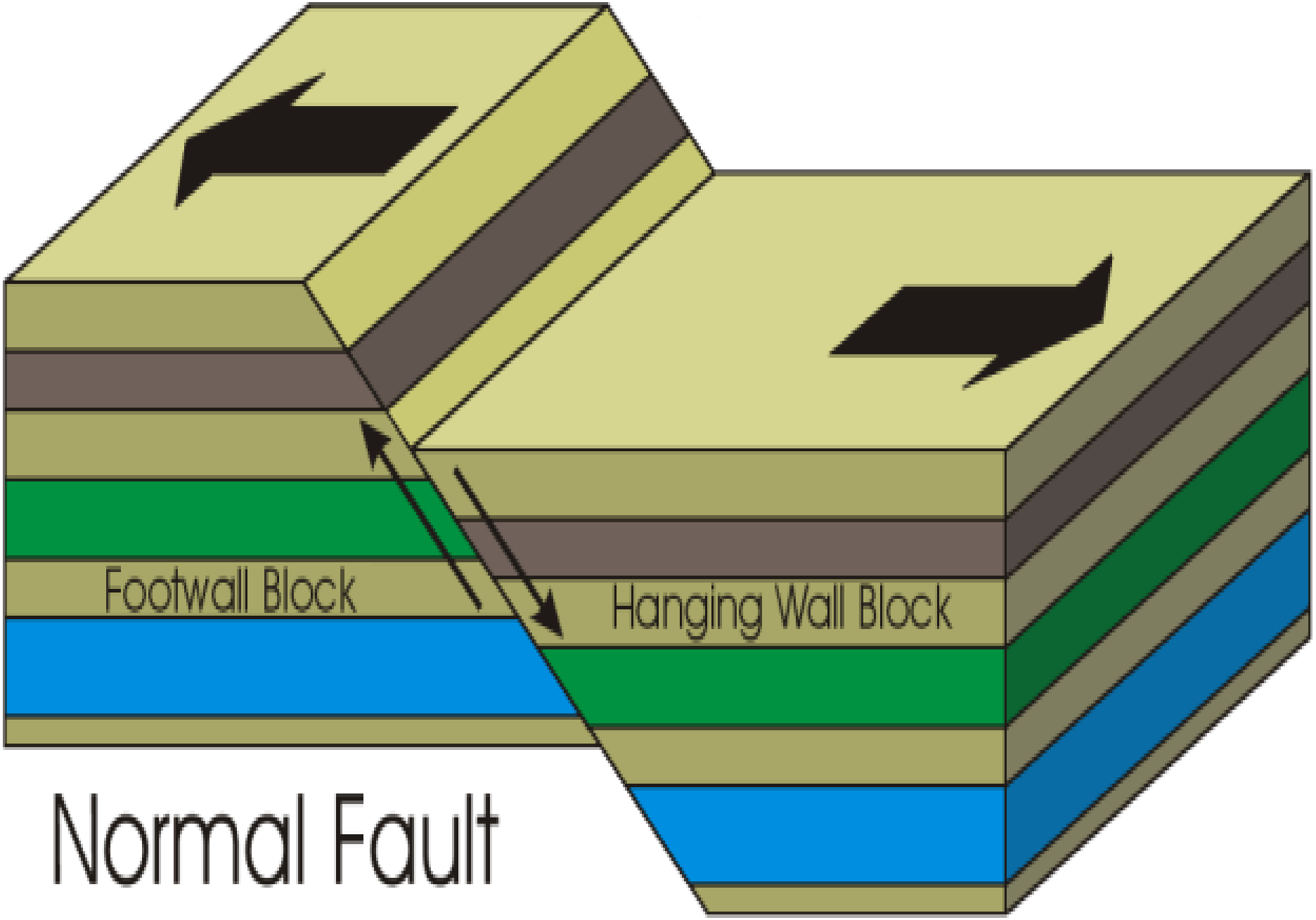

Normal Fault

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CAUSES OF FAULTING:

- Faults mainly occur in regions of structuralinstability.
- It may be recollected that faults develop mainly due to shearor sliding failures resulting from tensional, compression forces.
- When an earthquake occurs on one of these faults, the rock on one side of the fault slips with respect to theother.

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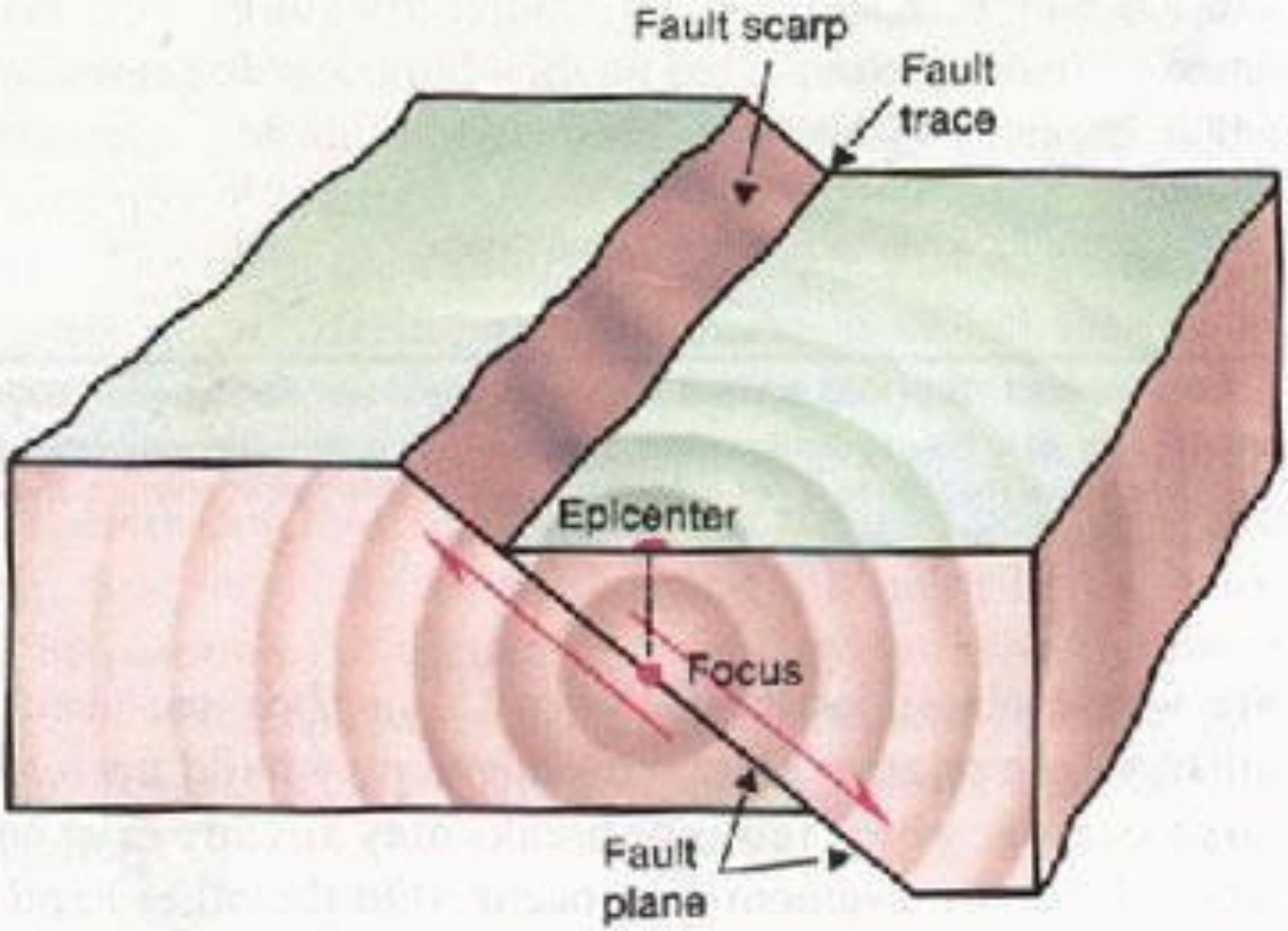

