Civinnovate

Discover, Learn, and Innovate in Civil Engineering

Engineering Geology

UNIT I PHYSICAL GEOLOGY

Geology in civil engineering – branches of geology – structure of earth and its composition – weathering of rocks – scale of weathering – soils - landforms and processes associated with river, wind, groundwater and sea – relevance to civil engineering. Plate tectonics – Earth quakes – Seismic zones in India.

UNIT II MINEROLOGY

Physical properties of minerals – Quartz group, Feldspar group, Pyroxene - hypersthene and augite, Amphibole – hornblende, Mica – muscovite and biotite, Calcite, Gypsum and Clay minerals.

UNIT III PETROLOGY

Classification of rocks, distinction between Igneous, Sedimentary and Metamorphic rocks. Engineering properties of rocks. Description, occurrence, engineering properties, distribution and uses of Granite, Dolerite, Basalt, Sandstone, Limestone, Laterite, Shale, Quartzite, Marble, Slate, Gneiss and Schist.

UNIT IV STRUCTURAL GEOLOGY AND GEOPHYSICAL METHODS

Geological maps – attitude of beds, study of structures – folds, faults and joints – relevance to civil engineering. Geophysical methods – Seismic and electrical methods for subsurface investigations.

UNIT V APPLICATION OF GEOLOGICAL INVESTIGATIONS

Remote sensing for civil engineering applications; Geological conditions necessary for design and construction of Dams, Reservoirs, Tunnels, and Road cuttings - Hydrogeological investigations and mining - Coastal protection structures. Investigation of Landslides, causes and mitigation.

Unit -1 PHYSICAL GEOLOGY

Geology in civil Engineering – branches of geology – structure of earth and its composition – weathering of rocks – scale of weathering - soils – landforms and processes associated with river , wind , groundwater and sea – relevance to civil Engineering . Plate tectonics – Earth quakes – seismic zones in India

Geology

- It is the science that deals with the **study of earth.**

- Geology (from Greek)

  Geo – Earth , logos – science

It deals with different aspects of the earth

1. origin, age and interior structure of the earth.

2. **Evolution, modification, and extinction** of various **surface and subsurface physical features** like rivers , mountains , plateaus , plains , valleys , basins ,lakes and all coastal , marine and submarine forms.

- It also deals with the materials making up the earth and with the nature and functioning of surrounding gaseous envelope called **atmosphere**.

- And also with the study of all the water bodies existing on the surface or underground – **hydrosphere.**

Scope of Engineering geology

Application of geology for a **safe , stable** and **economic design** and construction of a civil Engineering project.

Objectives

1. It enables a civil Engineer to understand **Engineering implications** of certain conditions related to the **area of construction**, which are geological in nature.
2. It enables a geologist to understand the nature of geological information that is essential for a **safe design and construction** of civil engineering project.

Geology in Civil Engineering

Major activities of a professional civil Engineer are

- Construction
- Water Resource Development
- Town and regional planning

Geology in construction

- In all types of heavy construction jobs such as **buildings, towers , tanks , dams and reservoirs** , **highways and bridges , retaining structures** laying of pipe lines – **full geological information** about the site of construction and natural materials of construction is important.
- Useful - Planning , design and execution.

Planning – geological information is greatly useful

- **Topographic maps** (slope , size ,contour)
- **Hydrological maps** (details of surface & ground water)
- **Geological maps** (petro logical characters are depicted)

Design – Geological characters and conditions are useful for design of a project

- Existence of hard bed rocks
- Position of ground water table
- Seismic character of the area
- Porosity and permeability of the site area

Construction

- stability of a structure constructed depends on the **nature of rocks** .

- Construction of underground projects like **tunnels** requires thorough knowledge of geological characters and setting of rocks

- Geologically sensitive areas – coastal belts , Seismic zones ,Knowledge of geological history of the area is required

Geology in water resources development

- Water – necessity for survival of mankind
- Geological information is very important in exploration and exploitation of water resources
- Glacial Geology – origin , evolution and extinction of glaciers.
- **Water bearing properties of rocks** – aquifers (storage , movement and yield of water)
- Water resource Engineer – knowledge of geological formations

Geology in town and Regional planning

- Town planner – Geological Knowledge
- For allocation of lands (commercial centres , housing colonies , water supply projects , industrial centres)
- Proper land utilization for development of cities and towns
- Materials making the land – details of rocks , soils , vegetation , water bodies has to be understood

- **Railway station** , Should not be constructed in a belt lying **between a forested area and a big town** may change the entire **nature of the winds blowing** over the town from the forest zone.
- An **industrial township** , located along the banks of perennial river provides **easy and natural drainage for effluents** from industry. But it also affects flora and fauna and humans.

Branches of Geology

Physical geology

- It deals with the **origin, development** and ultimate fate of **various surface features of the earth** and also with its internal structure.

- **disposition of rock bodies, water bodies** and **huge moving deposits of ice** on the surface

Geomorphology

- Study of surface features of the earth, primarily of the land surface.
- Detailed investigations regarding development and **disposition of mountains, plains, plateaus, valleys and basins**

Mineralogy

Mineralogy deals with formation, occurrence, aggregation, properties, and uses of minerals.

Petrology

It deals with formation of various types of **rocks**, their mode of **occurrence, composition, textures and structures, geological and geographical distribution** on the earth

Historical geology

It deals with the past history of the Earth from the study of rocks and features associated with them.

Rocks – pages of earth's history

Economic Geology

The branch deals with the study of minerals and rocks and other materials (fuels etc) occurring on and in the earth **that can be exploited for the benefit of man.**

Allied Sciences

New branches of science in which geology makes a very important component

- **Geo chemistry** – science that uses the tools and principles of chemistry to explain the mechanisms behind major geological systems such as the **Earth's crust**.

- **Geophysics** – Identification of water and oil bearing strata below the surface of the earth by geophysical principles

- **Geo hydrology** – interaction between hydrology and geology , **ground water occurrence**

- **Mining Geology** – Exploration and exploitation of economic mineral deposits. Knowledge of petrology is required

- **Engineering Geology** – interaction between civil engineering and geological sciences ,improve the quality of construction

- **Rock Mechanics** – behaviour of rocks under various types of loads

- **Geo mechanics** – geologic study of the behavior of soil and rock

- **Meteorology** – study of atmosphere , concerned with weather

- **Oceanography** – deals with the extensive water bodies , oceans which cover about 70 % of surface area of the planet

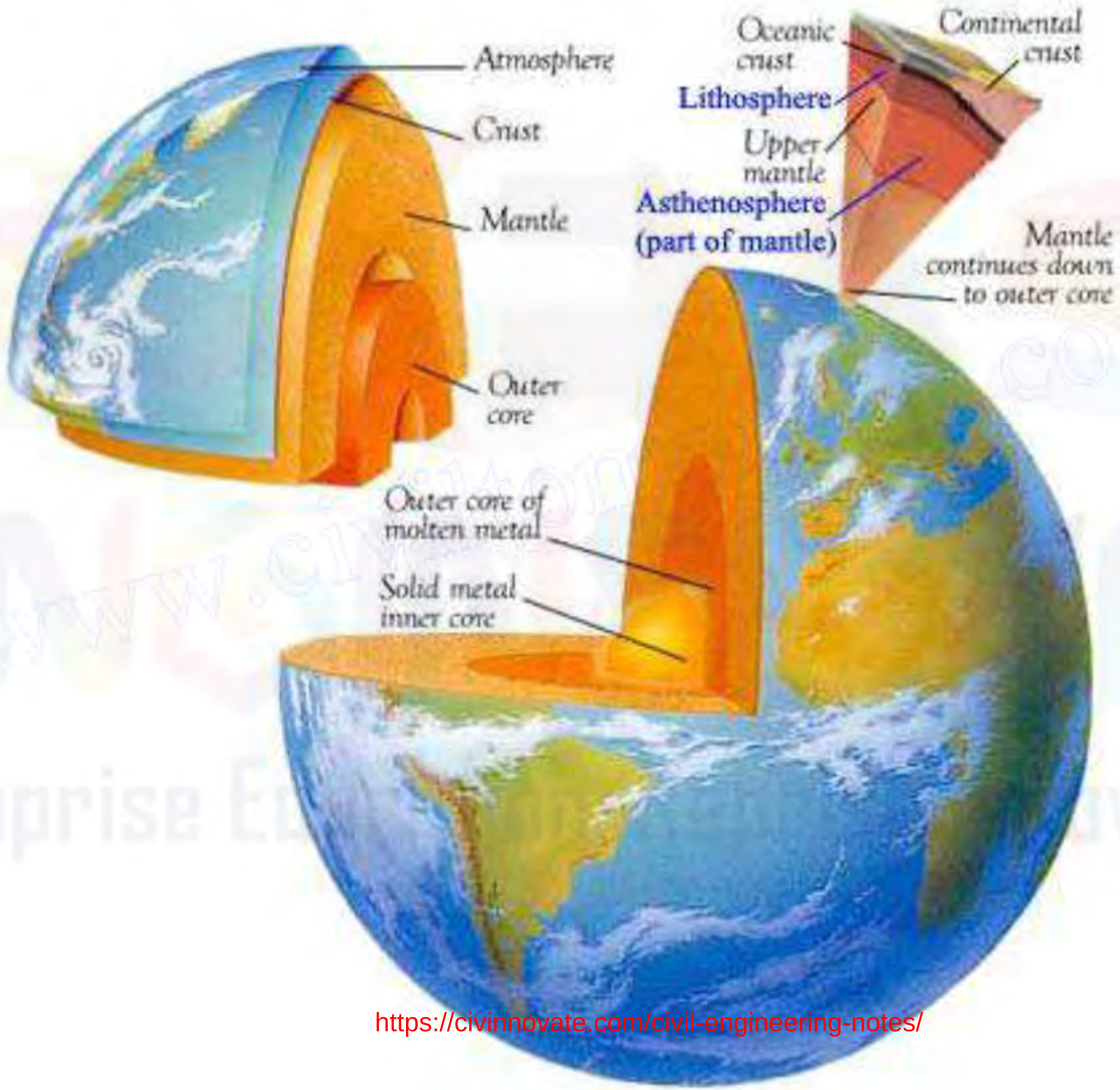
Structure of earth and its composition

Parts of earth – as a planet

Planet Earth is differentiated into three parts

1. Atmosphere
2. Lithosphere
3. Hydrosphere

Structure of earth



Atmosphere

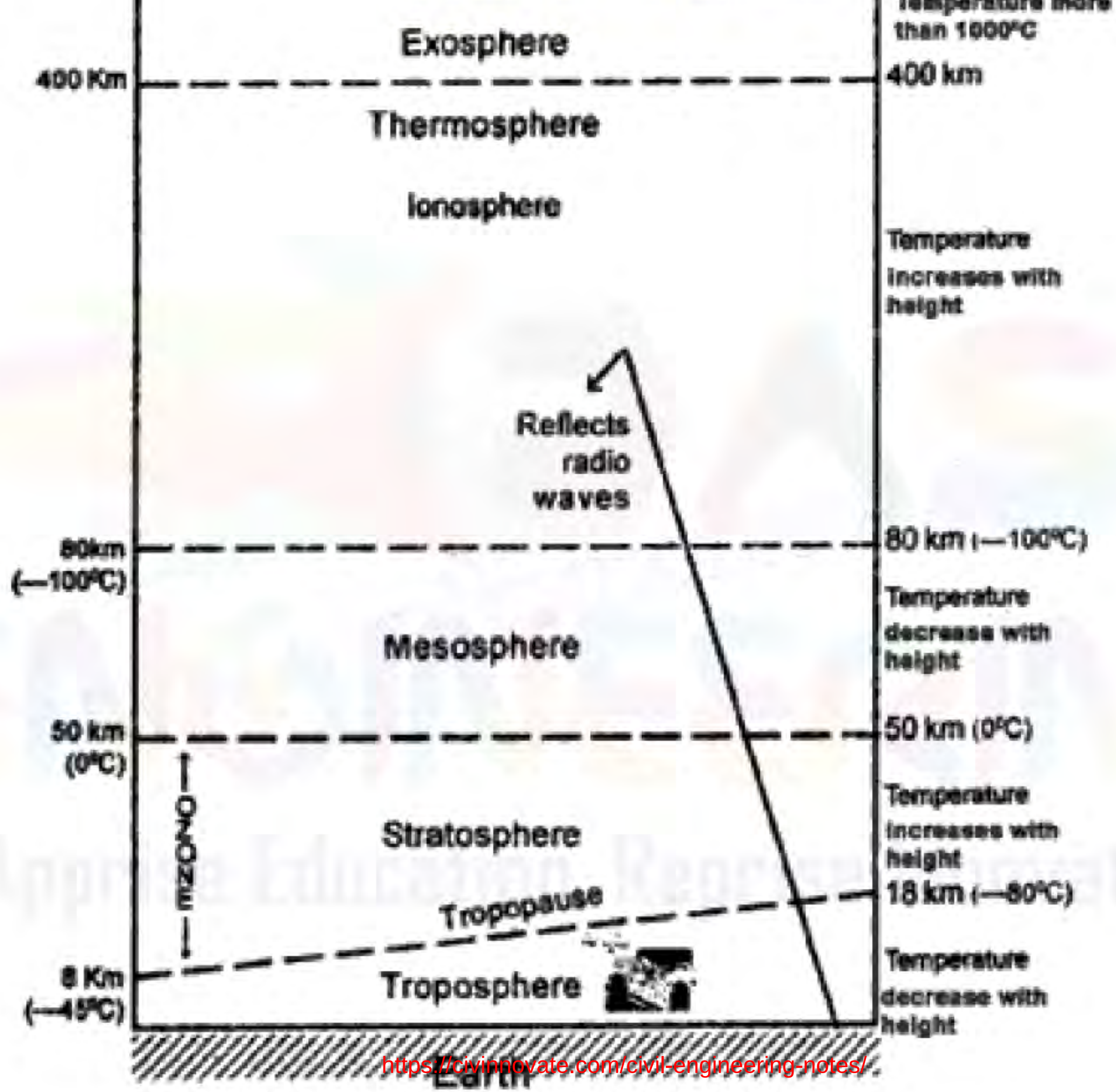
- The outer gaseous part of the Earth starting from the surface and extending as far as 700 km and even beyond is termed atmosphere.

- The gaseous envelope, is held around the planet due to gravitational pull of the body of the Earth.

Atmosphere

Based on thermal characters ,atmosphere is divided into following layers

1. Troposphere
2. Stratosphere
3. Mesosphere
4. Thermosphere



STRUCTURE OF THE ATMOSPHERE

Troposphere

- It is the lowermost zone of the atmosphere rising **from the surface of the earth** on an average to a height of 11 km.
- Its upper boundary called **tropopause** about 9km above the poles and at **18 km above the equator.**
- The troposphere **contains layer of gases** that is responsible for most of the weather forming or **meteorological processes on the earth**.

Stratosphere

- It is the second layer of the atmosphere starting from the tropopause and extending up to an average height of 50 km

- It contains almost the entire concentration of OZONE GAS that occurs above the Earth in the form of a well-defined envelope distinguished as the **Ozone layer**

- The upper boundary of the stratosphere is called stratopause.

Mesosphere

- This is the third thermal zone of atmosphere which begins at stratopause at about 50km above the surface and continues up to a **height of about 80 km**.

- It is characterized with a steep fall in temperature that **may go to as low levels as —100 °C** at the upper limit of mesosphere.

Thermosphere

- The **fourth and the last zone** of the atmosphere **starts at about 80 km and extends up to 500 km and beyond**.

- In this zone, temperature starts rising once again and reaches 1000°C and above.

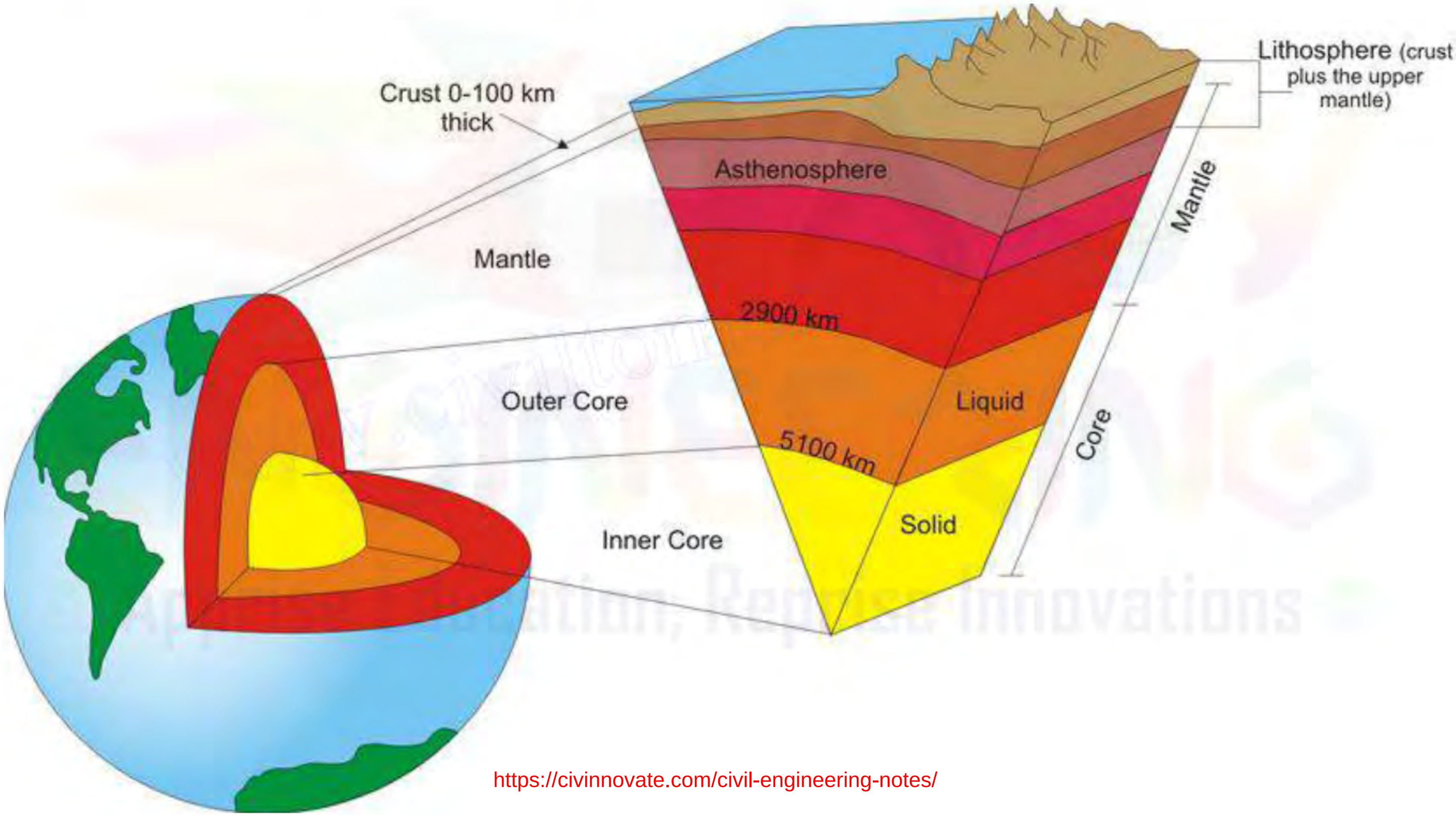
- The **IONOSPHERE** is a special zone recognized within the atmosphere. It starts from 80 km and extends upwards to variable heights.

Lithosphere

It is the **stony part of the earth** and it is subdivided into three specific layers or zones

1. The crust
2. Mantle
3. Core

Layers of Lithosphere



Crust

- It is the **uppermost solid shell of the earth** which has varying thickness in different areas as follows

(a) Under the **oceans** 5 - 6 km

(b) Under the **continents** 30 - 35 km

(c) Under the **mountains**: 60 - 70 km

- The **chemical composition of the crust**

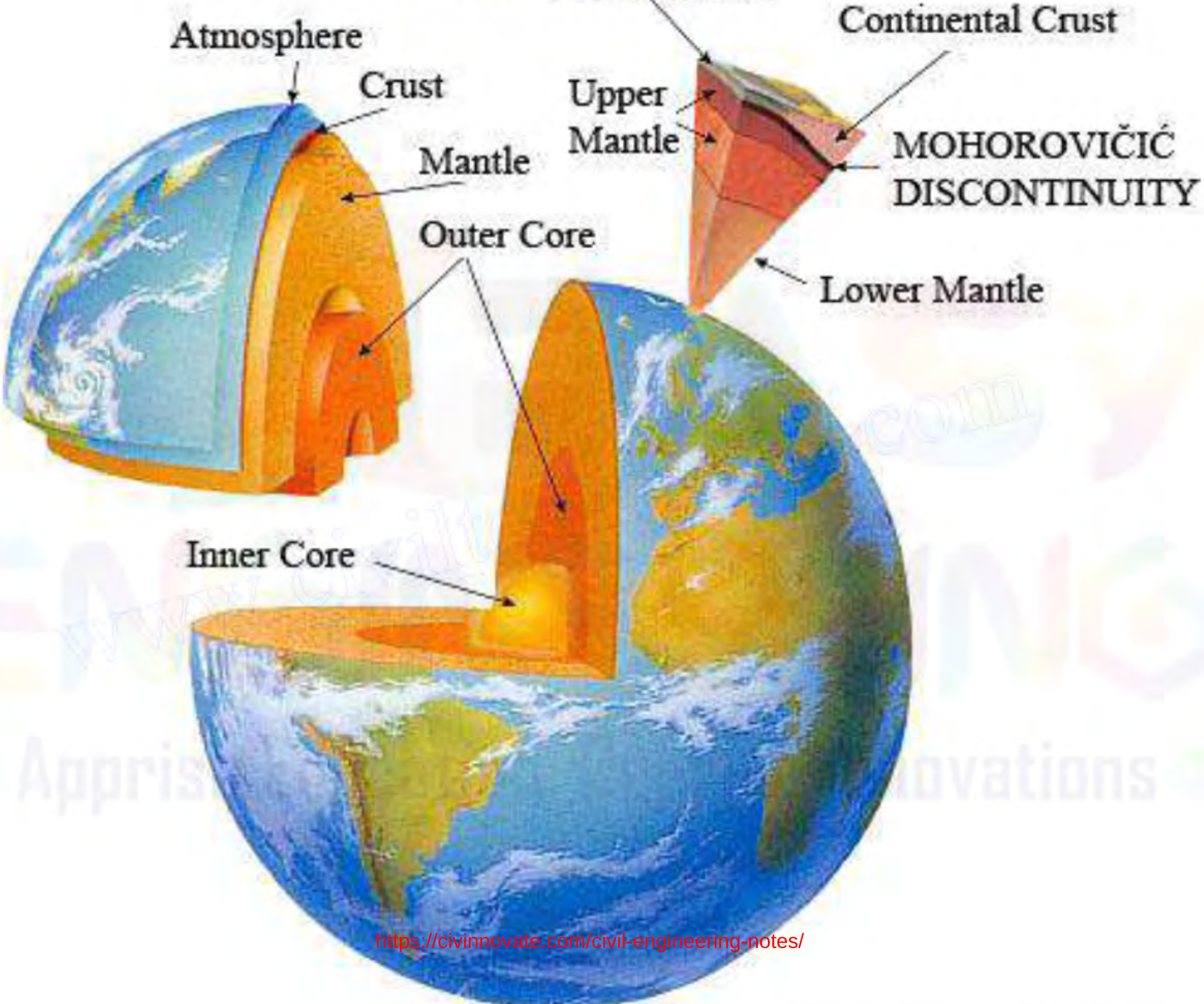
(1) **Silica** (above 50% by volume in the oceanic crust and above 62% in the continental crust;

(ii) **Alumina** (13-16 %)

(iii) Iron Oxide (Fe Lime (CaO)-6%; Sodium Oxide-4%, Magnesium Oxide-4%, Potassium Oxide and Titanium oxide- 2%

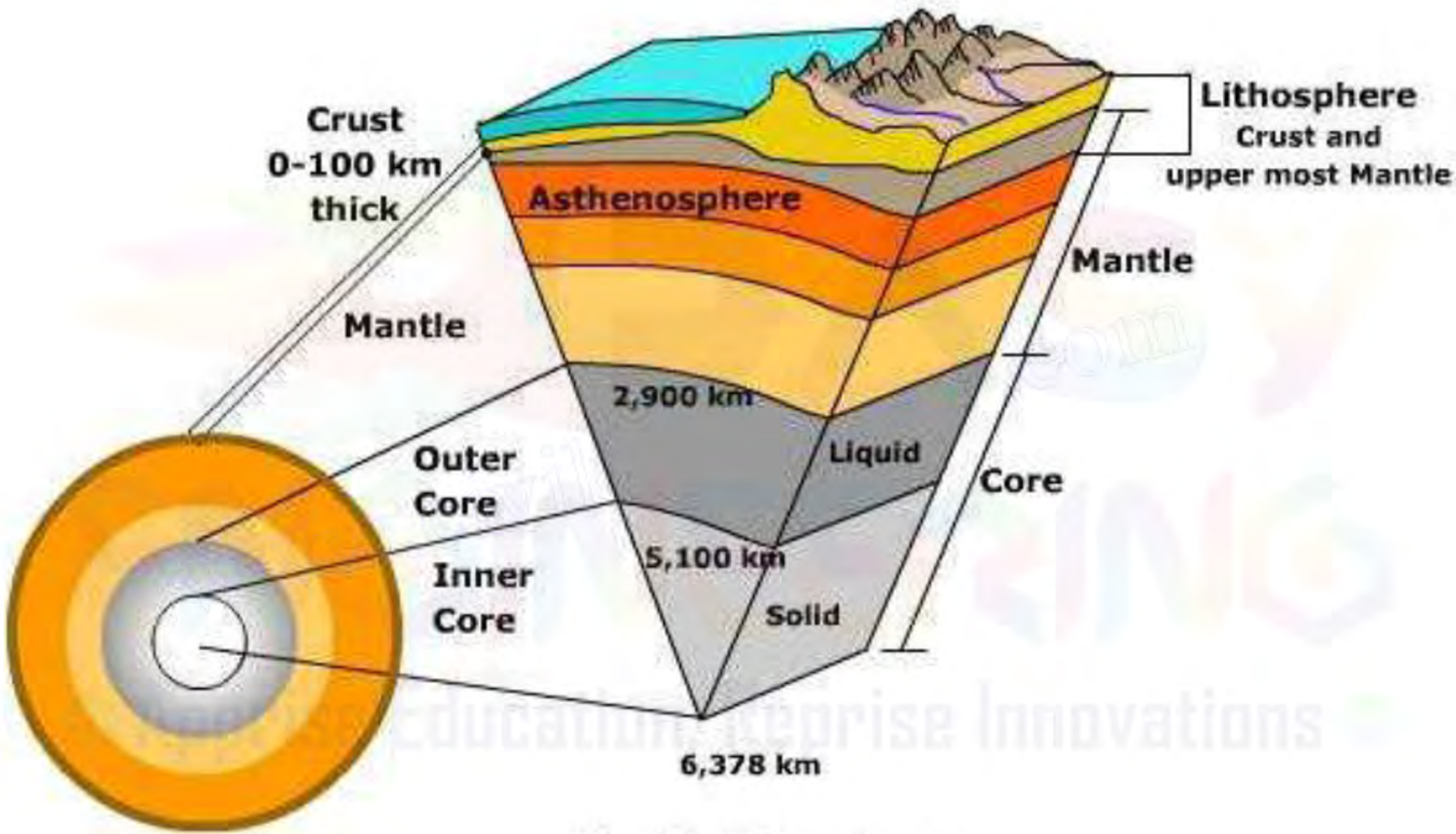
Mantle

- Mantle is a zone within the earth that starts from M-discontinuity and continues upto a **depth of 2900 km**.
- It is distinguished into **upper mantle , Middle mantle and lower mantle.**


Atmosphere
Crust
Mantle
Outer Core
Inner Core
Upper Mantle
Continental Crust
MOHOROVIČIĆ DISCONTINUITY
Lower Mantle

Core

- It is the third and the **innermost structural shell** of the earth
- It **starts at a depth of 2900 km** below the surface and extends right up to the center of the earth, at a depth of 6370 km.
- The **liquid like core** extending from a depth of 2900 km to about 4800 km is often termed as **outer core**.
- The inner core (solid core) - starting from **4800 km and extending up to 6370 km**



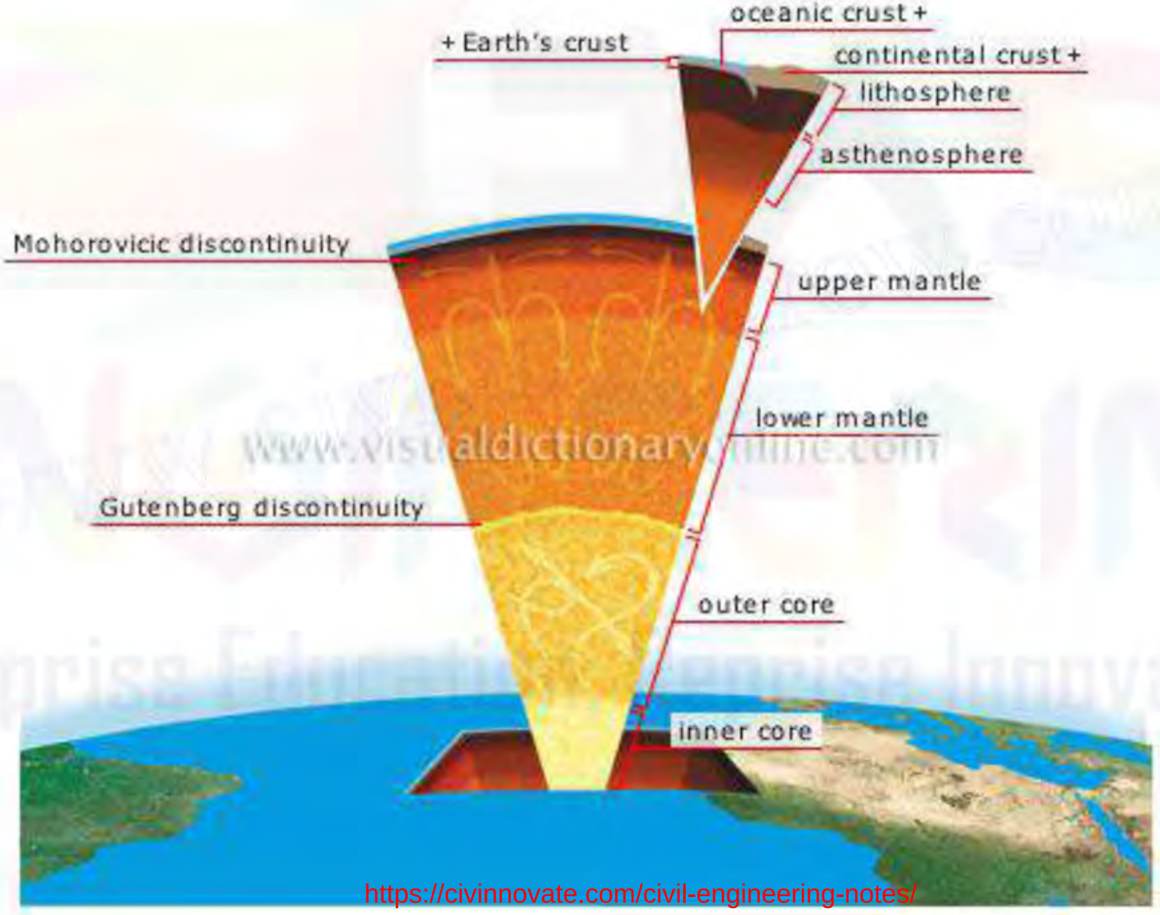
Earth Structure

Mohorovicic and Gutenberg discontinuity

- **At the base of the crust** ,striking change in properties of materials is observed known as **Mohorovicic discontinuity.**
- Mohorovicic discontinuity marks the lower limits of the skin of the earth , the crust.
- It is often referred as **M- discontinuity or Moho**.

- **Mantle core discontinuity** marks the beginning of the third major zone of the earth , CORE.
- It is also known as **Gutenberg discontinuity**

Mohorovicic and Gutenberg discontinuity



Hydrosphere

- Natural water bodies occurring on or below the surface. (Only 0.03 % of mass of the earth)

- More than 98 percent - saline water called seas and oceans.

- Rivers and lakes spread over hundreds of thousands square kilometers are the constituents of the hydrosphere.

- **Huge bodies of frozen water, the ice and snow,** together making up the glaciers are the third major **component of hydrosphere**.

Biosphere

- Biosphere is the term used to express the collective life form exists on the surface and under water.

- Biosphere depends for its existence on the **lithosphere, the atmosphere and the hydrosphere.**

Weathering

Weathering is a process of decay and disintegration of rocks under the influence of certain physical and chemical agencies of the atmosphere.

Geological work of Atmosphere (ROCK WEATHERING)

- Weathering is defined as a natural process of in-situ mechanical disintegration and/or chemical decomposition of the rocks by certain physical and chemical agencies of the atmosphere.

- Important aspect of this process is that the weathered product remains lying **over and above or near to the parent rock** unless it is removed from there by some other agency of nature.