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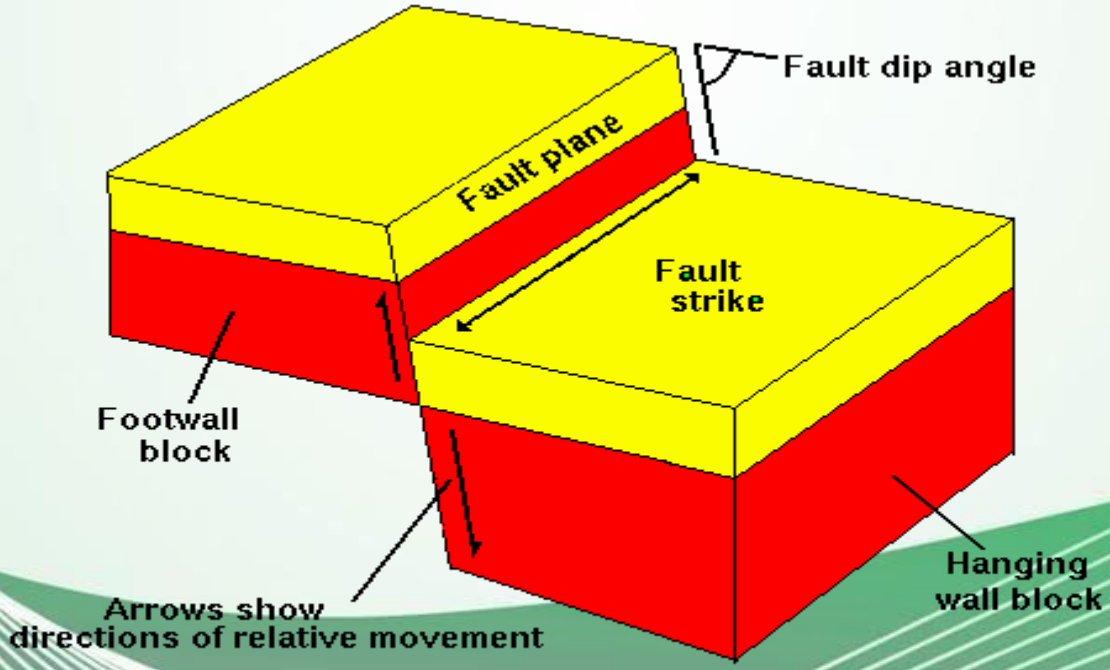
FAULT PLANE:

- This is the plane along which the adjacent blocks are relatively displaced.
- In other words, this is the fracture surface on either side of which the rocks had moved past oneanother.



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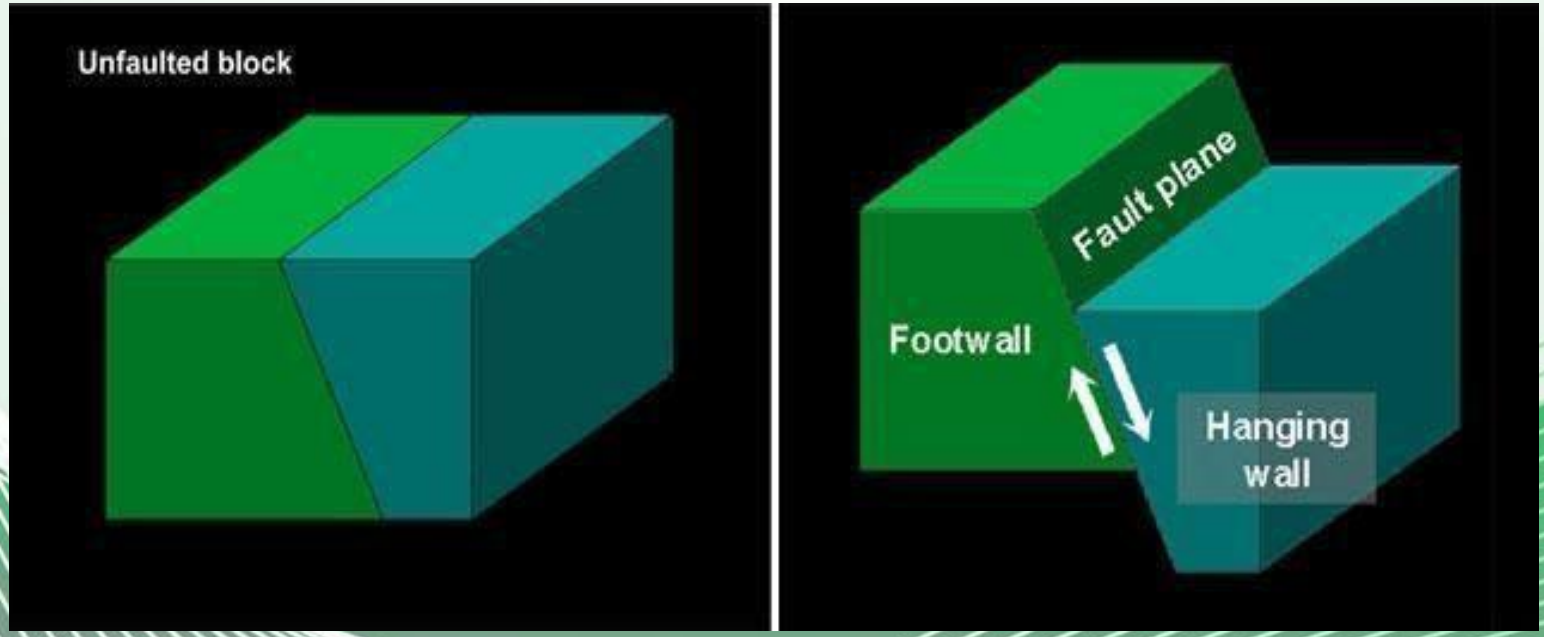
FOOT WALL AND HANGING WALL:

- When the fault plane is inclined the block which lies belowthe fault plane is called “Foot wall”.
- And the other block which rests above the fault plane is called “Hangingwall”.



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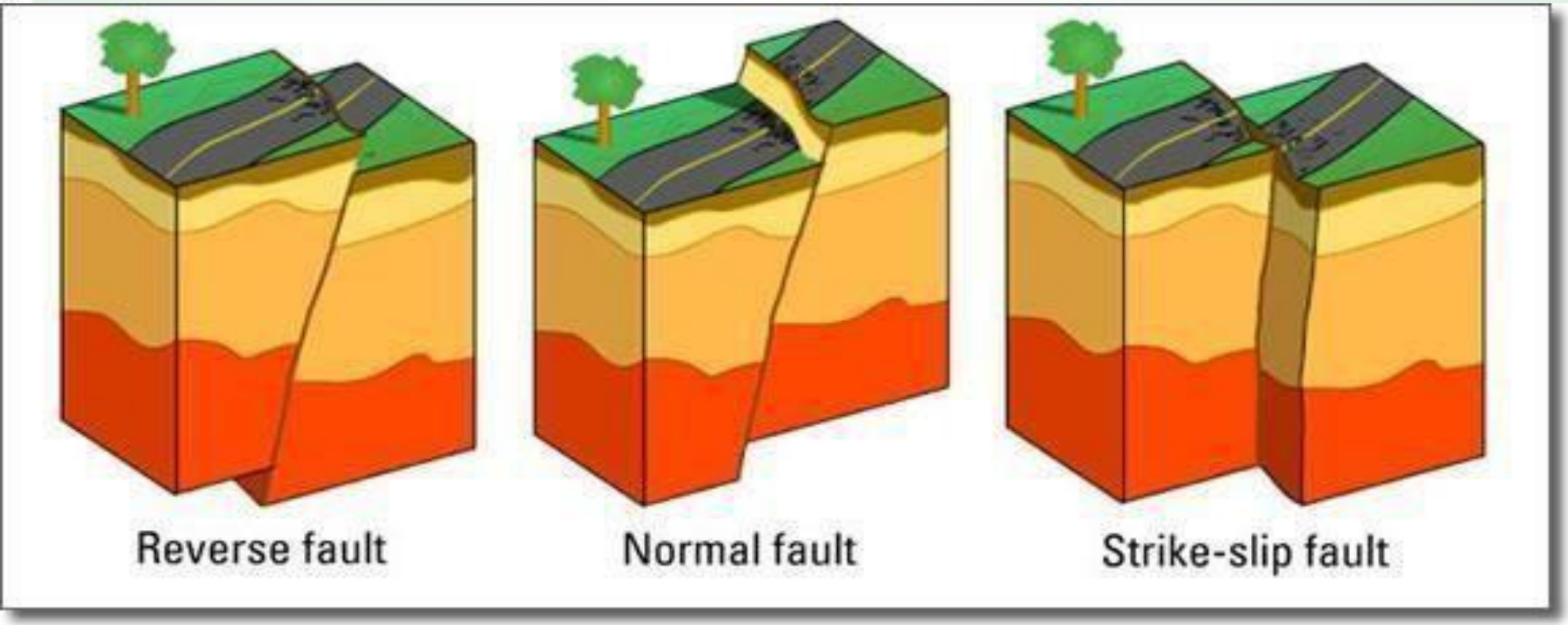
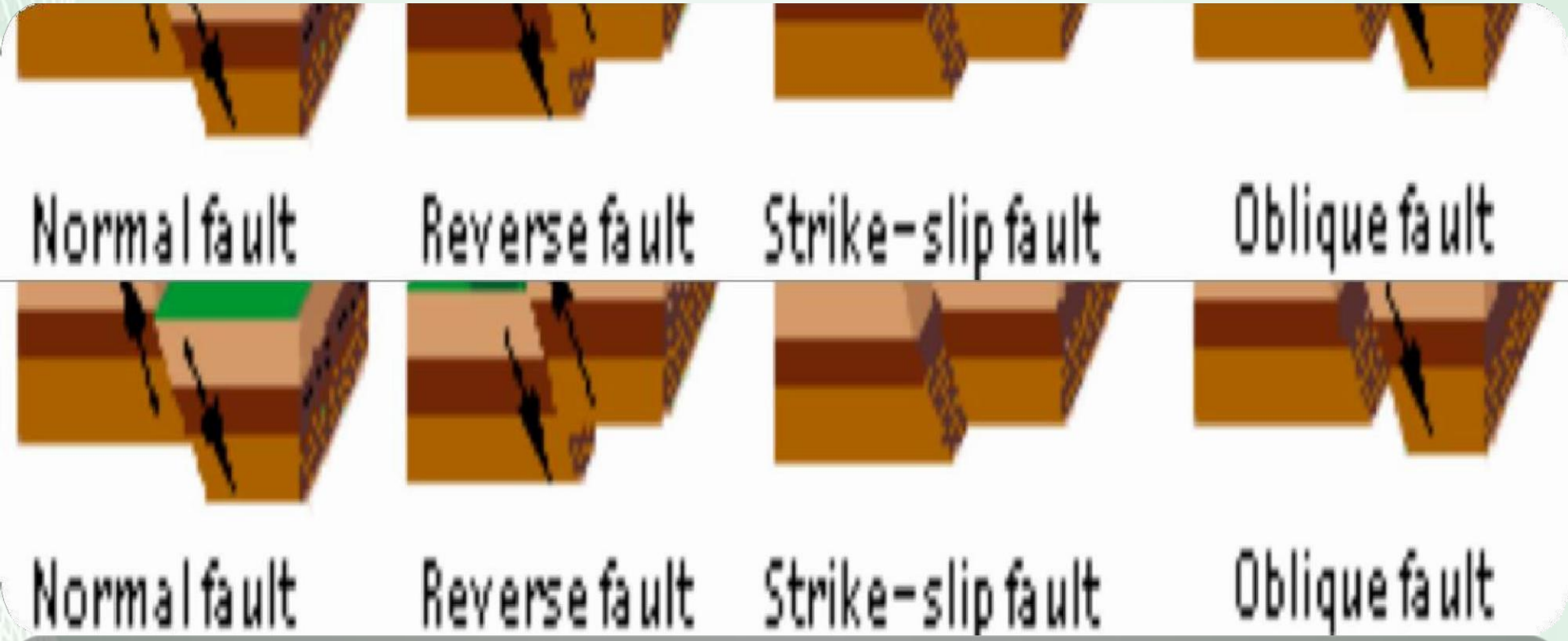
SLIP:

- The displacement that occurs during faulting is called theslip.
- The total displacement is known as the netslip.
- This may be along the strike direction or the dipdirection.




Normal fault
Reverse fault
Strike-slip fault
Oblique fault
Normal fault
Reverse fault
Strike-slip fault
Oblique fault

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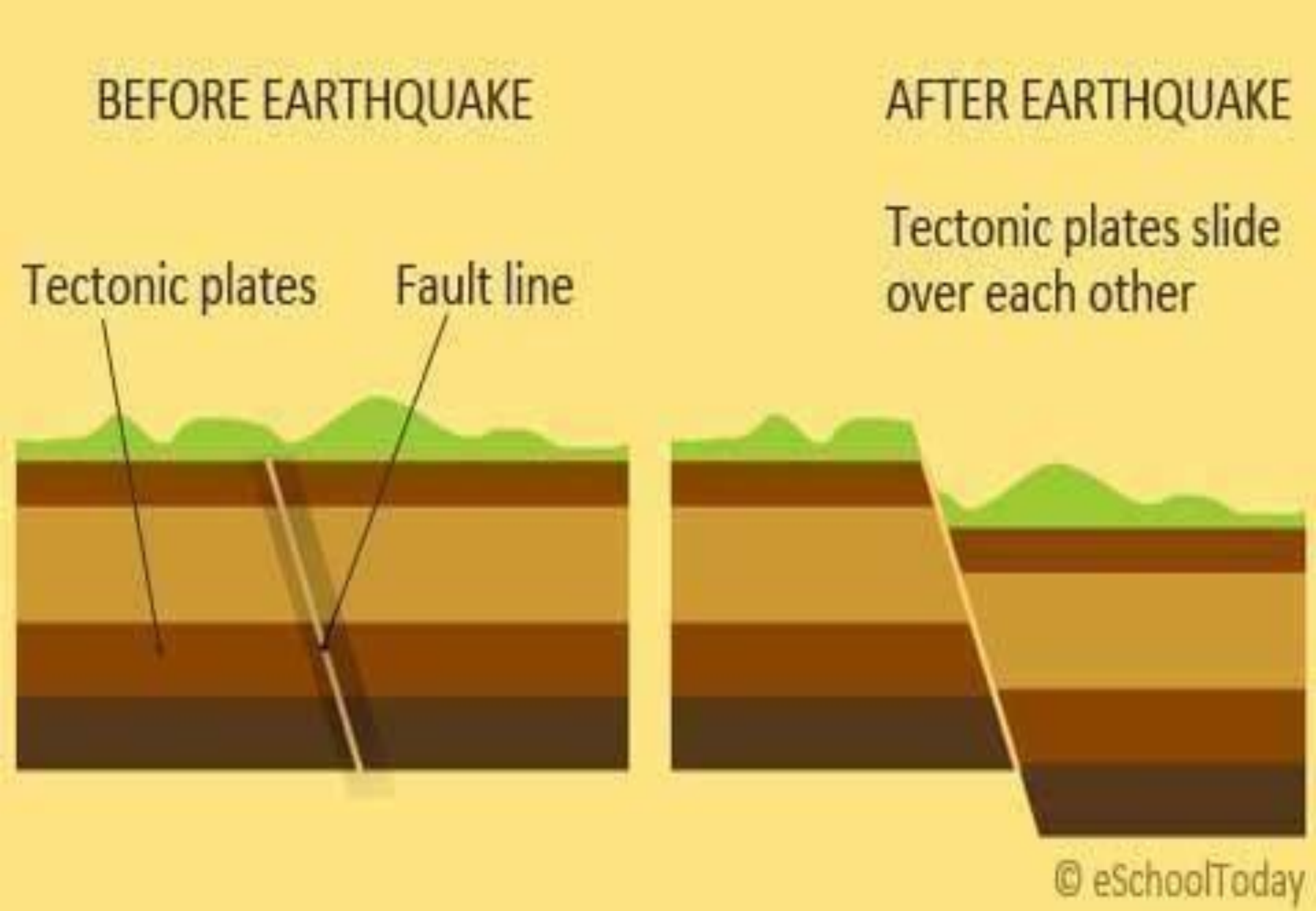
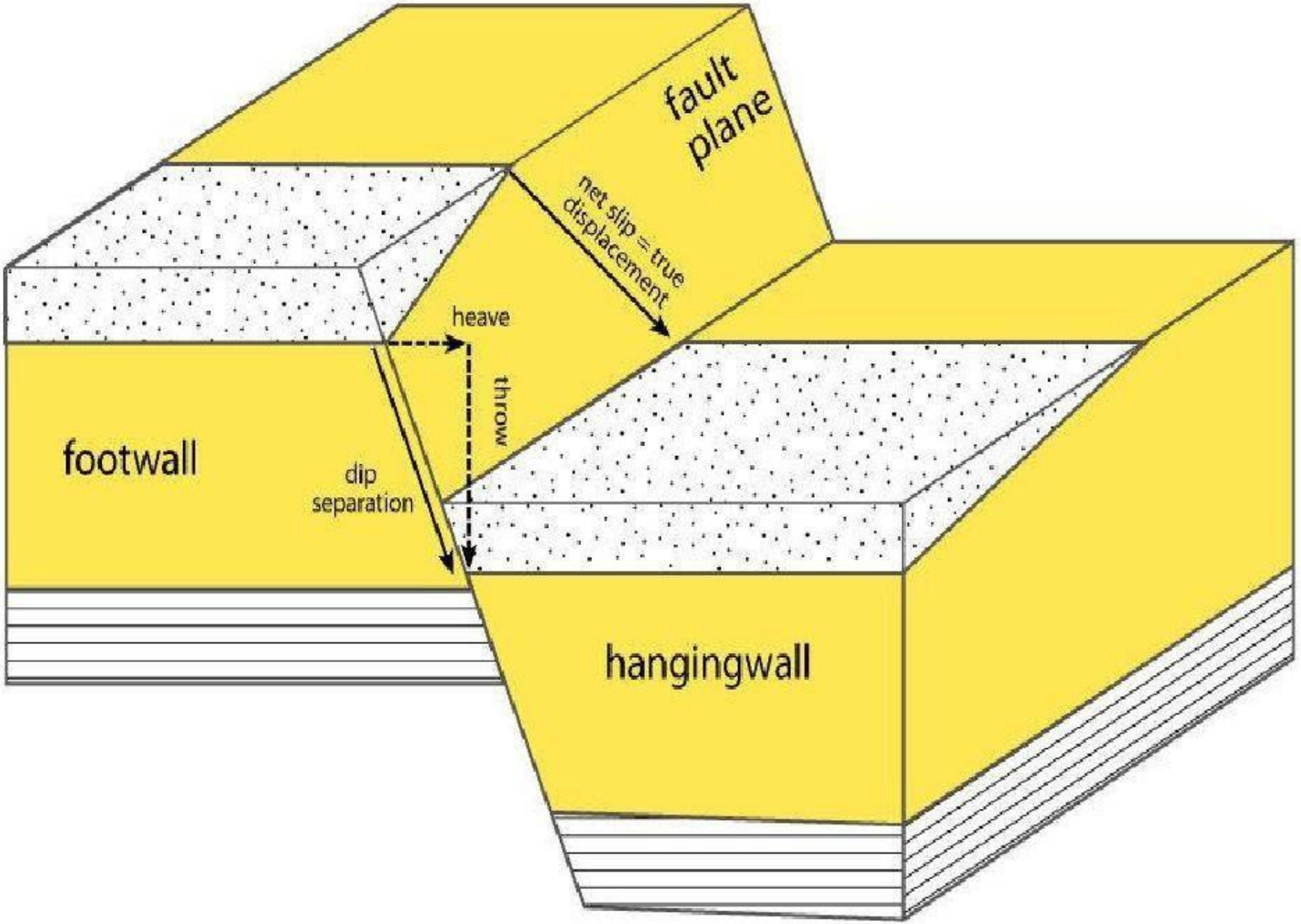