Rock weathering may be classified as

- Mechanical or physical weathering
- Chemical weathering

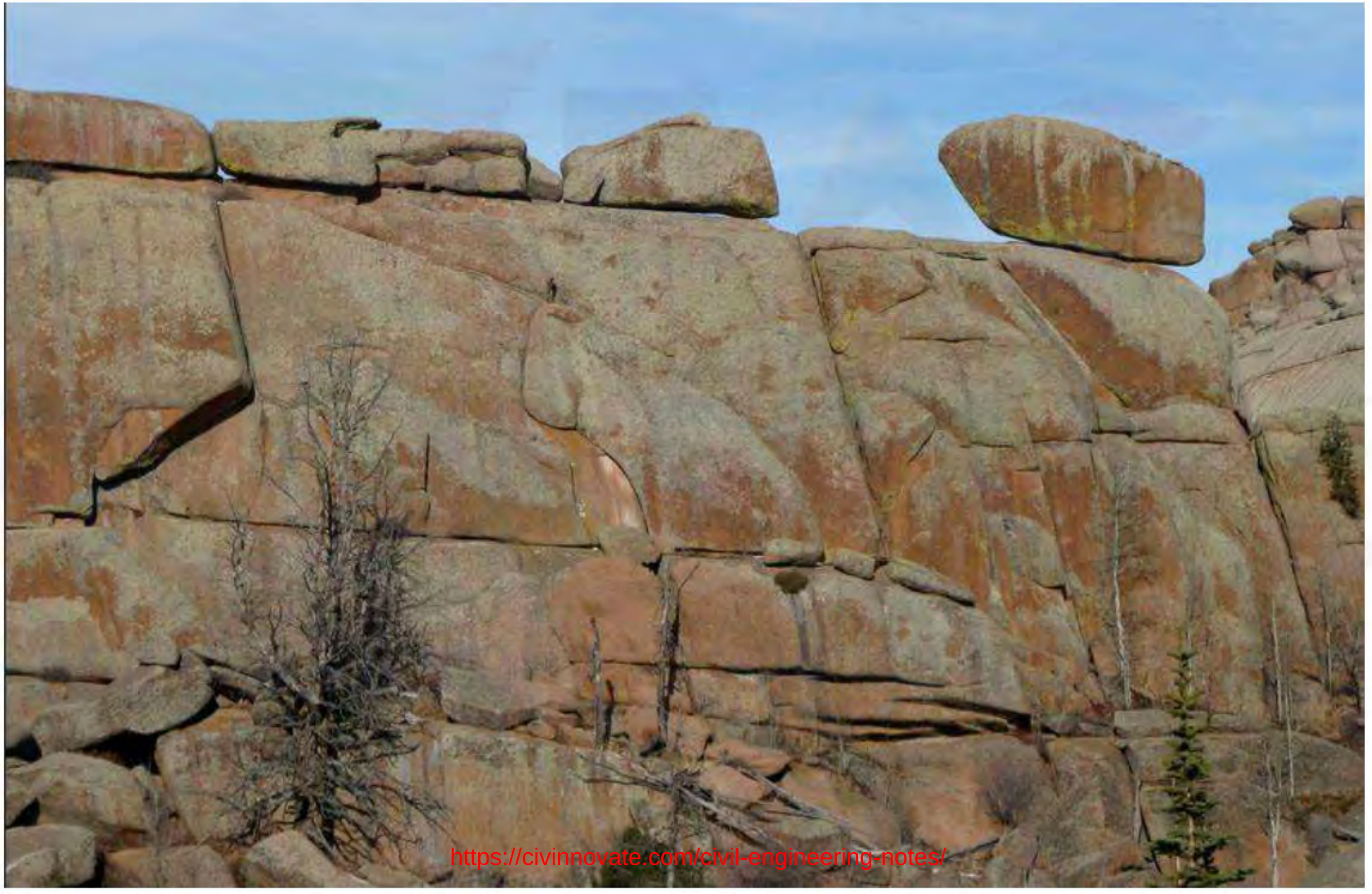
Mechanical (physical) weathering

- It is a natural process of physical disintegration and reduction in size of rocks into smaller fragments and particles without change in their chemical composition.

- A single rock block on a hill slope or a plain may be disintegrated gradually into numerous small irregular fragments through frost action that in turn may break up naturally into fragments and particles of still smaller dimensions.

- These loose fragments and particles may rest temporarily on the surface if it is a plain.

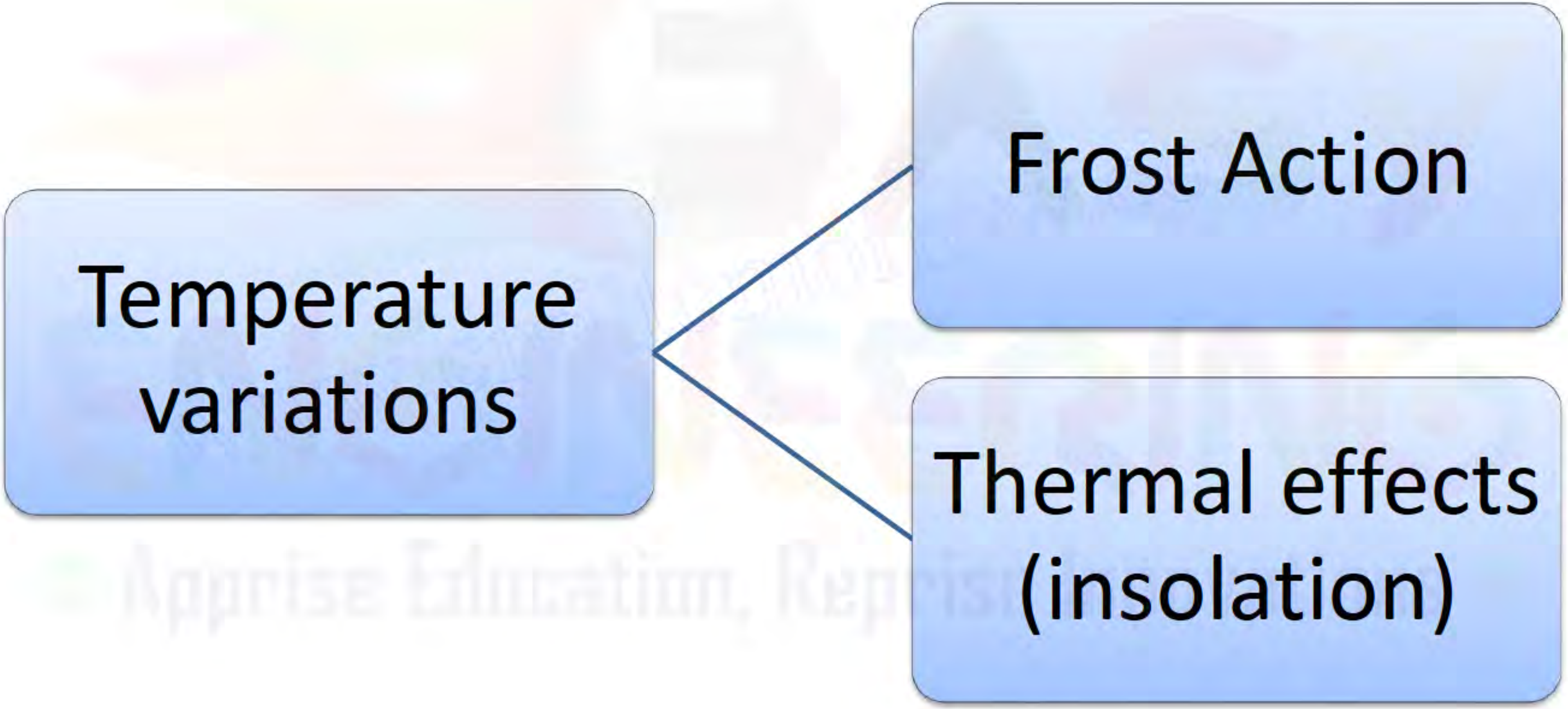
Weathered rock materials lying in a plane surface



- On slopes, the fragments and particles may roll down under the influence of gravity and get accumulated at the base as heaps of unsorted debris.
- All these fragments and particles, however, have the same chemical composition as the parent rock.

Weathered particles lying at the base

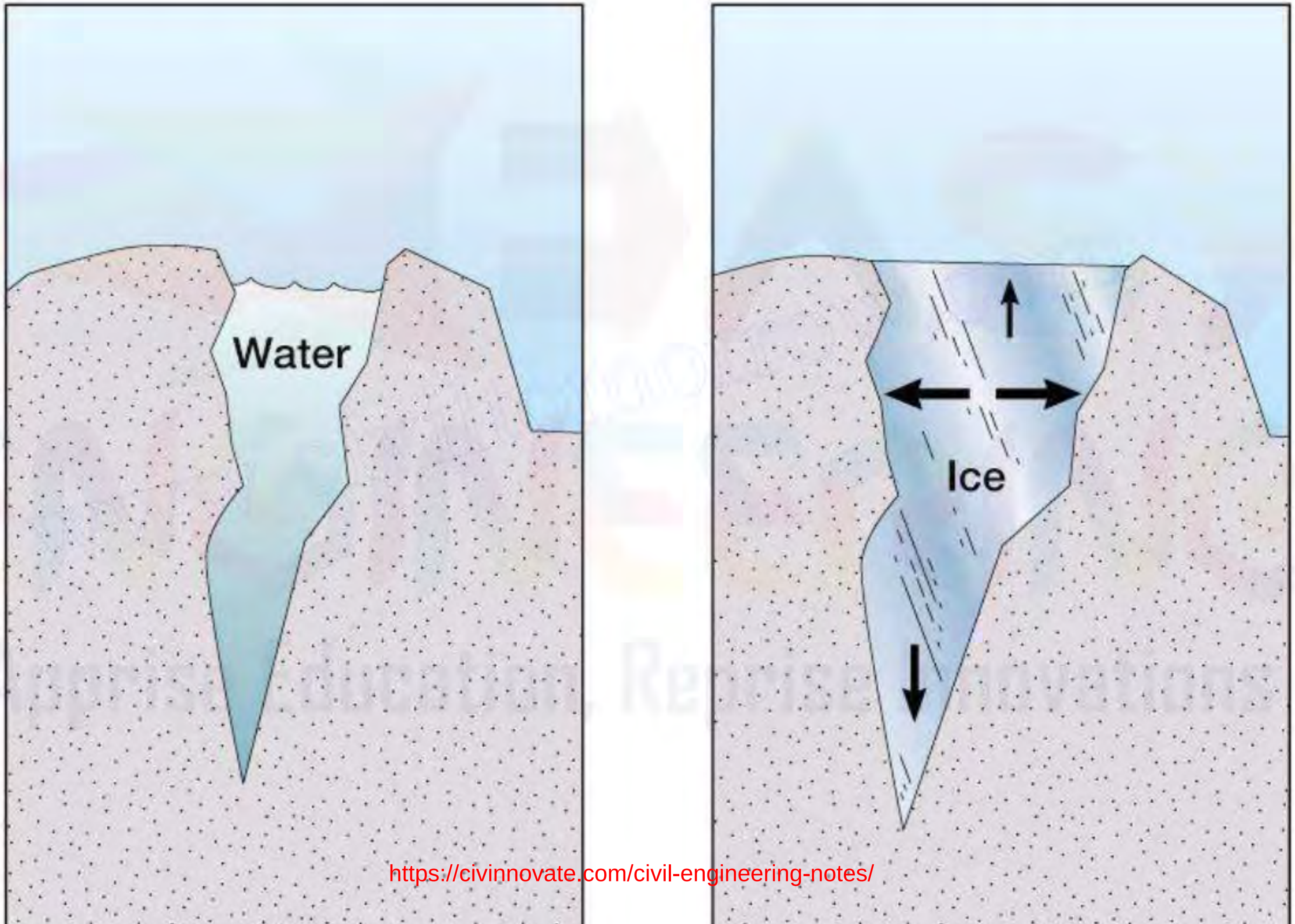
- Mechanical weathering is one of the very common geological processes of slow natural rock disintegration in all parts of the world.
- Temperature variations and organic activity are two important factors that bring about this change under specific conditions.


Temperature variations
Frost Action
Thermal effects (insolation)

Frost Action

- Frost action or Frost wedging is a mechanical weathering process caused by the freeze-thaw action of water that is trapped between cracks in the rock.
- When water freezes, it expands and applies pressure to the surrounding rock forcing the rock to accommodate the expansion of the ice.
- This process gradually weakens, cracks, and breaks the rock through repetitive freeze-thaw weathering cycles.

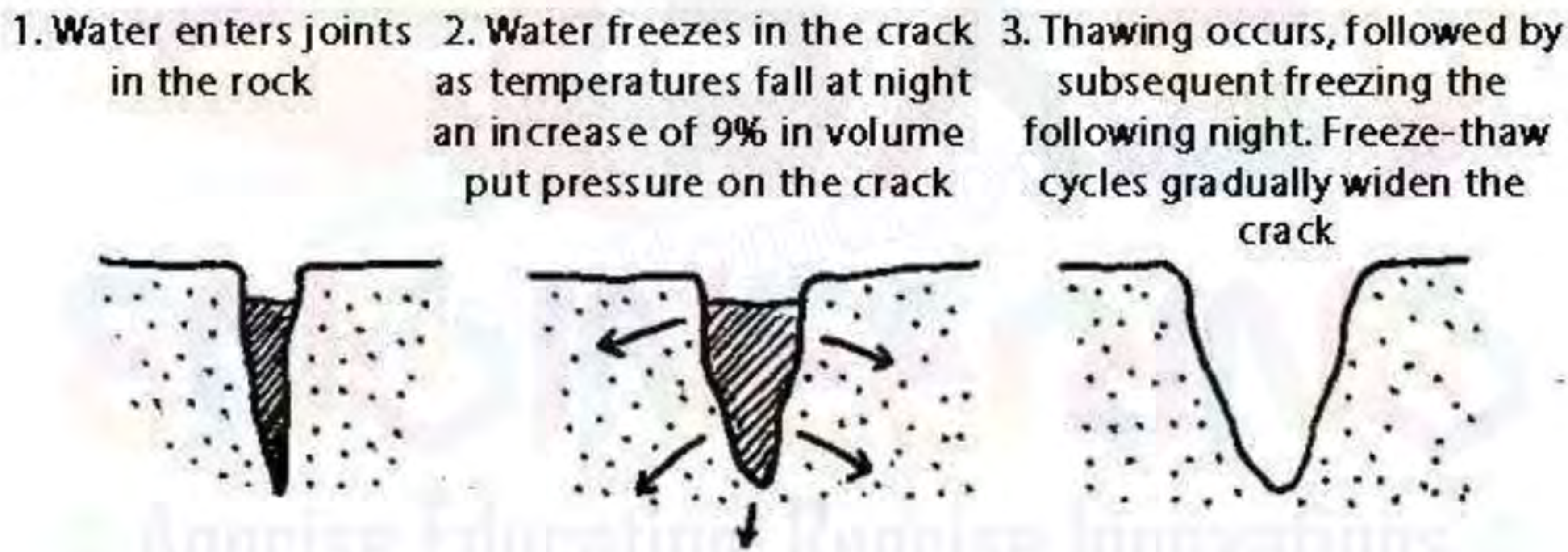
Frost action on rocks



Frost Action

- Generally, Water on freezing undergoes an increase in its volume by about nine per cent exerting a pressure at the rate of 140 kg/cm2 on the walls of the vessel containing the freezing water.
- In areas of intensive cold and humid climates, during winter months, freezing of water results in widening of rocks at the first stage of attack and thereby accommodate more and more water to come and freeze in subsequent cycles.

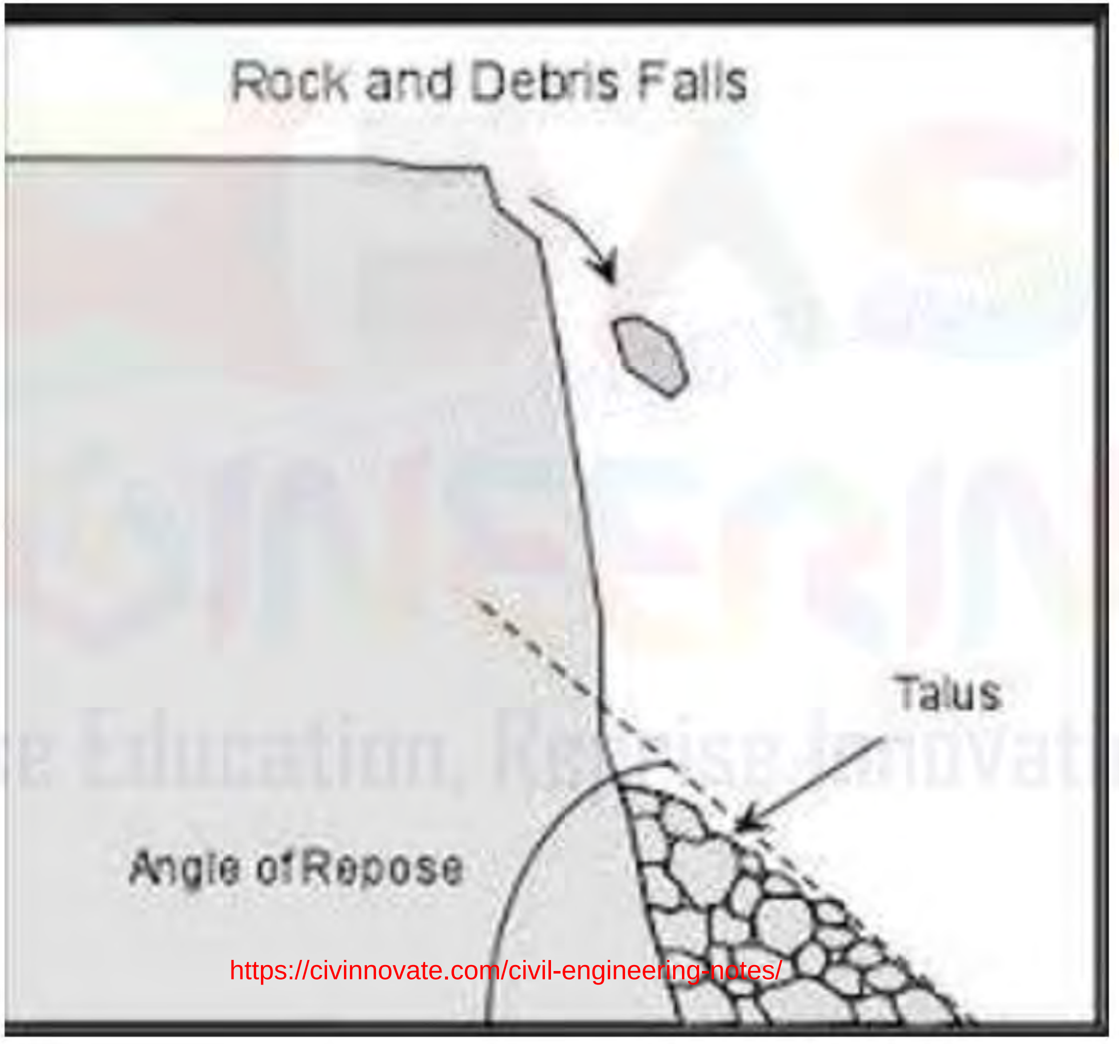
Freeze – thaw weathering cycle




Ice

- In case of hilly and mountain regions , the frost fragments get heaved up from crevices and cavities and then roll down the slope under the influence of gravity and accumulate at the base as heaps commonly called as Scree deposits.
- When the slopes are stabilized and pull of gravity is weaker, the fragments remain over the surface of the slopes. Such slopes covered by frost formed scree are referred to as talus slopes.