BEFORE EARTHQUAKE
AFTER EARTHQUAKE
Tectonic plates slide over each other
Tectonic plates
Fault line
© eSchoolToday

Parts of a Fault

Heave and Throw

- The **horizontal component of displacement** is called **"heave"** and **the vertical component of displacement** is called **"throw"**
- In vertical faults, there is only throw, but no heave. In horizontal faults, there is only heave, but no throw.


fault plane
net slip = true displacement
heave
throw
footwall
dip separation
hangingwall

UNIT-IV
DAMS AND RESERVIORS

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EARTHQUAKES

DEFINITION:

A sudden violent shaking of the ground, typically causing great destruction, as a result of movements within the earth's crust or volcanic action.

A sudden release of energy in the earth's crust or upper mantle, usually caused by movement along a fault plane or by volcanic activity and resulting in the generation of seismic waves which can be destructive.

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Sesimic Waves:

Seismic waves are **waves** of energy that travel through the Earth's layers, and are a result of an **earthquake**, explosion, or a volcano that gives out low-frequency acoustic energy.

Seismic waves are studied by geophysicists called **seismologists**. Seismic wave fields are recorded by a seismometer, hydrophone (in water), or accelerometer.ncy acoustic energy.

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•The propagation velocity of the waves depends on density and elasticity of the medium.

• Velocity tends to increase with depth and ranges from approximately 2 to 8 km/s in the Earth's crust, up to 13 km/s in the deep mantle.

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Classification and causes of Earthquake:

Based on depth of their origin, earthquake are described as shallow or intermediate or Deep.

- Earthquake with a focus depth less than 60km are called shallow earthquake.
- If the depth more than 60km but less than 300km, they are called Intermediate earthquake.
- Which have focus depth more than 300km, they are called Deep earthquake.

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Based on the causes responsible for their occurrence, earthquakes are described as Tectonic or non Tectonic.

•**Tectonic earthquake** are exclusively due to internal causes, due to disturbances or adjustments of geological formations taking place in the earth's interior, they are les frequent, but more intensive and hence more destructive in nature.

•The **Non Tectonic earthquake** on the other hand, are generally due to external or surfacial causes. This type of earthquake is very frequent, but minor in intensity and generaly not destructive in nature.

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Types:

Among the many types of seismic waves, one can make a broad distinction between *body waves* and *surface waves*.

•Body waves travel through the interior of the Earth.

•Surface waves travel across the surface.

•Surface waves decay more slowly with distance than do body waves, which travel in three dimensions.

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Includes Primary and Secondary waves:

Primary waves(P-wave):

•Primary waves are compression waves that are longitudinal in nature.

•P waves are pressure waves that travel faster than other waves through the earth to arrive at seismograph stations first, hence the name "Primary".

•These waves can travel through any type of material, including fluids, and can travel at nearly twice the speed of S waves.

•In air, they take the form of sound waves, hence they travel at the speed of sound.

•Typical speeds are 330 m/s in air, 1450 m/s in water and about 5000 m/s in granite.

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Secondary waves(S-Waves):

•Secondary waves (S-waves) are shear waves that are transverse in nature.

•Following an earthquake event, S-waves arrive at seismograph stations after the faster-moving P-waves.

•S-waves can travel only through solids, as fluids (liquids and gases) do not support shear stresses.

• S-waves are slower than P-waves, and speeds are typically around 60% of that of P-waves in any given material.

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Definition:

•An Earthquake is a sudden and rapid shaking of the ground due to passage of vibrations beneath caused by transient disturbance of elastic or gravitational equilibrium of rocks.

•The scientific study of earthquakes is called Seismology.

•Earthquakes are measured using observations from seismometers.

• Seismic waves are recorded on instruments called seismographs.

•The time, locations, and magnitude of an earthquake can be determined from the data recorded by seismograph stations.

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RICHTER MAGNITUDE SCALE:

•The Richter magnitude scale was developed in 1935 by Charles F. Richter.

•Earthquakes with magnitude of about 2.0 or less are usually called micro earthquakes; are generally recorded only on local seismographs.

•Events with magnitudes of about 4.5 or greater, are strong enough to be recorded by sensitive seismographs all over the world.

•Great earthquakes have magnitudes of 8.0 or higher.

•On the average, one earthquake of such size occurs somewhere in the world each year.