Talus slope - Slope covered by frost formed Scree



Exudation

- Exudation is a process similar to frost action but in this case disintegration takes place due to formation of crystals of salts like sodium chloride within the cavities of rocks. This process is seen in rocks near seashore.

Thermal Effects (Insolation)

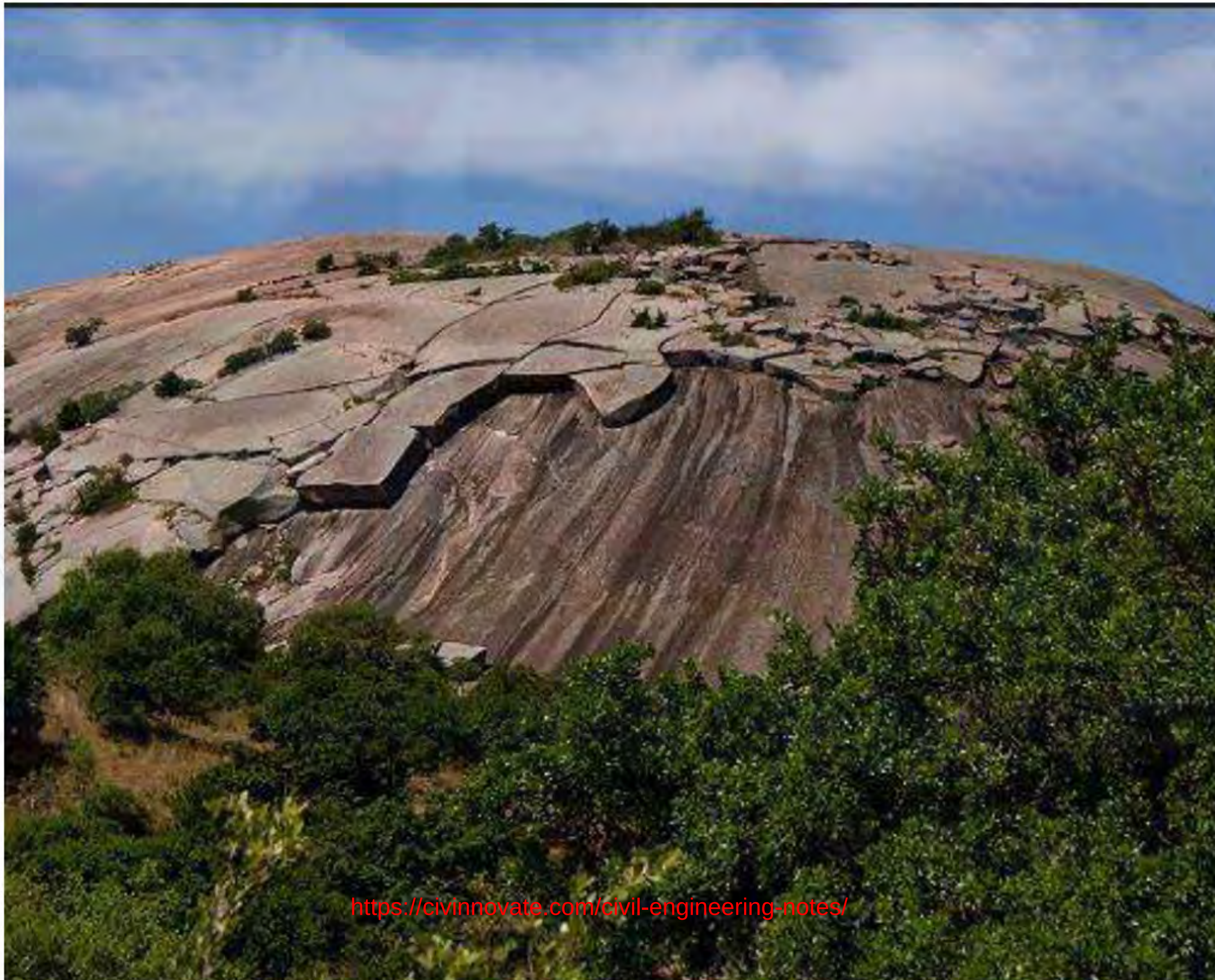
- In arid, desert and semi-arid regions where summer and winter temperatures differ considerably, rocks undergo physical disintegration.
- Such repeated variations in temperature experienced by a body of rock gradually break it into smaller pieces, especially in the top layers, by development of tensile stresses developing from alternate expansion and contraction.

Exfoliation

- In a thick rock body or where the rock is layered, the upper layer gets affected mostly due to the temperature variations . As a result, the upper layers may virtually peal off from the underlying rock mass.
- This phenomenon of pealing off of curved shells from rocks under the influence of thermal effects in association with chemical weathering is often termed as Exfoliation.

Exfoliation

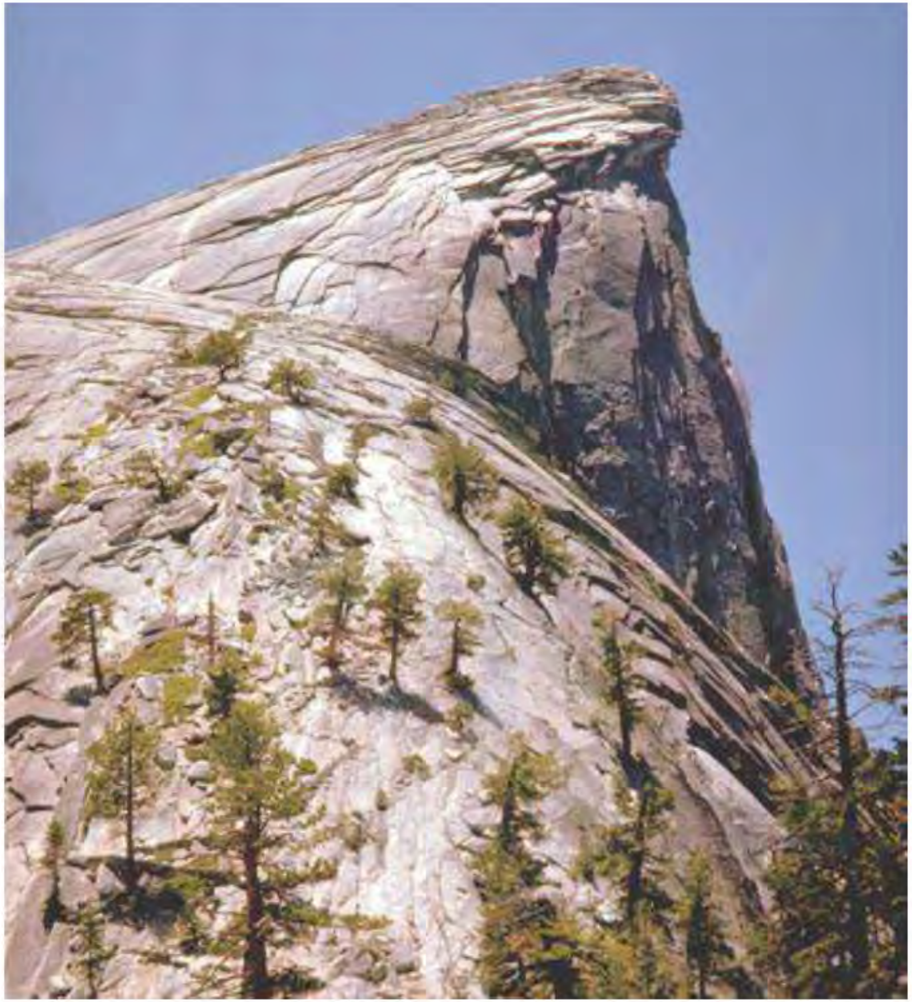
Exfoliation – peeling of upper layer



Unloading

- This is another process of Mechanical weathering.
- Rock masses remain confined from sides but due to relief of pressure from above, they expand upwards; consequently joints develop in them parallel to the uncovered surface dividing them into sheets.
- Further mechanical weathering along these joints leads to pealing off and converting into an Exfoliation dome.

Sheet joints



Exfoliation dome

Chemical weathering

- It is a process of alteration of rocks of the crust by chemical decomposition brought about by atmospheric gases and moisture.

- Moisture contains many active gases from the atmosphere such as carbon dioxide, nitrogen, hydrogen and oxygen

- Chemical reaction between surface of rocks and atmospheric gases is called chemical weathering
- The end product of chemical weathering has a different chemical composition and poorer physical constitution as compared to the parent rock

Following are some of the main processes of chemical weathering

1. Solution
2. Hydration and hydrolysis
3. Oxidation and reduction
4. Carbonation
5. Base exchange and formation of colloids

Solution

- Some rocks contain one or more minerals that are soluble in water to some extent.
- Rock salt, gypsum and calcite are few common examples.
- pure water is not a good solvent of minerals in most cases, but when pure water is carbonated, its solvent action for many common minerals is enhanced.
- limestone is not easily soluble in pure water but carbonated water dissolves the rock effectively.
- Limestone gets pitted and porous due to chemical weathering.

Pits and pores in limestone due to solution process

Hydration and hydrolysis

- These two processes indicate the direct attack of atmospheric moisture on the individual minerals of a rock that ultimately affect its structural make up.
- The process of addition of the water molecule is termed as hydration.
- Anhydrite gets slowly converted into gypsum by hydration.

$$CaSO_4 + 2H_2O \longrightarrow CaSO_4 2H_2O$$

(Anhydrite) (Water) (Gypsum)

- Ions may be exchanged whereby some ions from water may enter into the crystal lattice of the mineral. This process of exchange of ions is called hydrolysis.

- Weathering process of mineral Orthoclase, a feldspar is given below

$K + Al\ Si_3O_8 + H^+ \longrightarrow H\ Al\ Si_3O_8 + K^+$	
(Orthoclase) + (Ion from water)	Silicic acid like structure + (Pot. ion)

Oxidation

- Iron is a chief constituent of many minerals and rocks.
- The iron bearing minerals (and hence rocks) are especially prone to chemical weathering through the process of oxidation and reduction.

- Ferrous iron (Fe++) of the minerals is oxidized to ferric iron (Fe+++) on exposure to air rich in moisture.
- Ferric iron is not stable and is further oxidized to a stable ferric hydroxide:

(i)	$4Fe + 3\ O_2 \longrightarrow 2Fe_2O_3$
(ii)	$Fe_2O_3 + H_2O \longrightarrow Fe_2O_3.H_2O$

Reduction

- In specific types of environment, such as where soil is rich in decaying vegetation (swamps), minerals and rocks containing iron oxide may undergo a reduction of the oxides to elemental iron.
- In this case the decaying vegetation supplies the carbonaceous content causing reduction.

Carbonation

- It is the process of weathering of rocks under the combined action of atmospheric carbon dioxide and moisture, which on combination form a mildly reacting carbonic acid
- Atmospheric carbon + Moisture = carbonic acid
- The acid so formed exerts an especially corrosive action over a number of silicate bearing rocks.

- The silicates of potassium, sodium and calcium are particularly vulnerable to decay under conditions of carbonation.

$$2KAlSi_3O_8 + 2H_2O + CO_2 \longrightarrow Al_2Si_2O_5(OH)_4 + K_2CO_3 + 4SiO_2$$

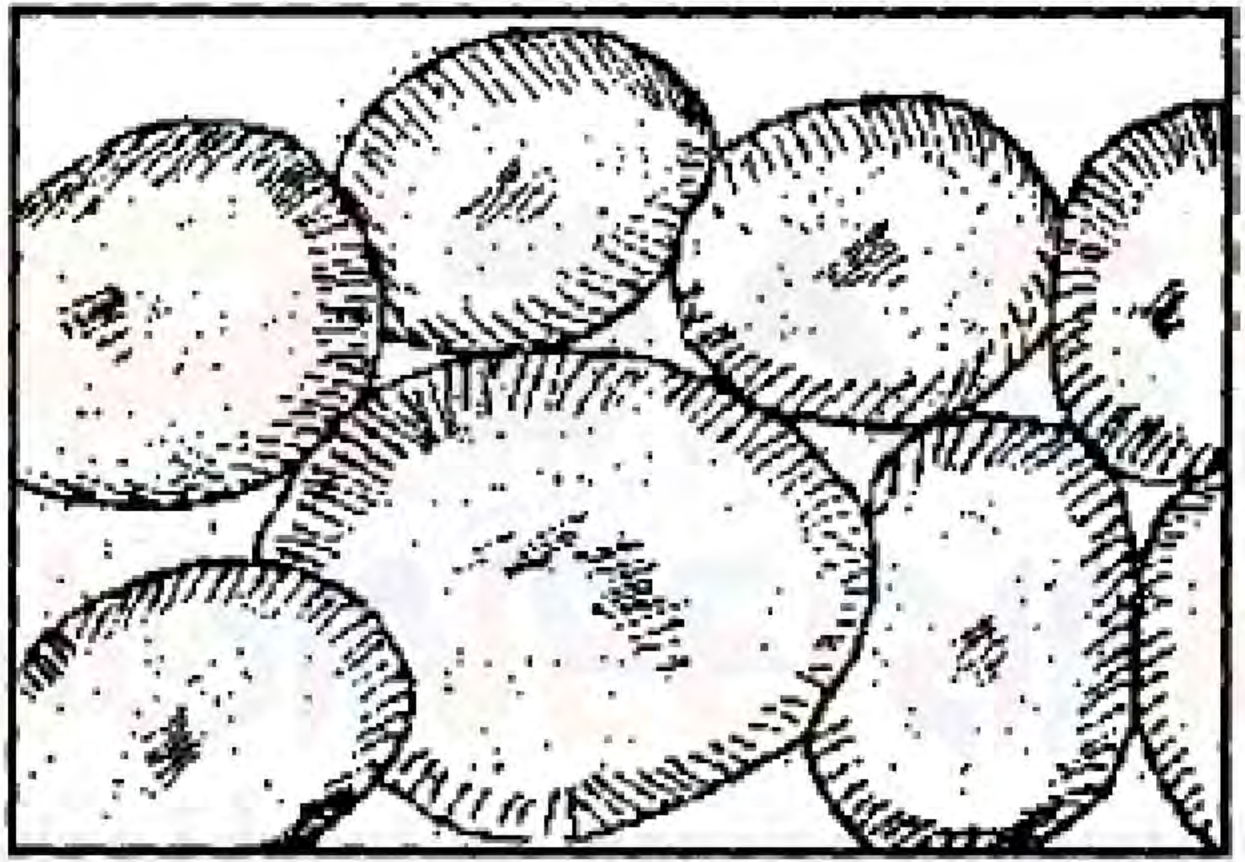
(Orthoclase) + Carbonic acid ⟶ (Kaolinite) + (Pot. Carbonate) + Silica

Colloid formation

- The processes of hydration, hydrolysis, oxidation and reduction operating on the rocks and minerals under different atmospheric conditions may not always end in the formation of stable end products.
- Often they result in splitting of particles into smaller particles- the colloids

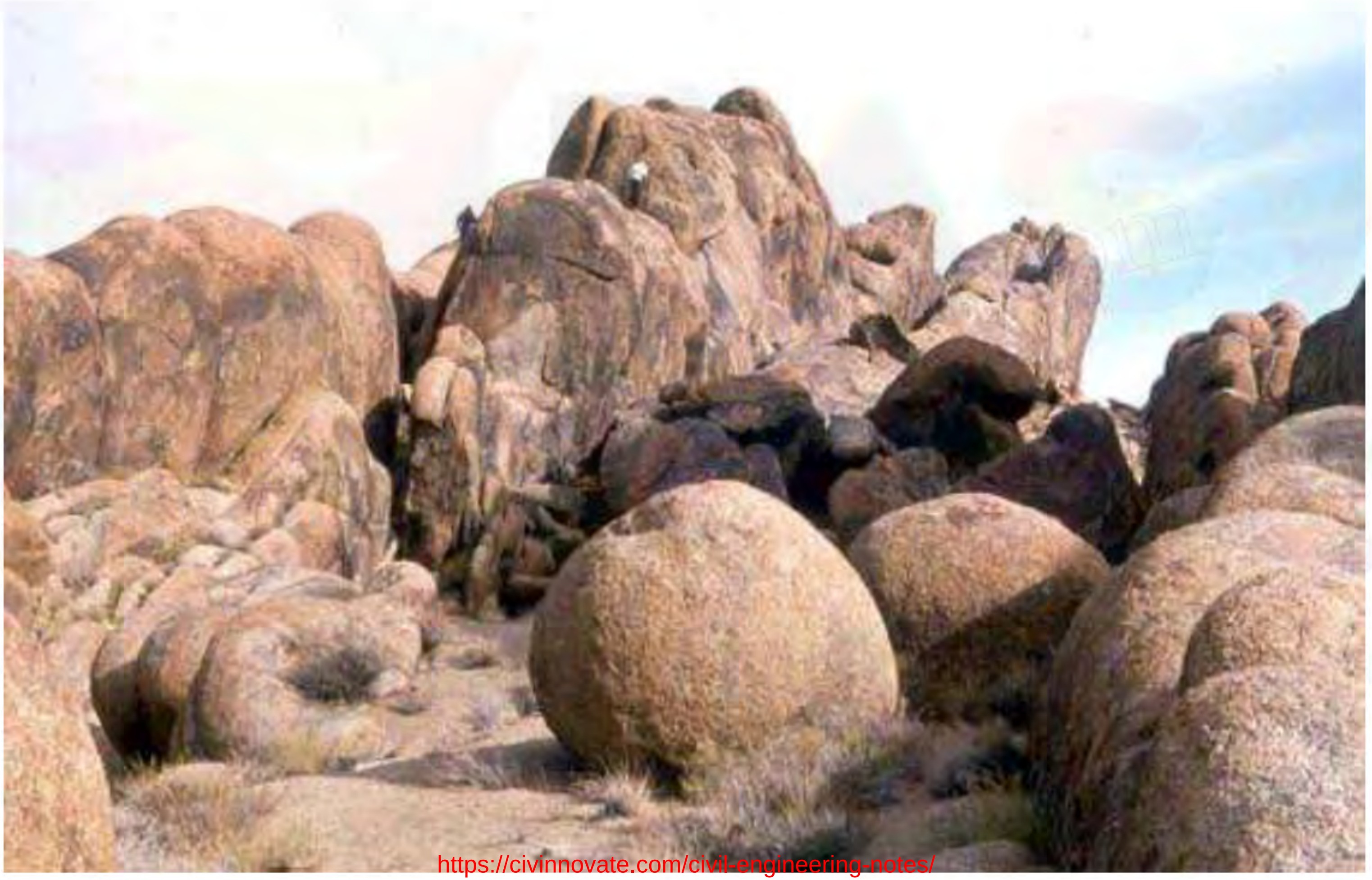
Spheroidal weathering

- It is a complex type of weathering observed in jointed rocks and characterized with the breaking of original rock mass into spheroidal blocks.
- Both mechanical and chemical weathering is believed to actively cooperate in causing spheroidal weathering.
- The original solid rock mass is split into small blocks due to thermal effects (insolation).
- Simultaneously, the chemical weathering processes corrode the borders and surfaces of the blocks causing their shapes roughly into spheroidal contours.



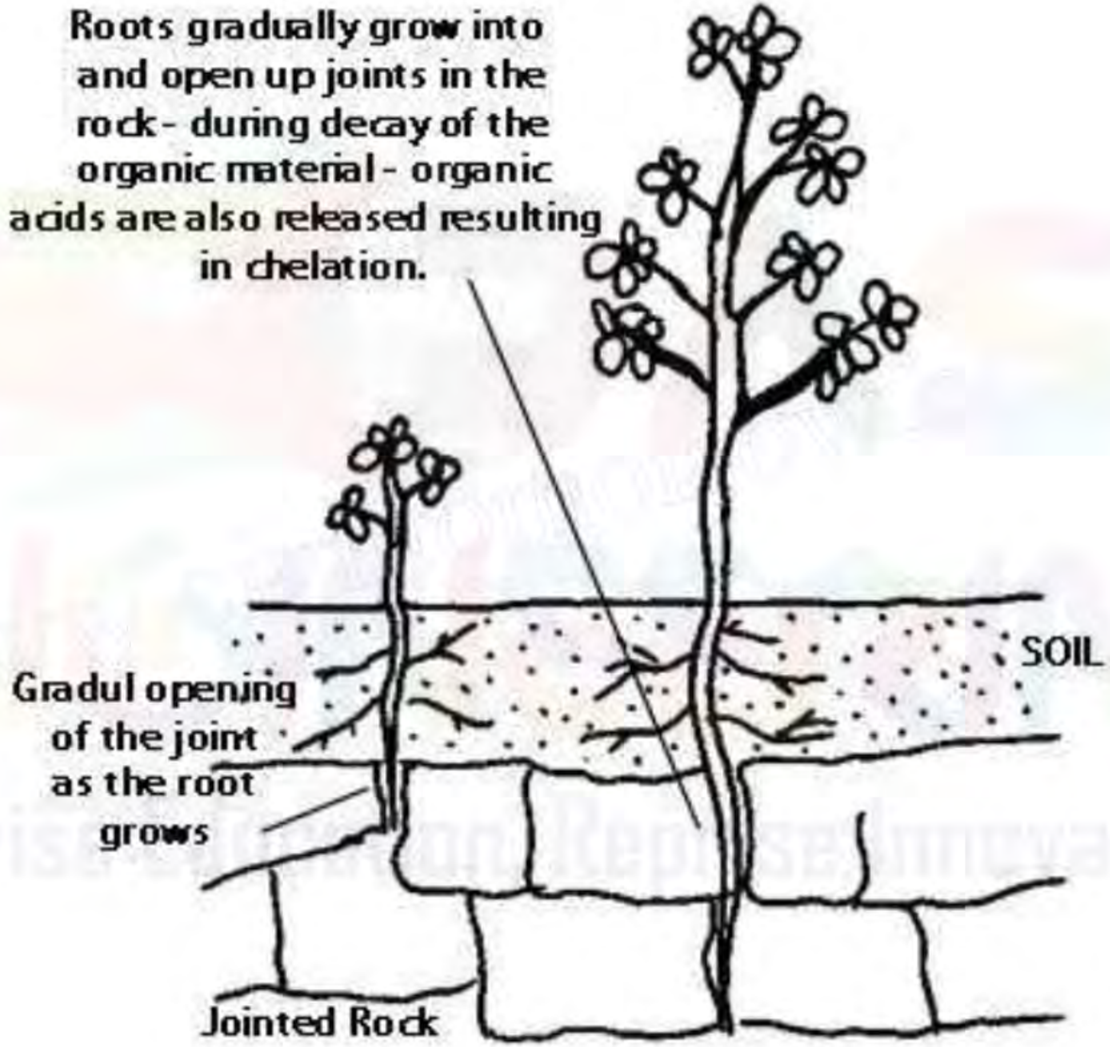
Spheroidal Weathering

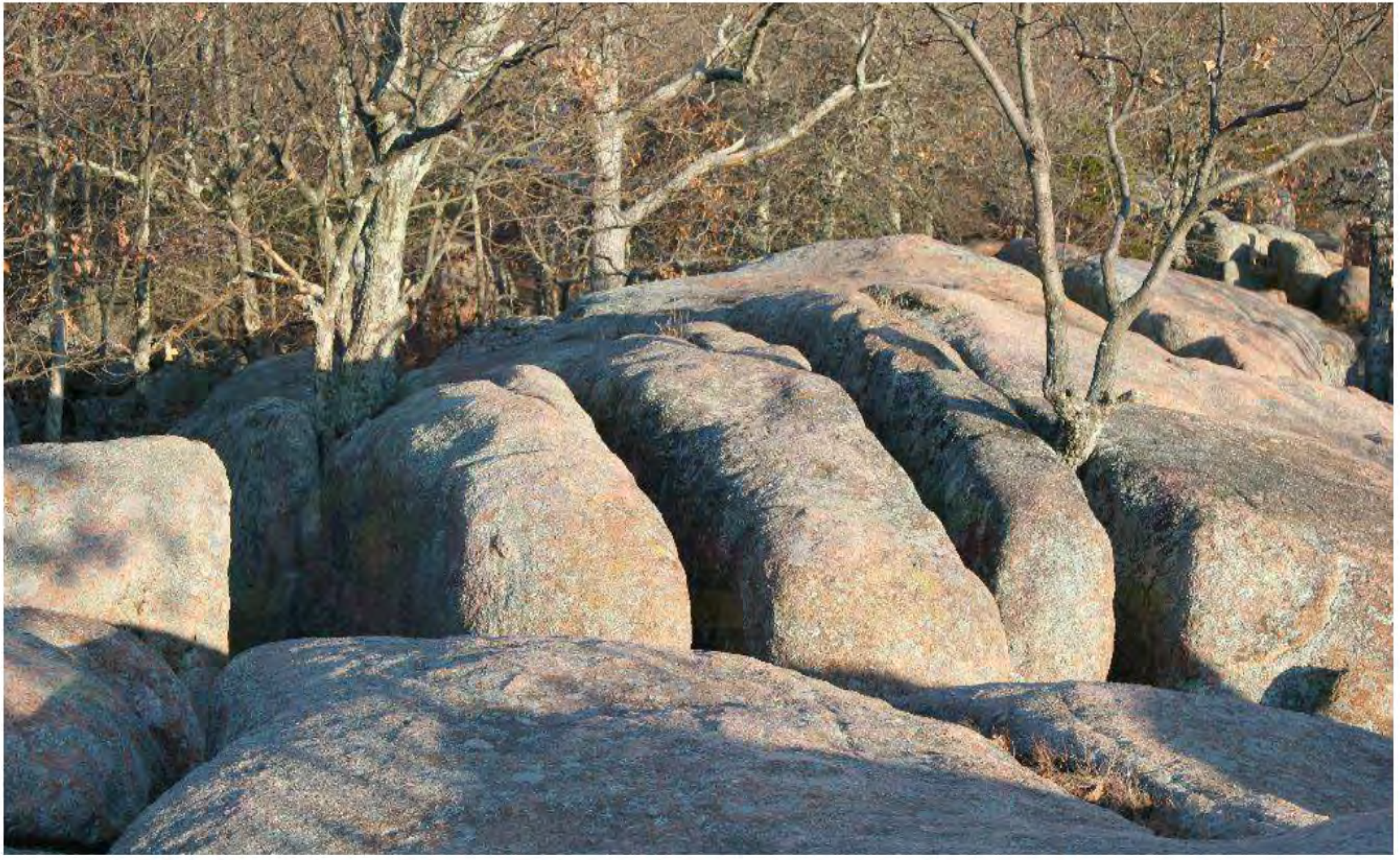
Spheroidal weathering



Biological weathering

- As roots of plants and trees grow downwards, they often enter and exploit cracks joints in rock. resulting in detachment of rock fragments (similar to freeze-thaw)
- Hydrogen ions are released at the roots of plants which are capable of decomposition and disintegration of rocks
- Man himself is known to be the greatest destroyer of rocks.


Roots gradually grow into and open up joints in the rock - during decay of the organic material - organic acids are also released resulting in chelation.
SOIL
Gradul opening of the joint as the root grows
Jointed Rock



Factors affecting Weathering

1. Nature of rock

- Rocks vary in chemical composition and physical constitution.
- Some rocks are easily affected by weathering processes in a particular environment whereas others may get only slightly affected and still others may remain totally unaffected under the same conditions.
- Thus of granite and sandstones exposed to atmosphere simultaneously in the same or adjoining areas having hot and humid climate, the sandstone will resist weathering to a great extent because they are made up mainly of quartz (Si02) which is highly weathering resistant mineral.

2. Climate

Same types of rocks exposed in three or more types of climates may show entirely different trends of weathering.

3. Physical environment

- The topography of the area where rocks are directly exposed to the atmosphere also affects the rate of weathering to a good extent.

Geological work of wind

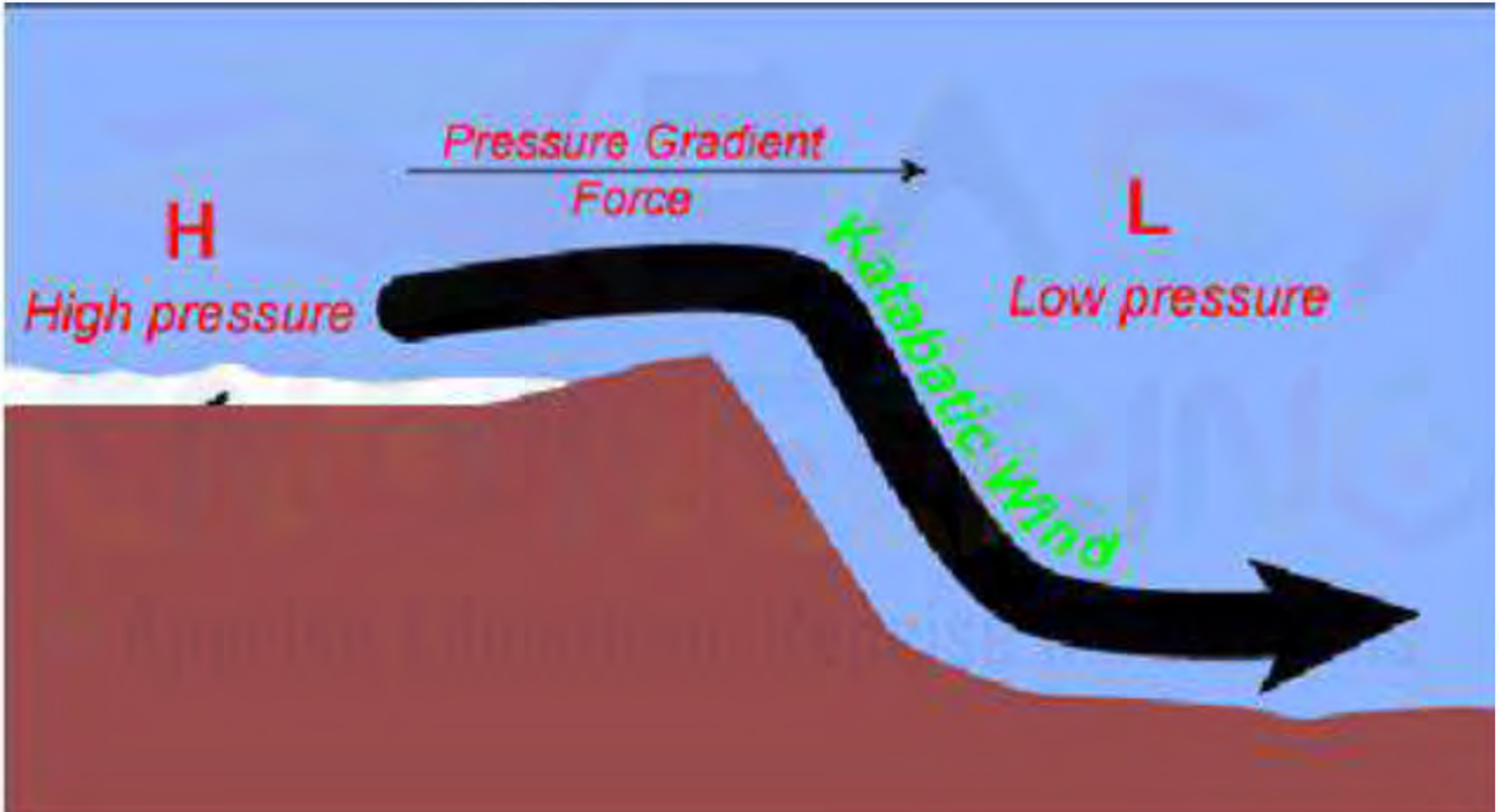
Wind

- Atmosphere is composed mainly of gases that are collectively known as air.
- Air in motion is called wind.

- winds are born mainly due to non-uniform heating of the surface of the earth at different places causing differences in atmospheric pressure

- The pressure difference so created makes the atmospheric gases (the air) to move from areas of high pressure to areas of low pressure in the form of winds.
- During such a movement, wind may create temporary or semi permanent changes on the land surface.
- Wind acts as agent of erosion, as a carrier for transporting particles and grains.
- Three principal modes of activity i.e. Erosion , Transportation and Deposition

Wind formation



Wind erosion

- Wind performs work of erosion by at least three different methods:

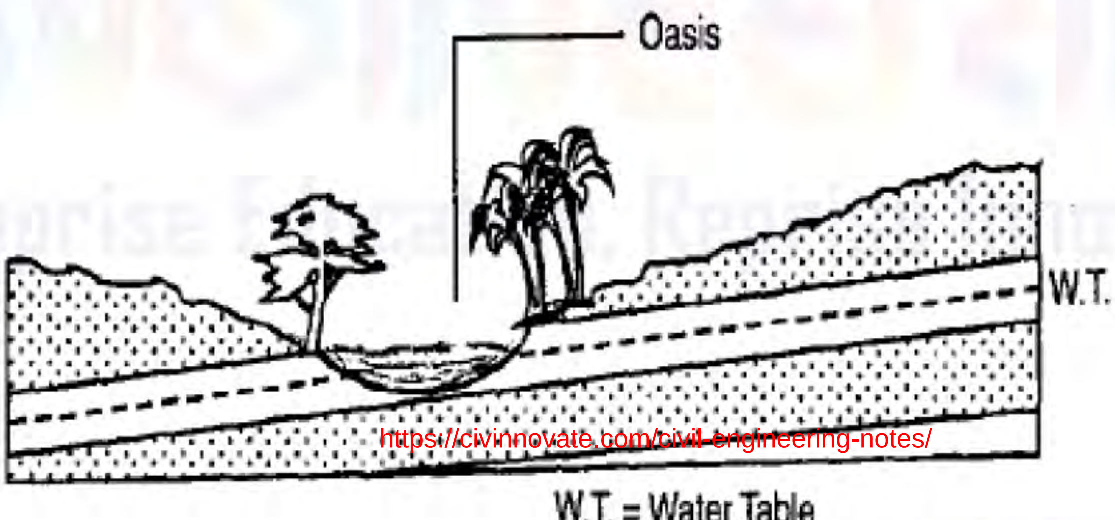
1. Deflation
2. Abrasion
3. Attrition

1. Deflation (Latin: deflare = to blow away)

- The process of removal of particles of dust and sand by strong winds is called deflation.
- It is the main process of wind erosion in desert regions.
- wind possesses not much erosive power over rocks or over the ground covered with vegetation.
- when moving with sufficient velocity over dry and loose sands or bare ground over dust, it can remove or sweep away huge quantity of the loose material from the surface.