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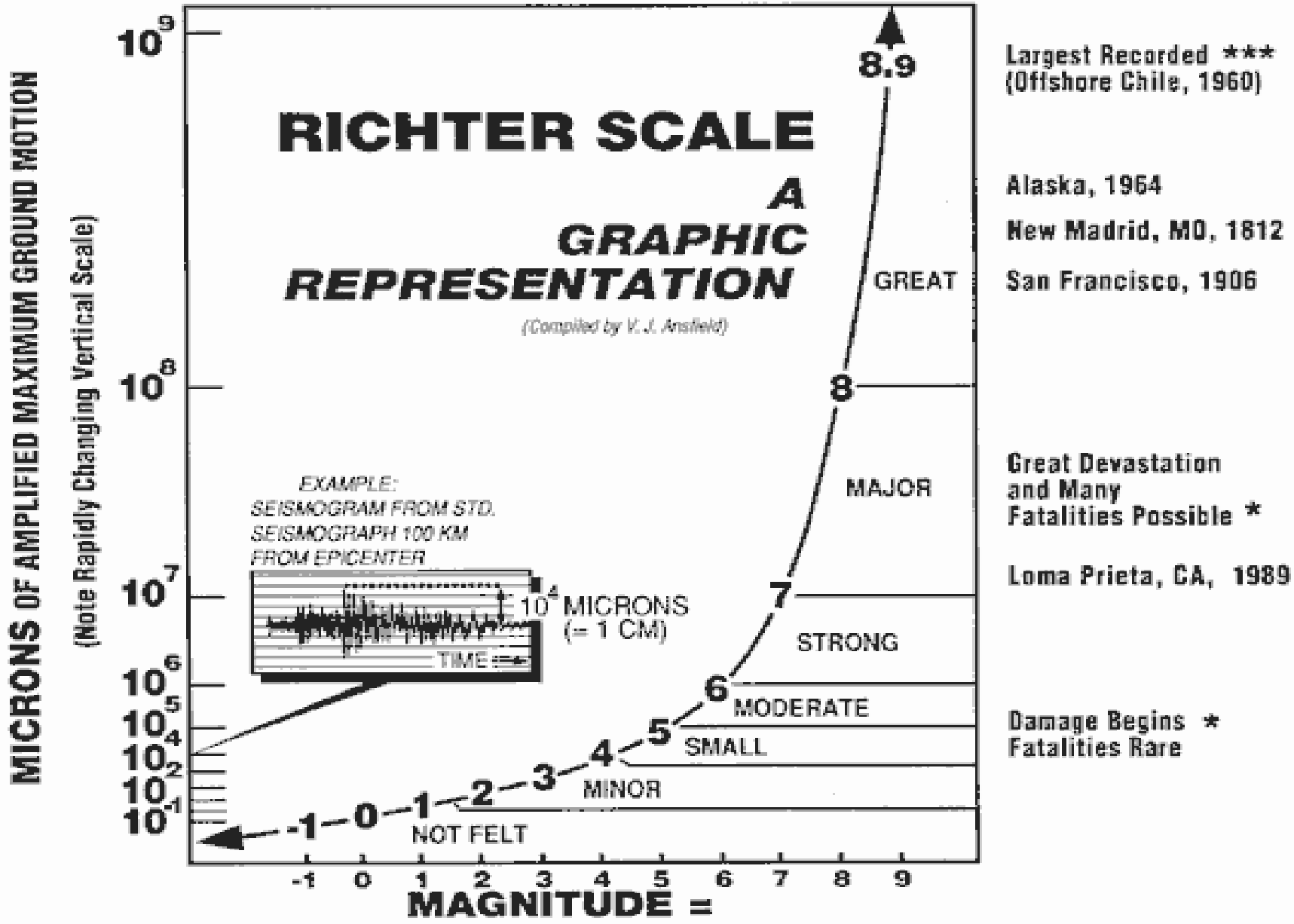

* EFFECTS MAY VARY GREATLY DUE TO CONSTRUCTION PRACTICES, POPULATION DENSITY, SOIL DEPTH, FOCAL DEPTH, ETC.

** MICRON = A MILLIONTH OF A METER

*** EQUIVALENT TO A MOMENT MAGNITUDE OF 9.5

Man-made Earthquakes:

- The impounding of large quantities of water behind dams disturbs the crustal balance.
- The shock waves through rocks set up by the underground testing of Atom bombs or Hydrogen bombs may be severe to cause earthquake.

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CAUSES :

Natural Causes of Earthquake:

- Tectonic Movement
- Volcanic Activity
- Pressure of gases in the interior
- Landslides and avalanches
- Faulting and folding in the rock beds are responsible for causing minor earthquakes.

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Man-made Earthquakes:

•The impounding of large quantities of water behind dams disturbs the crustal balance.

•The shock waves through rocks set up by the underground testing of Atom bombs or Hydrogen bombs may be severe to cause earthquake.

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EFFECTS:

Destructive Effects:

- Earthquake causes dismantling of buildings, bridge and other structures at or near epicenter.
- Rails are folded, underground wires broken.
- Earthquakes originate sea waves called Tsunamis.
- Earthquakes result in the formation of cracks and fissures on the ground formation.
- The earthquakes cause landslides.
- Landslide due to earthquake may block valleys to form lakes.

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SEISMIC BELT:

Narrow geographic zone on the Earth's surface along which most earthquake activity occurs.

The outermost layer of the Earth (lithosphere) is made up of several large tectonic plates.
There are three main seismic belts in the world :
1.Circum-Pacific seismic belt
2.Alpine-Himalayan seismic belt
3.Ridge seismic belt

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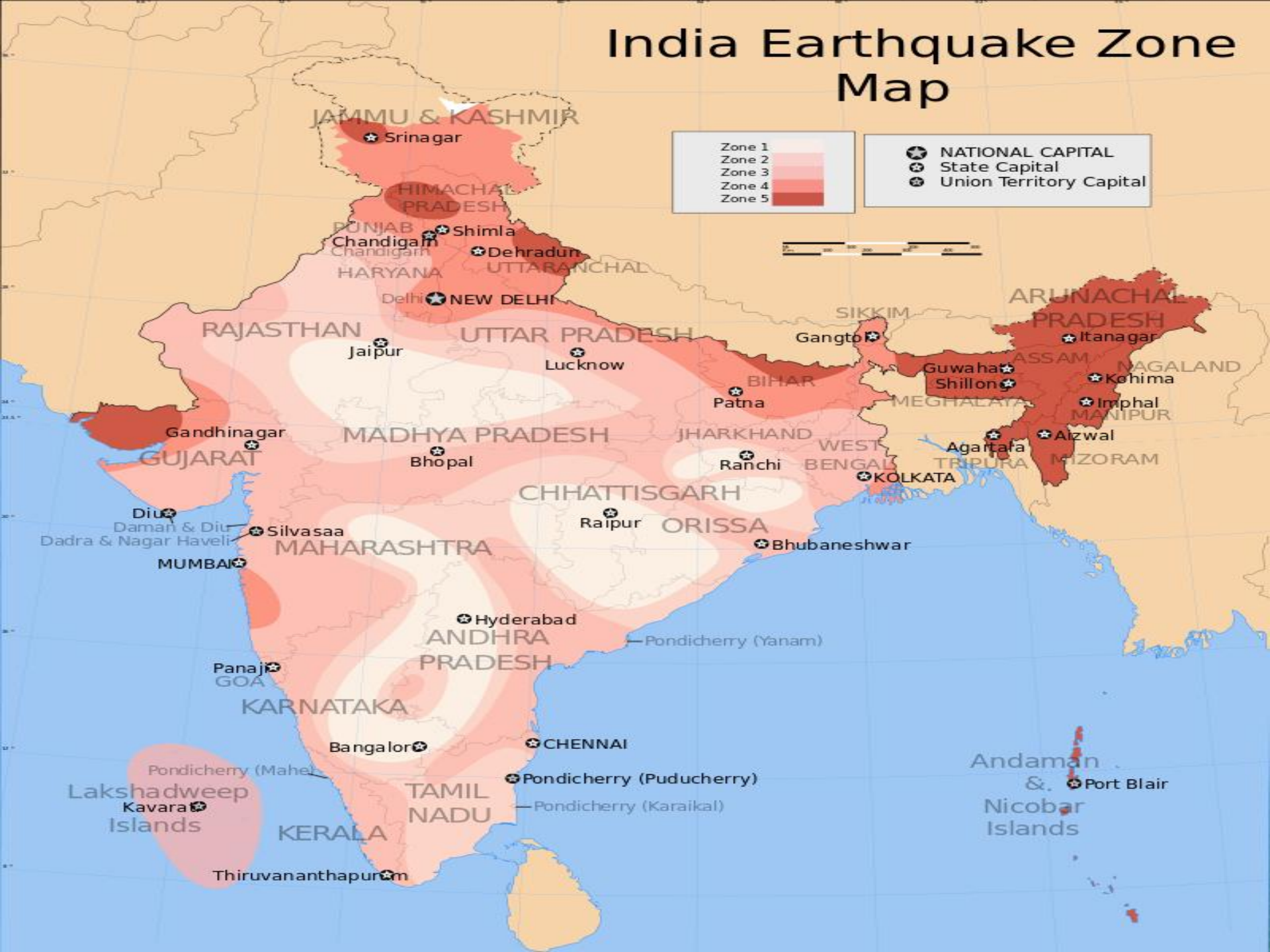
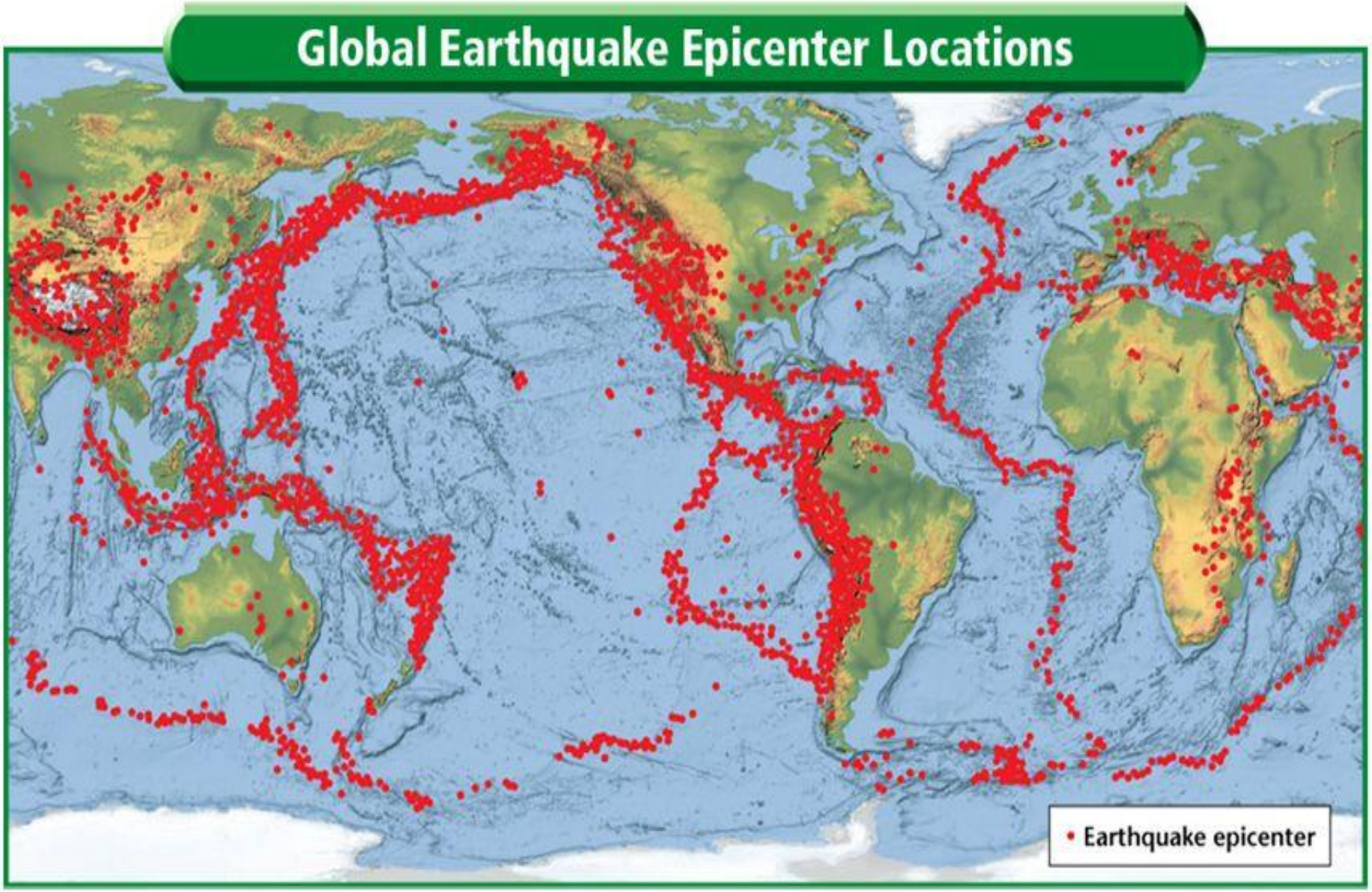