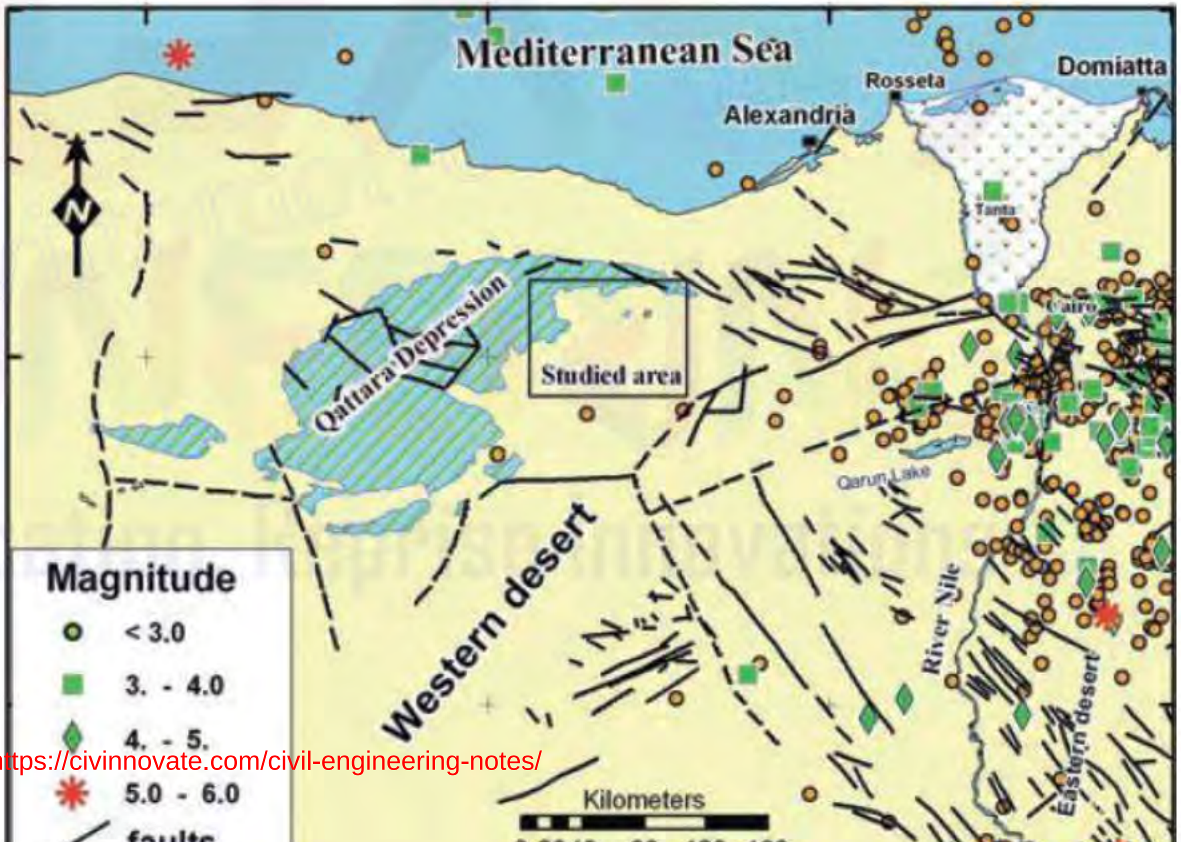
- In some deserts, deflation may cause the removal of sand from a particular location to such an extent that a big enough depression is created, sometimes with its base touching the water table at quite a depth.
- Such depressions are variously called blowouts when developed on a small scale and of shallower depth.

- Much deeper and extensive depression where the water table is intersected and it gets partially filled up with water is called an OASIS.
- Slack is another term used for such depressions created by deflation

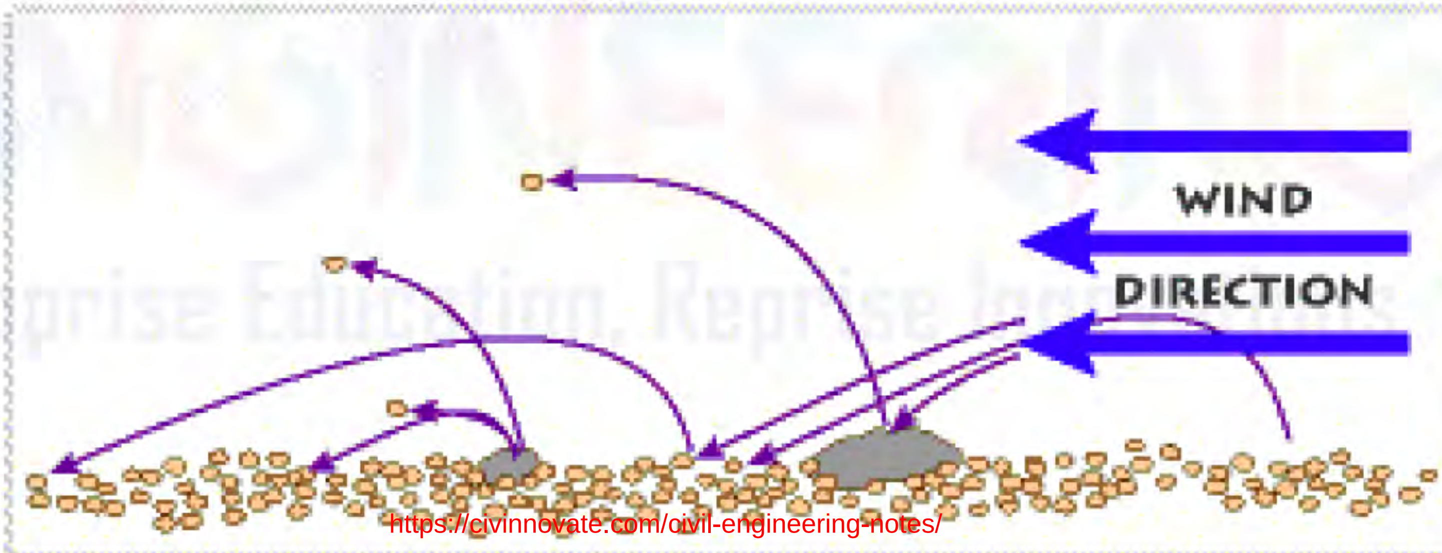


Oasis

- The Qattara depression of western Egypt is one of the biggest slacks. It is 300 km long and 150 km wide; its base is 130 m below sea level.



- Another feature produced due to deflation is called a **Hammada.**
- It is a bare rock surface in a desert from over which thin cover of sand has been blown away by strong winds.



2. Wind Abrasion

- Erosion which involves rubbing, grinding, abrading and polishing the rock surfaces by any natural agent (wind, water or ice) with the help of its load while passing over the rocks is termed as abrasion.
- The load is acquired by the strong winds quite easily when blowing over sand dunes in deserts and over the dry ploughed fields.

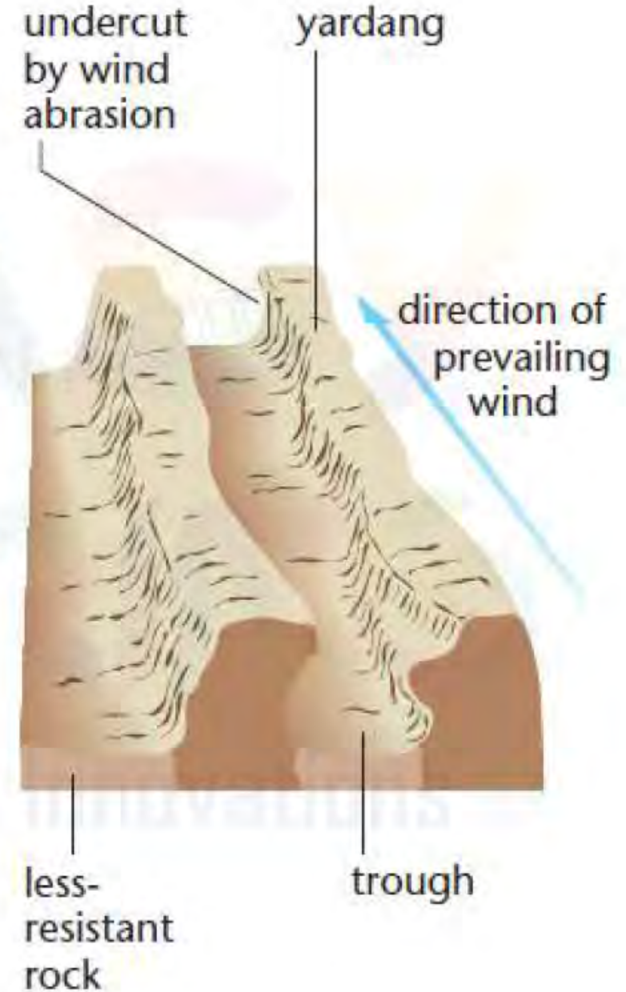
Wind abrasion

- Few examples of wind abrasion in arid areas are

1. Yardangs
2. Pedestal rocks
3. Ventifacts
4. Desert pavements

Yardangs

- These are elongated, low-lying ridges forming overhangs above local depressions.
- Their trend is parallel to the direction of prevailing winds.



Yardangs

Yardangs are formed in areas where rocks of alternate hard and soft character are laying one above another with a general gentle slope.

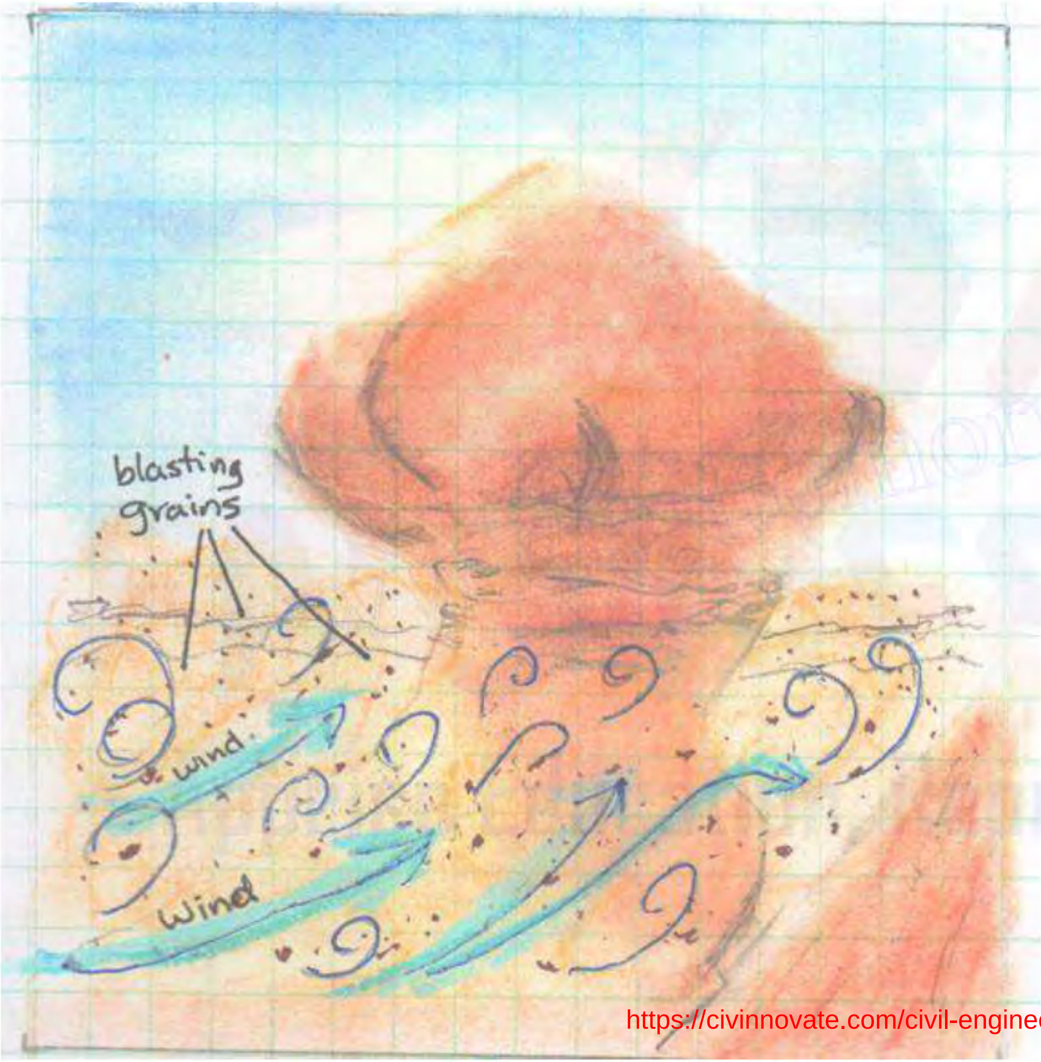
Pedestal Rocks

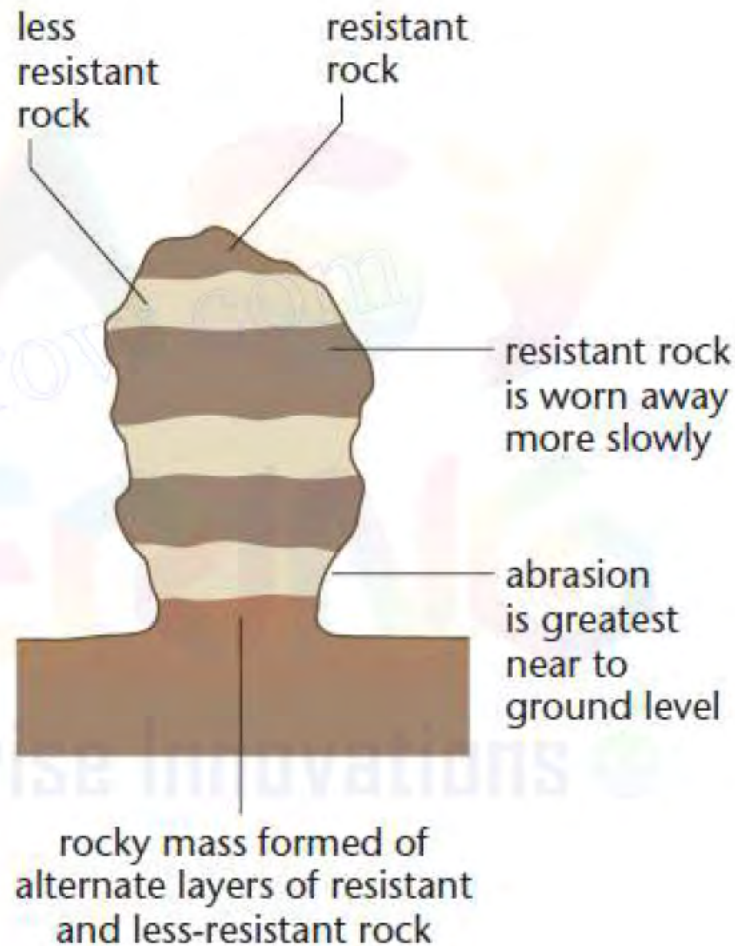
Pedestal Rocks

- These are also often called as mushroom rocks.
- They are flat topped rock masses with slender supporting rock stems.

- The top is commonly called as overhang and slender stem as pedestal
- Most of the sand particles are carried at a height of about 2 meters from the surface
- Abrasive capacity of winds moving close to the surface is much higher than that of winds blowing in the upper regions.

Formation of pedestal rocks

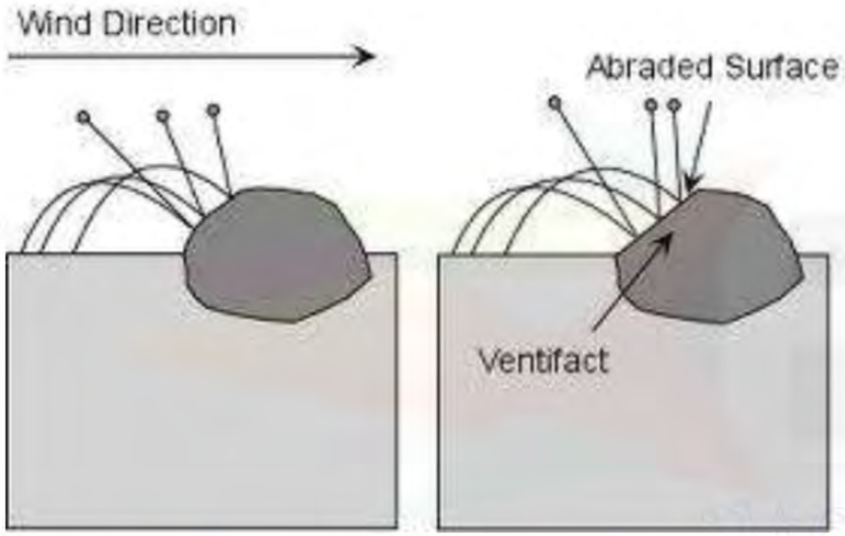




Ventifacts

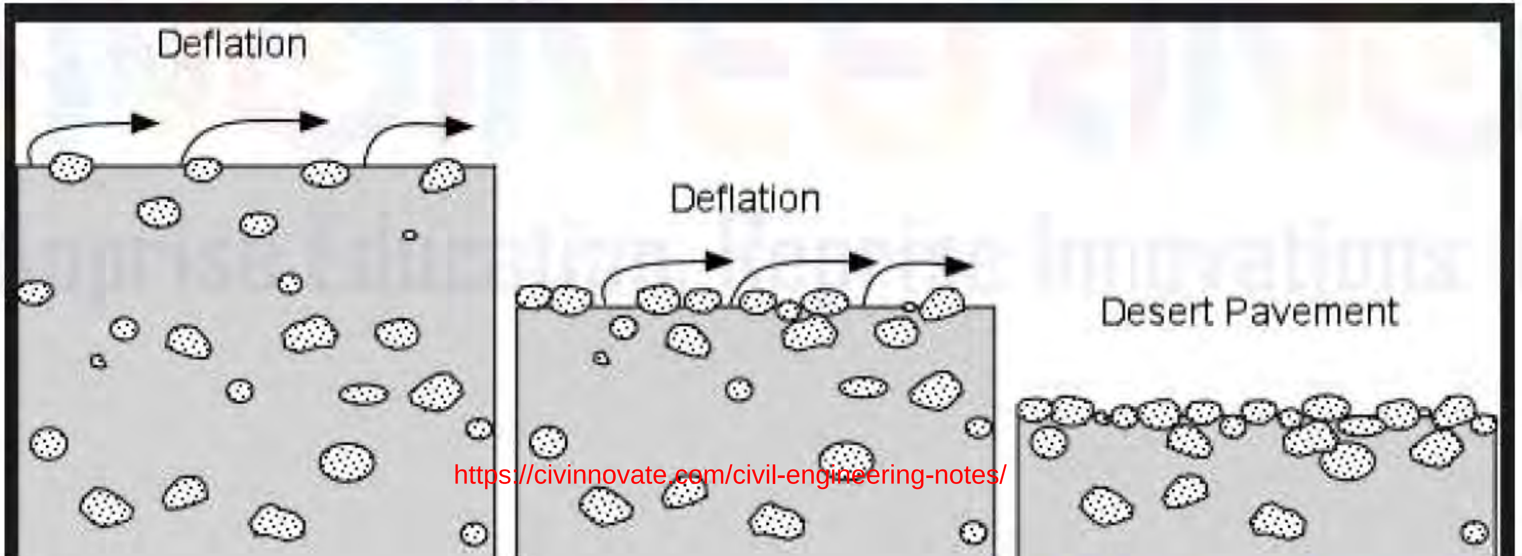
- These are small sized rock fragments showing one, two or three or even more typically Wind polished surfaces called faces.
- Polished and faceted rock fragments are called Ventifacts.
- Wind blowing in a particular direction, produce smooth and flat surfaces.

Ventifacts



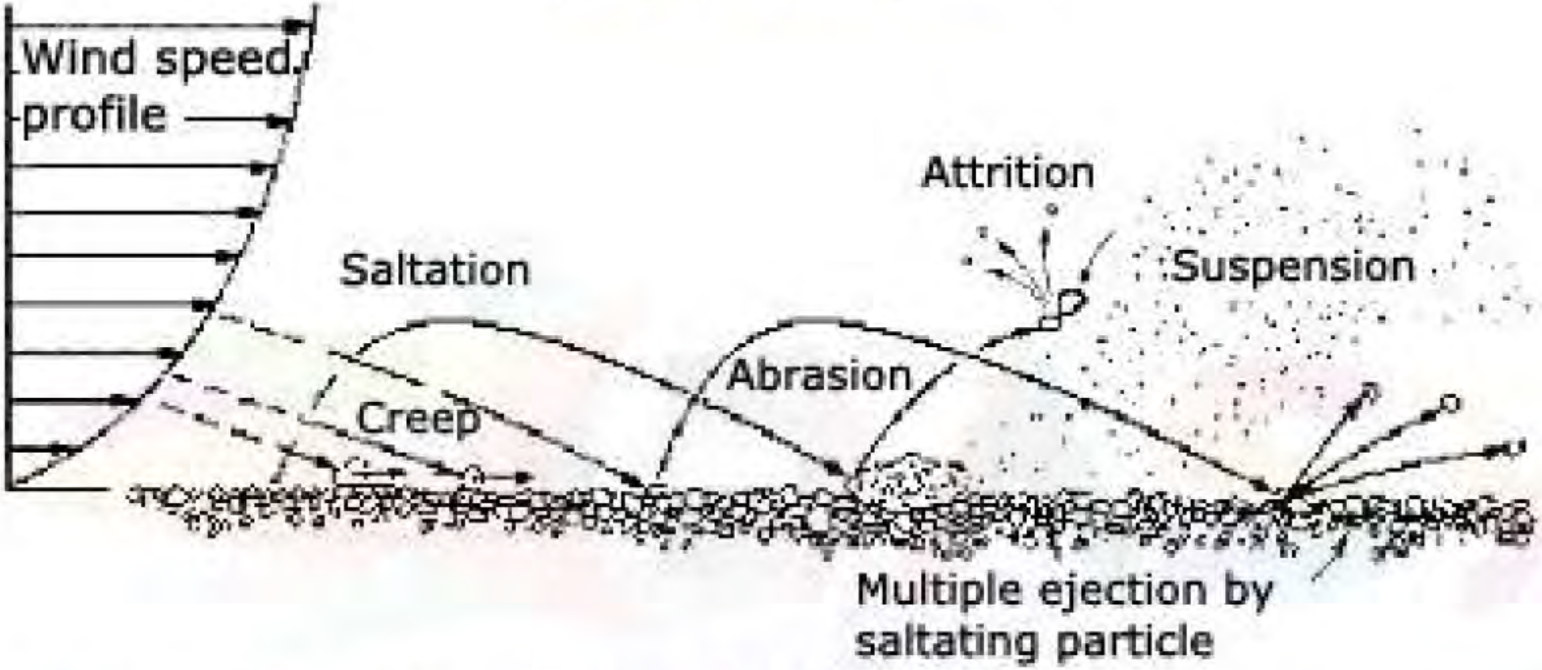
Desert pavements

- These are flat rock surfaces covered by rounded or sub rounded pebbles.
- Initially these rock surfaces are covered with fine particles of clay , silt and sand that have been removed by wind action



3. Attrition by wind

- The sand grains and other particles lifted by winds from different places move in a zigzag fashion, colliding with one another again and again.
- Such mutual collision amongst themselves causes a further grinding of the particles and the process is described as attrition.
- Attrition process is responsible for reduction in size of the load particles during their transport.



- Intensity of wind erosion depends on

1. Nature of the region
2. Velocity of wind
3. Duration

Sediment transport by wind

- Sediment transport by wind is an important aspect of geological work of wind

1. Source of Sediments
2. Methods of transport
3. Transporting power of wind

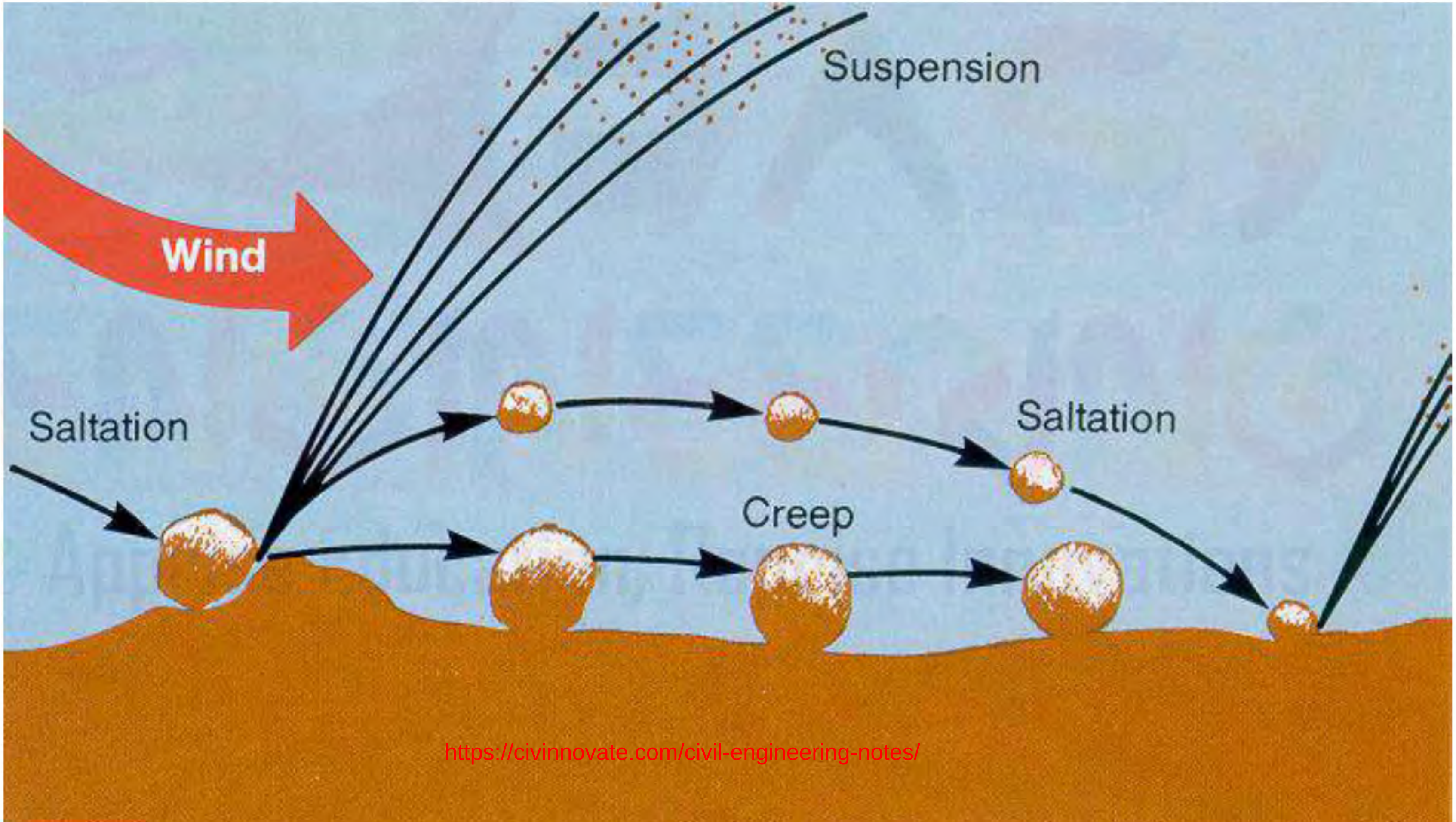
Source of sediments

- Material of fine particle size – clay , silt , sand are transported in huge volumes (thousand tons a day)

- Wind load is contributed by sand deserts and freshly ploughed fields.

Methods of transport

Suspension , saltation and creep



Suspension – light density clay and silt particles lifted by the wind from ground are carried high up to the upper layers of the wind. This is called suspension

Saltation

- Saltation – heavier and coarse sediments such as grains , pebbles and gravels are lifted up periodically during high velocity times only for short distances that too for small heights above the ground.
- In saltation process , each particle suffers a fall after reaching a maximum height . On falling , the particle transmits an impact to another stationary particle resting on ground.
- Saltation – sediment transport in a series of jumps.

Creep

- Heavier materials of odd shapes and sizes may not be actually lifted up. They are transported by strong winds through rolling , skidding and sliding motion along the ground. This displacement is referred to as creep.

Transporting power of wind

It depends on its

1. velocity
2. Size
3. Shape
4. Density of the particles

Deposition by wind

Aeolian Deposits

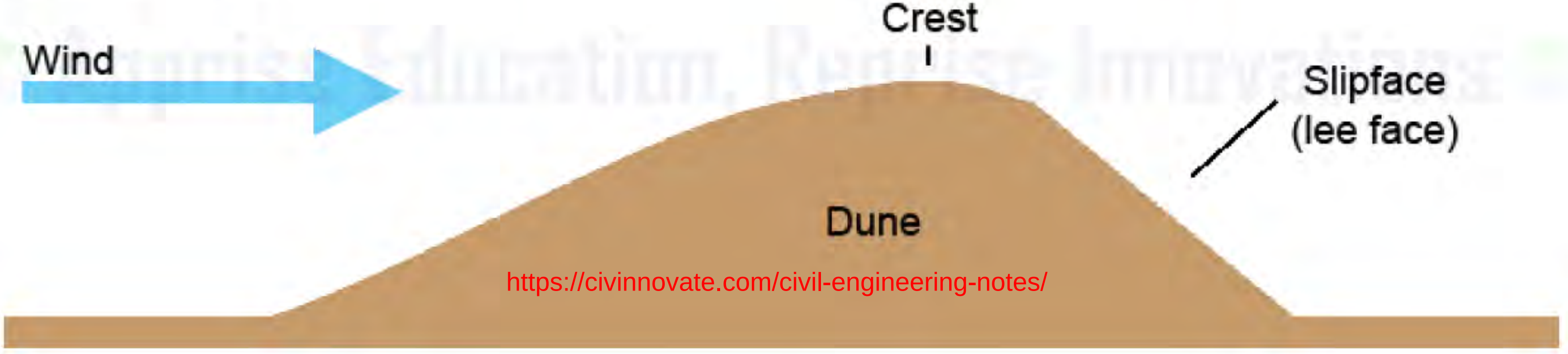
- Whenever wind looses its velocity, by any obstacle in their path like hills, mountains , boulders , buildings the sediments and particles are dropped back to the ground resulting in accumulation of wind deposits . Such deposits are called as Aeolian Deposits.
- The two main types of depositional features formed by the wind are

1] sand dunes and

2] loess

Dunes or Sand Dunes

- A sand dune is defined as a broad conical heap of sand characterized with two slopes on either side of a medial ridge or crest.
- It is normally developed when sand laden wind comes across some obstruction – raised surface.



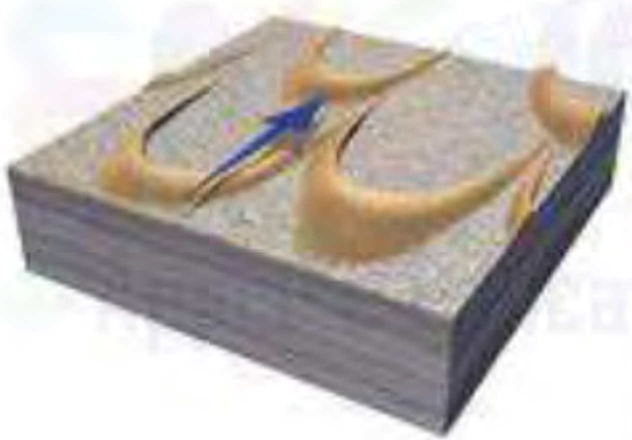
- A typical dune is characterized with a gentle windward side and a steep leeward side meeting at the crest.