India Earthquake Zone Map
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
NATIONAL CAPITAL
State Capital
Union Territory Capital
JAMMU & KASHMIR
Srinagar
HIMACHAL PRADESH
PUNJAB
Shimla
Chandigarh
Chandigarh
Dehradun
HARYANA
UTTARANCHAL
Delhi
NEW DELHI
RAJASTHAN
Jaipur
UTTAR PRADESH
Lucknow
SIKKIM
Gangtok
ARUNACHAL PRADESH
Itanagar
ASSAM
Guwahati
Shillong
NAGALAND
Kohima
BIHAR
Patna
MEGHALAYA
Imphal
MANIPUR
Gandhinagar
MADHYA PRADESH
JHARKHAND
Aizwal
GUJARAT
Bhopal
Ranchi
WEST BENGAL
Agartala
TRIPURA
MIZORAM
KOLKATA
CHHATTISGARH
Diu
Daman & Diu
Dadra & Nagar Haveli
Silvasaa
Raipur
ORISSA
MAHARASHTRA
Bhubaneshwar
MUMBAI
Hyderabad
ANDHRA PRADESH
Pondicherry (Yanam)
Panaji
GOA
KARNATAKA
Bangalor
CHENNAI
Pondicherry (Mahe)
Pondicherry (Puducherry)
Lakshadweep
Kavaratti
Islands
TAMIL NADU
Pondicherry (Karaikal)
KERALA
Andaman & Nicobar Islands
Port Blair
Thiruvananthapuram

Seismic Belts



SEISMIC WAVES:

•Seismic waves are waves of energy that travel through the Earth's layers, and are a result of earthquakes, volcanic eruptions, magma movement, large landslides and large man-made explosions that give out low-frequency acoustic energy.

•Seismic wave fields are recorded by a seismometer, hydrophone (in water), or accelerometer.

P-waves:

•**P-waves** are a type of body wave, that travel through a continuum and are the first waves from an earthquake to arrive at a seismograph.

•Typical values for P-wave velocity in earthquakes are in the range 5 to 8 km/s.

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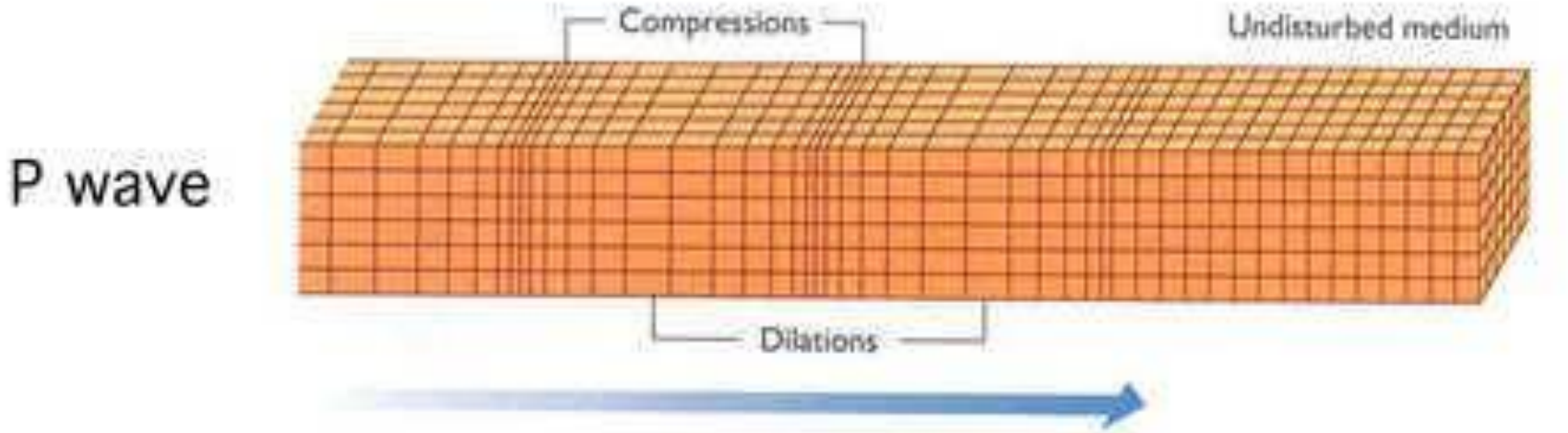

S-WAVES:

• S-waves, secondary waves, or shear waves (sometimes called an elastic S-wave) are a type of elastic wave.

• The S-wave moves as a shear or transverse wave, so motion is perpendicular to the direction of wave propagation.

•Velocity tends to increase with depth and ranges from approximately 2 to 8 km/s in the Earth's crust, up to 13 km/s in the deep mantle.

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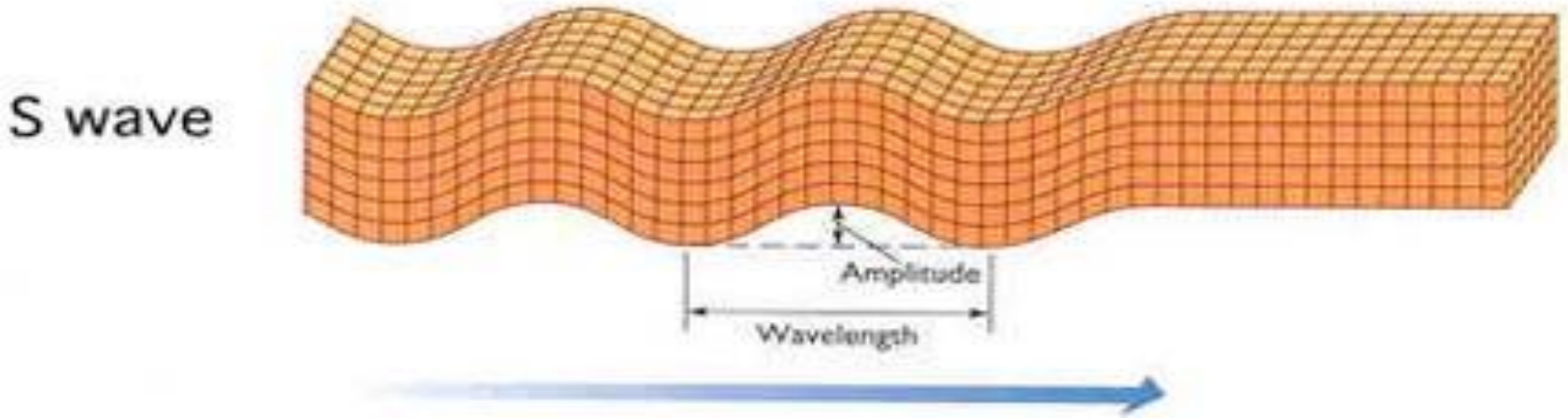

L-WAVES:

- The third general type of earthquake wave is called a surface wave, reason being is that its motion is restricted to near the ground surface.
- Such waves correspond to ripples of water that travel across a lake.
- The typical range of velocities is between 2 and 6 km/second.

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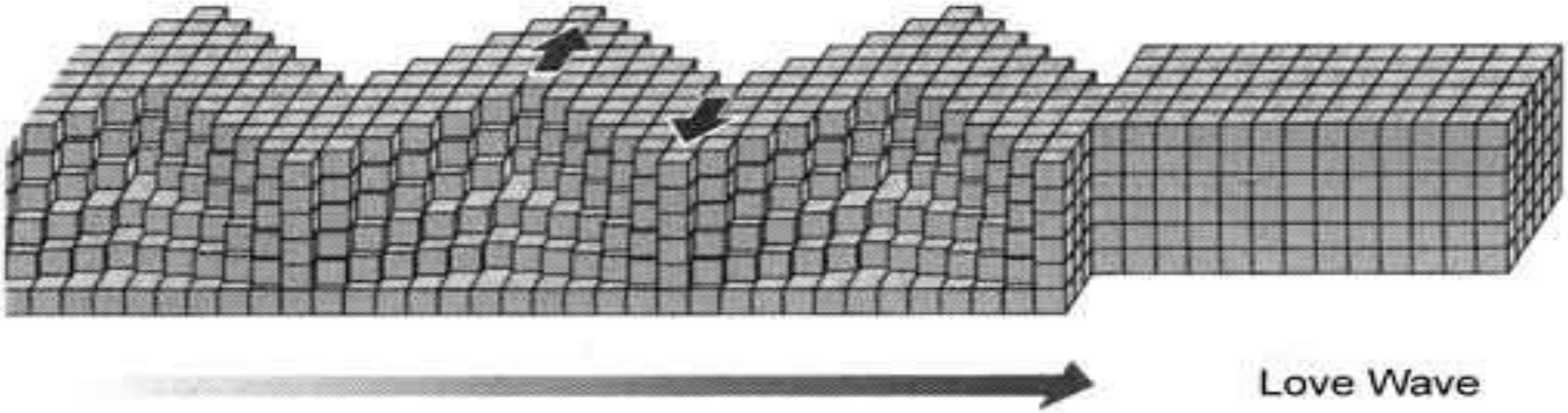

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UNIT-V
TUNNELS

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PRECAUTIONS:

- First do the soil test. Structures will be constructed after testing the soils compaction tendency.
- Design of the structures or buildings should be made by professional engineer.
- Use rods according to the foundation type.
- The rod must provide necessary earthquake resistance to the building or structure.
- Maintain the quality of cement, rod and sand. Provide necessary rod in the joint of foundation and grade beam.
- This helps to provide extra earthquake resistance to the structures or buildings.
- Check column and slab design requirements by the authority.

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•For earthquake resistance purposes, there will be no connection in the intersection of beam column.

•Columns of the structures or buildings need to be made strong to provide needed resistance. Column size can be increased from the foundation necessarily.

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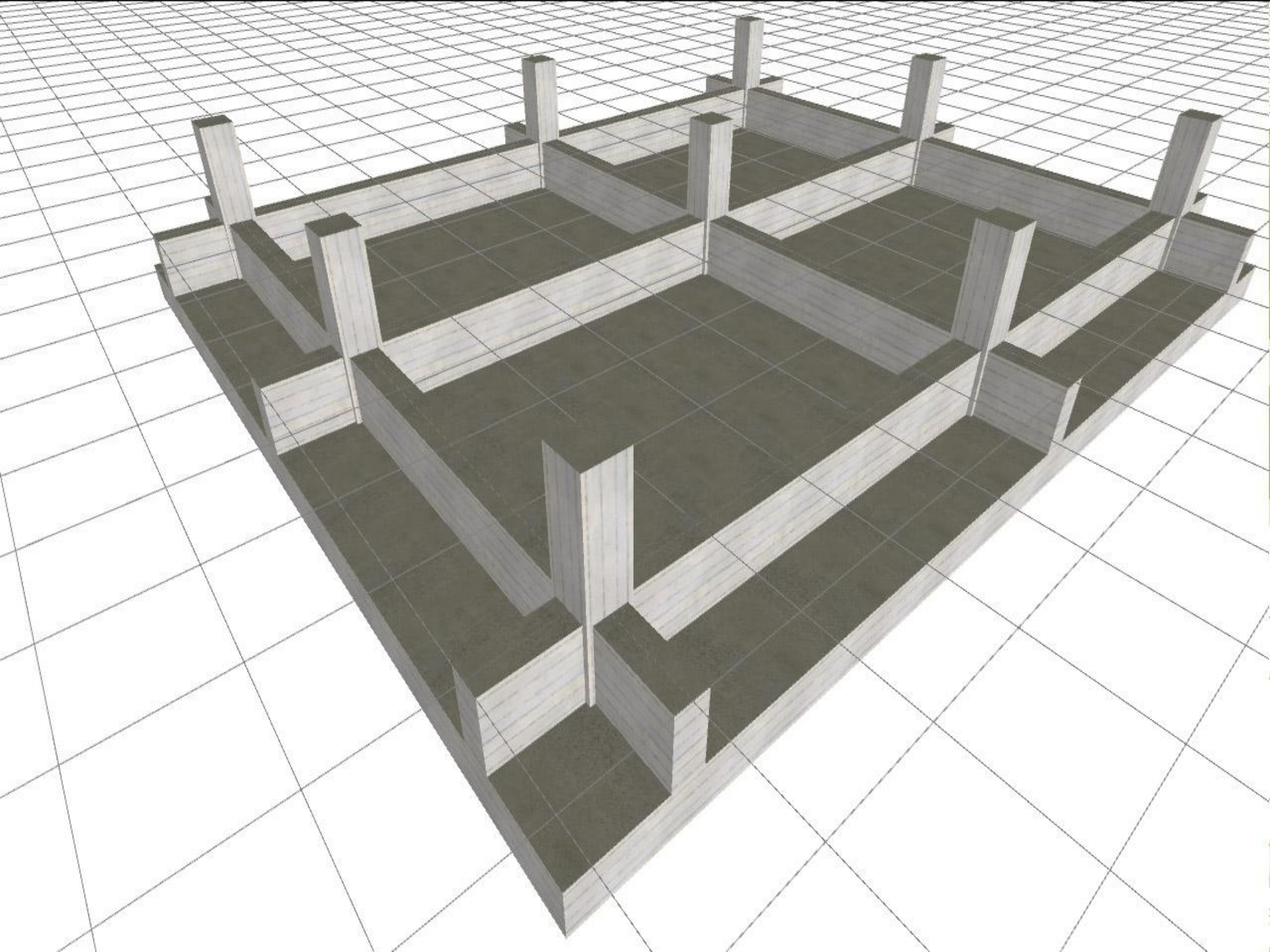
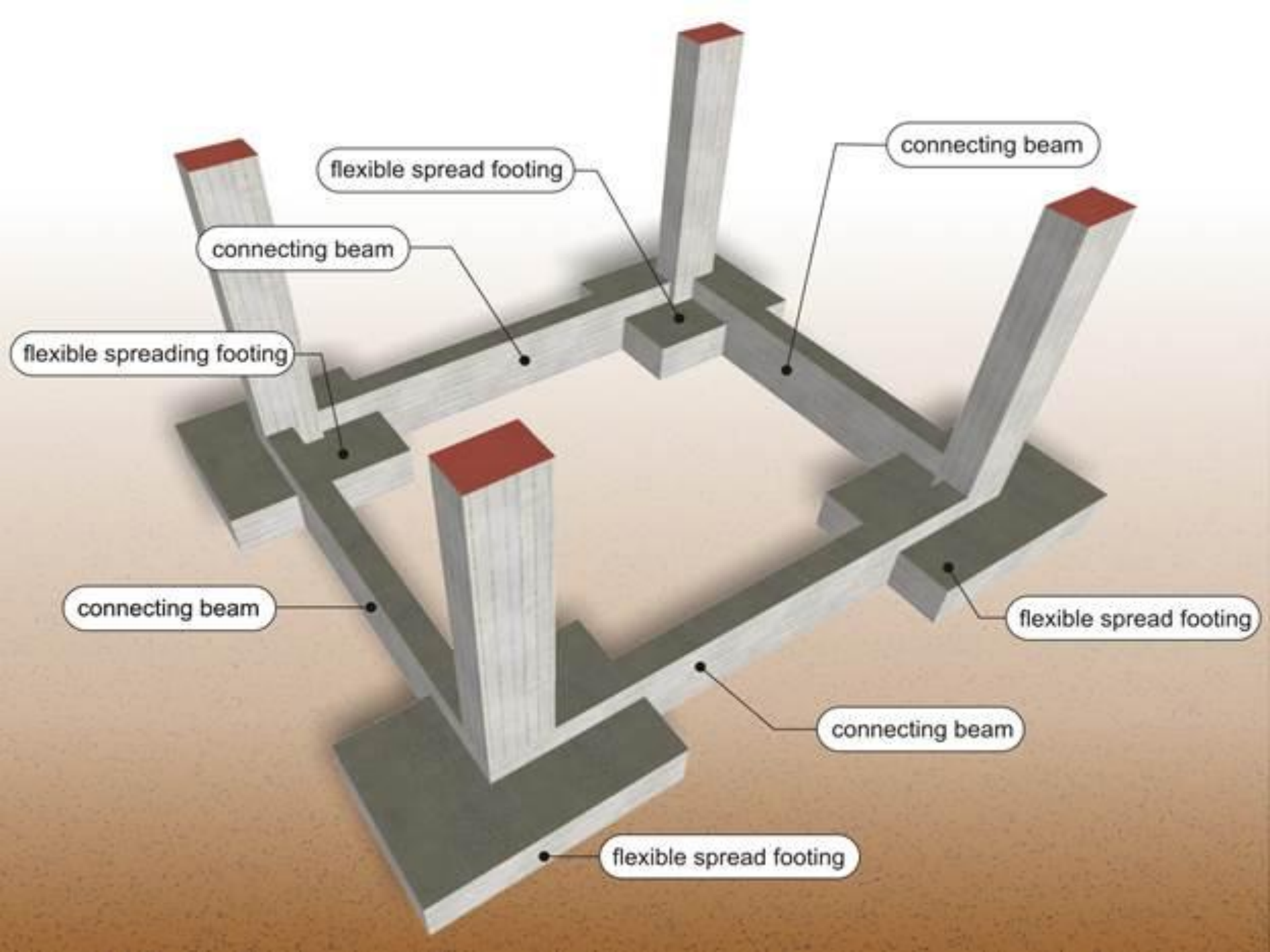
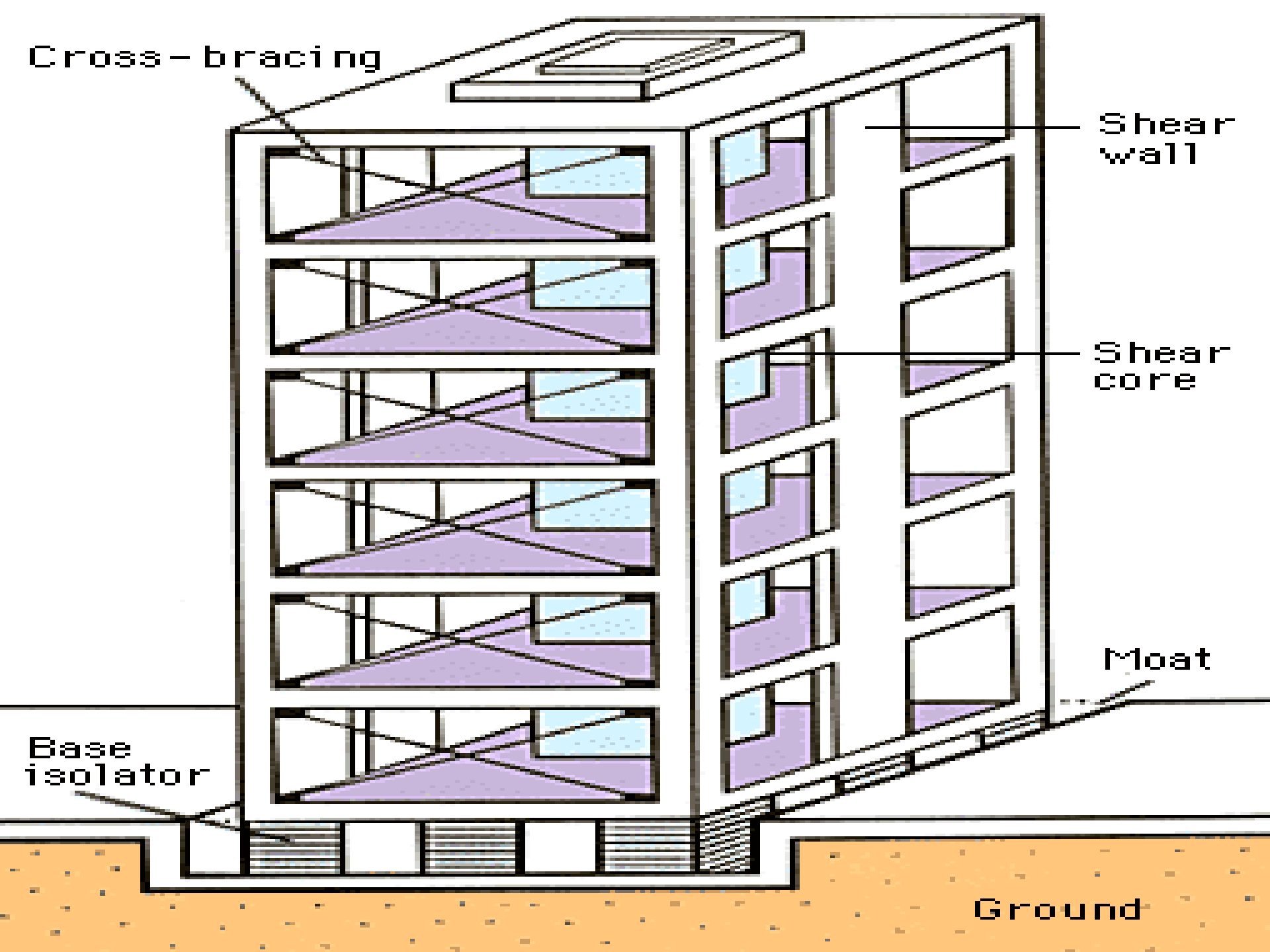



flexible spread footing
connecting beam
connecting beam
flexible spreading footing
connecting beam
flexible spread footing
connecting beam
flexible spread footing


Cross-bracing
Shear wall
Shear core
Moat
Base isolator
Ground

LANDSLIDES:

•A landslide is the movement of rock, debris or earth down a slope.

•They result from the failure of the materials which make up the hill slope and are driven by the force of gravity.

•Landslides are known also as landslips, slumps or slope failure.

•This is the most destructive and turbulent form of landslide.

• Flows have a high water content which causes the slope material to lose cohesion, turning it into a slurry.

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LANDSLIDES HAZARDS:

•Although landslides are primarily associated with mountainous regions, they can also occur in areas of generally low relief.

• In low-relief areas, landslides occur as cut-and fill failures (roadway and building excavations).

•Slope saturation by water is a primary cause of landslides.

•This effect can occur in the form of intense rainfall, snowmelt, changes in ground-water levels.

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Natural causes include:

- Elevation of pore water pressure by saturation of slope material from either intense or prolonged rainfall and seepage
- Vibrations caused by earthquakes
- Undercutting of cliffs and banks by waves or river erosion
- Volcanic eruptions

Human causes include:

- Removal of vegetation
- Interference with, or changes to, natural drainage
- Leaking pipes such as water and sewer reticulation
- Modification of slopes by construction of roads, railways, buildings, etc

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5. Modification of slopes by construction of roads, railways, buildings, etc
6. Mining and quarrying activities

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THANK YOU

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