Types of Dunes

- Crescent Dunes
- Sigmoidal Dunes

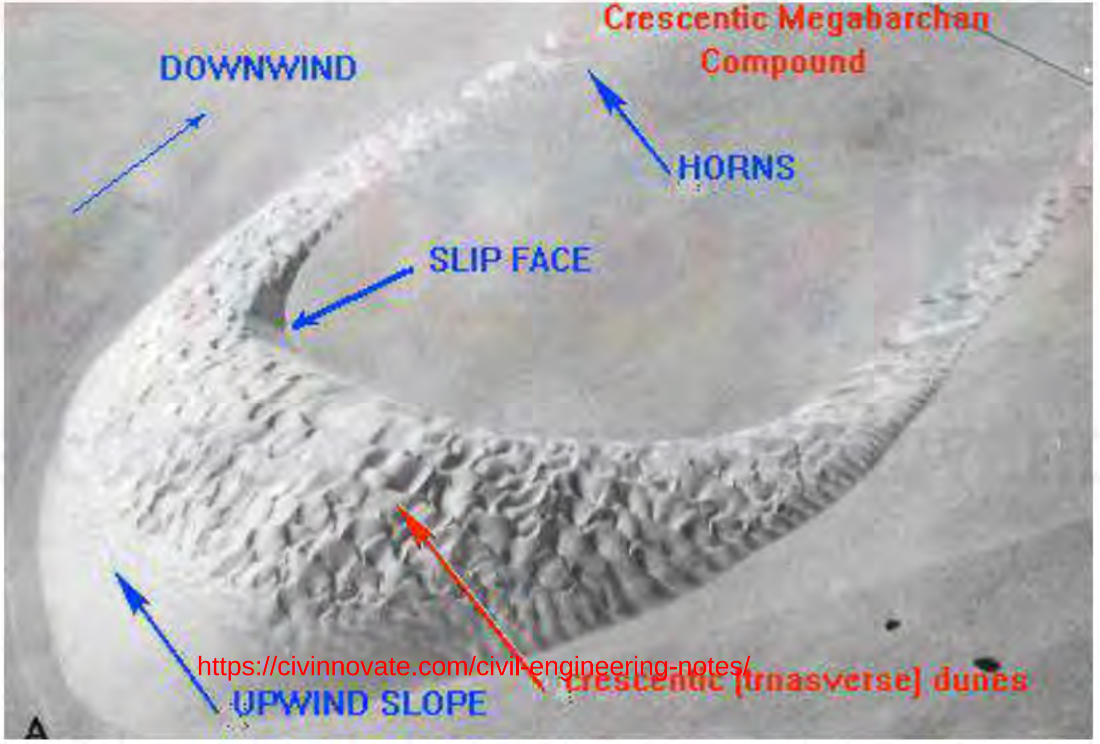
Crescentic dunes

- Crescentic dune is characterized with two slopes in such a way that the windward slope is convex and rises gently between 7° and 20 °



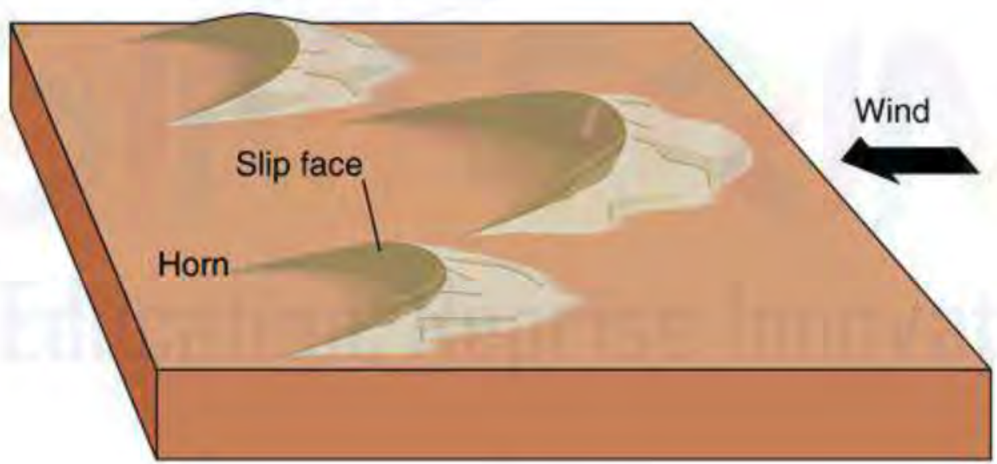
crescentic dune

- The downward slope has two well defined parts : the slip face and the cusps or horns
- The slip face starts from the crest and it is quite steep (20° to 30 °) and is concave in outline.



Barchans

- Simple type of crescentic dunes with a half moon shape developed by winds blowing in the same direction for considerable length of time.

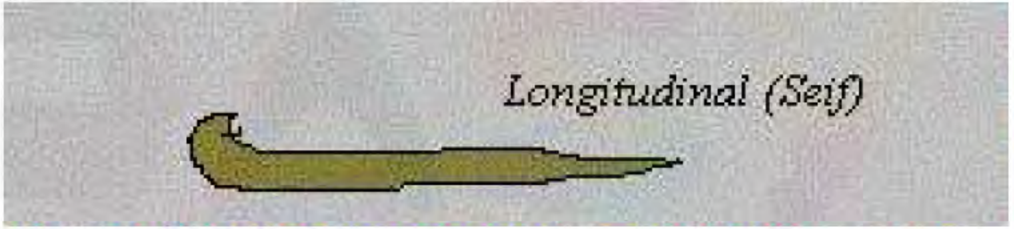


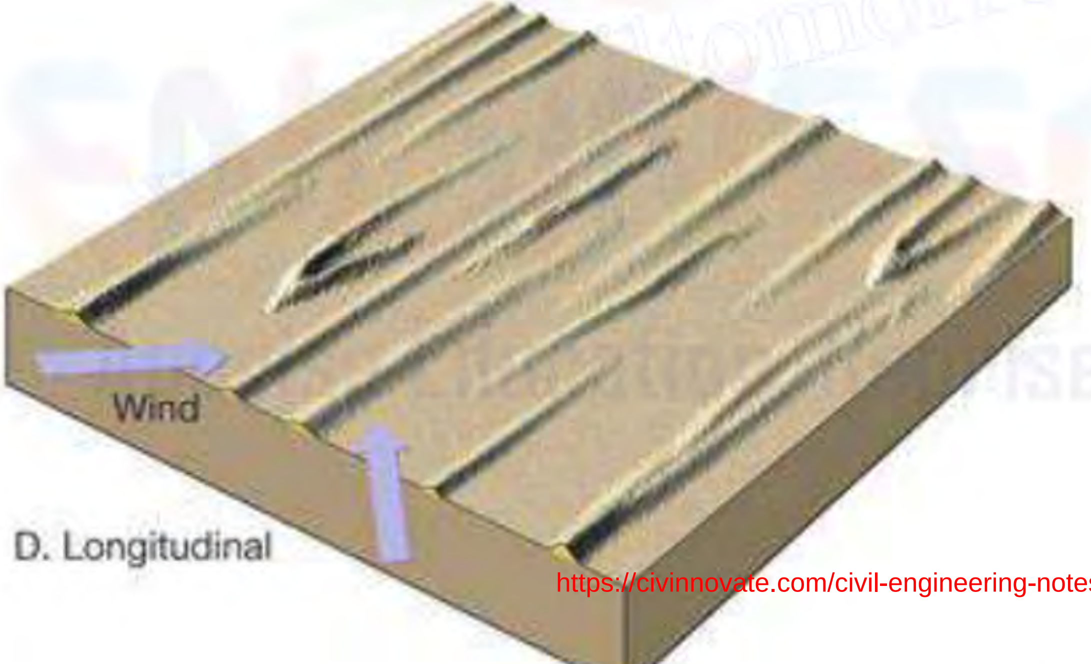
Barchans

Sigmoidal or Longitudinal Dunes

- Sigmoidal Dune is characterized with the absence of horns.
- Both the sides of a sigmoidal dune are steeply inclined at angles of 25° to 32 °
- They are also called as SEIFS.

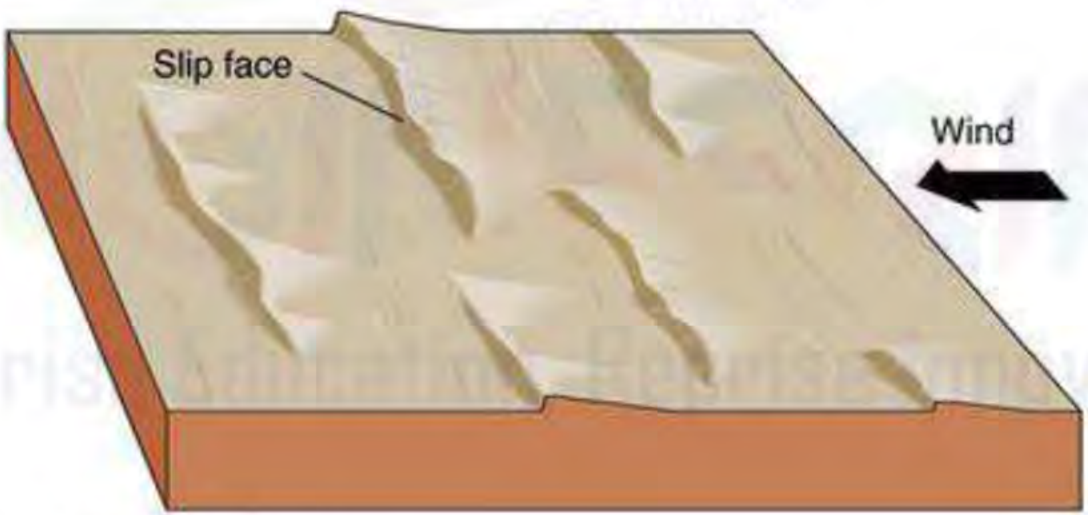
Longitudinal Dune has a sinuous or S shaped outline



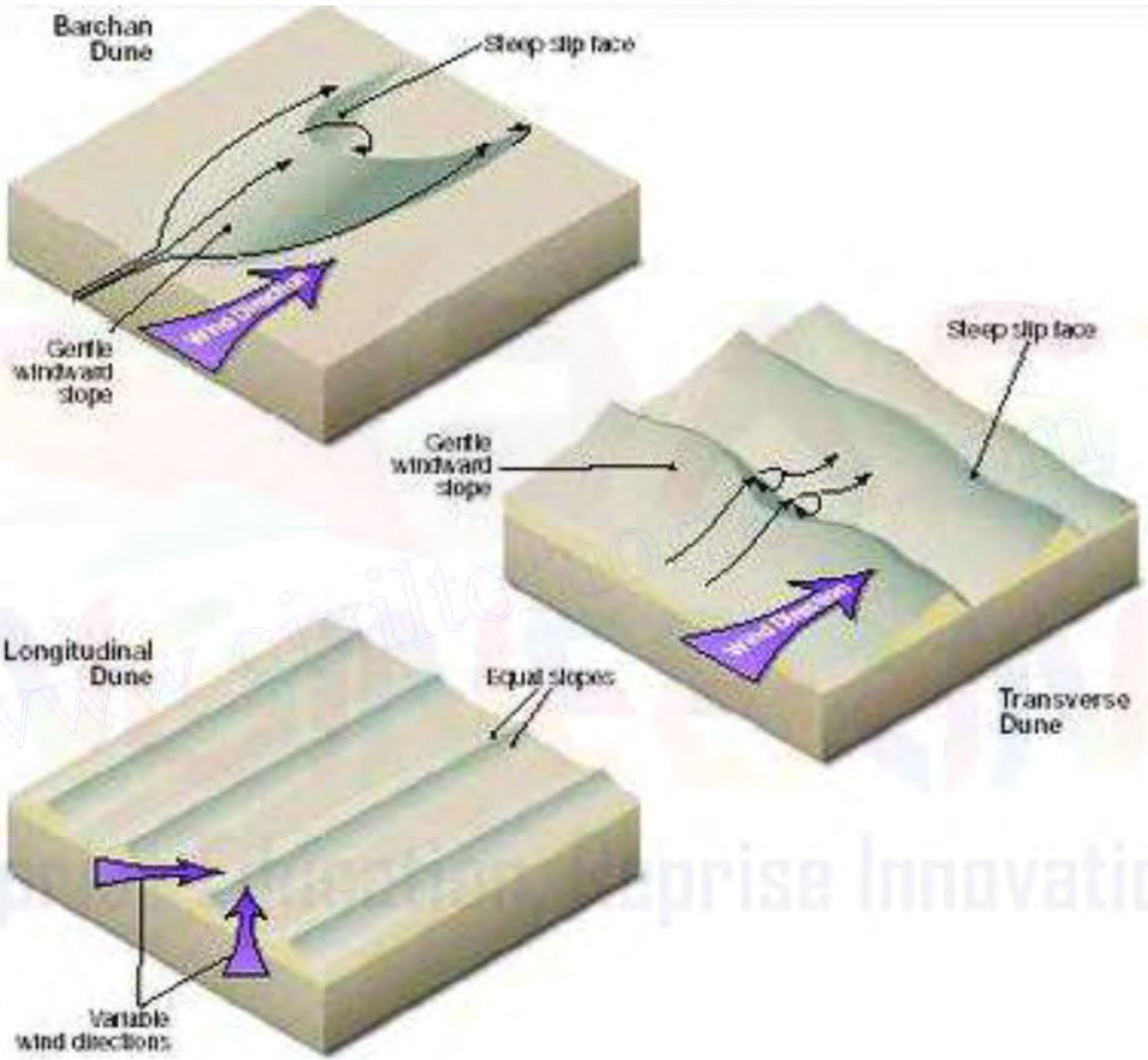


Transverse Dunes

- Transverse dunes are generally crescent dunes in nature and formed across the prevailing winds.



Transverse dunes



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Classification of dunes

- Simple dune – single dune of the above fundamental types
- Compound dune – consists of two or more dunes of the same type
- Complex dune – group of dunes of different types occurring in a close vicinity to each other.

Geological work of Streams and Rivers

Methods of River Erosion

Streams and Rivers are the most powerful agents of erosion. Running water performs erosion in five ways

- Hydraulic Action
- Cavitation
- Abrasion
- Attrition
- Corrosion

Hydraulic action

- It is the mechanical loosening and removal of the material from the rocks due to pressure exerted by the running water.
- The higher- the velocity, the greater is the pressure of the running water on the rock or grains of soil which moves out the parts from the parent body occurring along its base or sides.
- potholes may be developed due to hydraulic action.

Pot holes due to hydraulic action

cavitation

- It is particularly observed where river water suddenly acquires exceptionally high velocity such as at the location of a waterfall.
- It is known that where stream velocity exceeds 12m/sec , the water pressure developed at the impinging points equals vapour pressure.

Abrasion

- It involves wearing away of the bedrocks and rocks along the banks of a stream or river by the running water
- sand grains, pebbles and gravels ,rock fragments moving along with river water are collectively known as tools of erosion.

Attrition

- Attrition is the wear and tear of the load sediments by mutual impacts and collusions during their transport.
- Due to these mutual collusions, the irregularities and angularities of the particles are worn out. These become spherical in outline and rounded and polished at the surface.

Corrosion

- The slow but steady chemical (especially solvent) action of the stream water on the rocks is expressed by the term corrosion.
- The extent of corrosion depends much on the composition of rocks and also on the composition of flowing water.

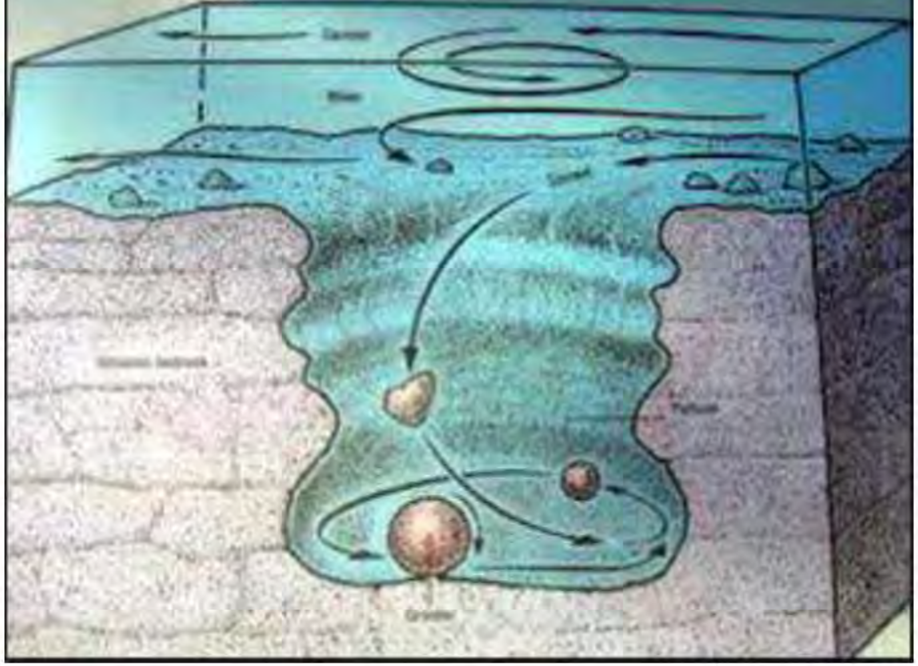
Features of stream erosion

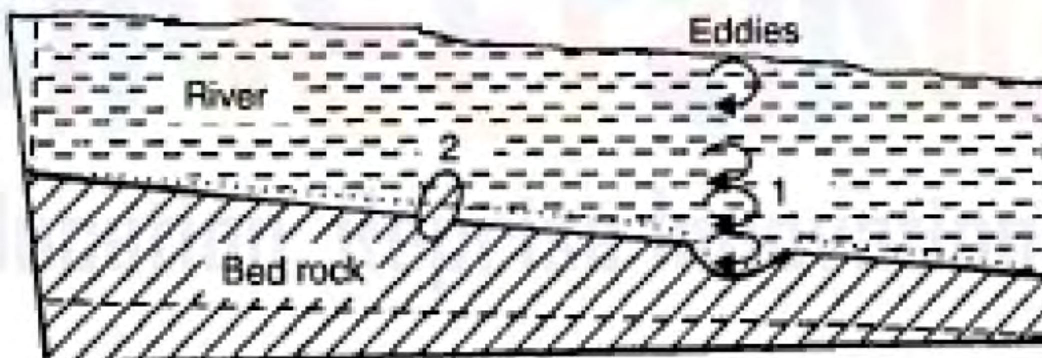
Common features developed on the surface of land as a result of river erosion are

1. Potholes
2. River valleys
3. Dip slope
4. Water falls
5. Stream terraces

potholes

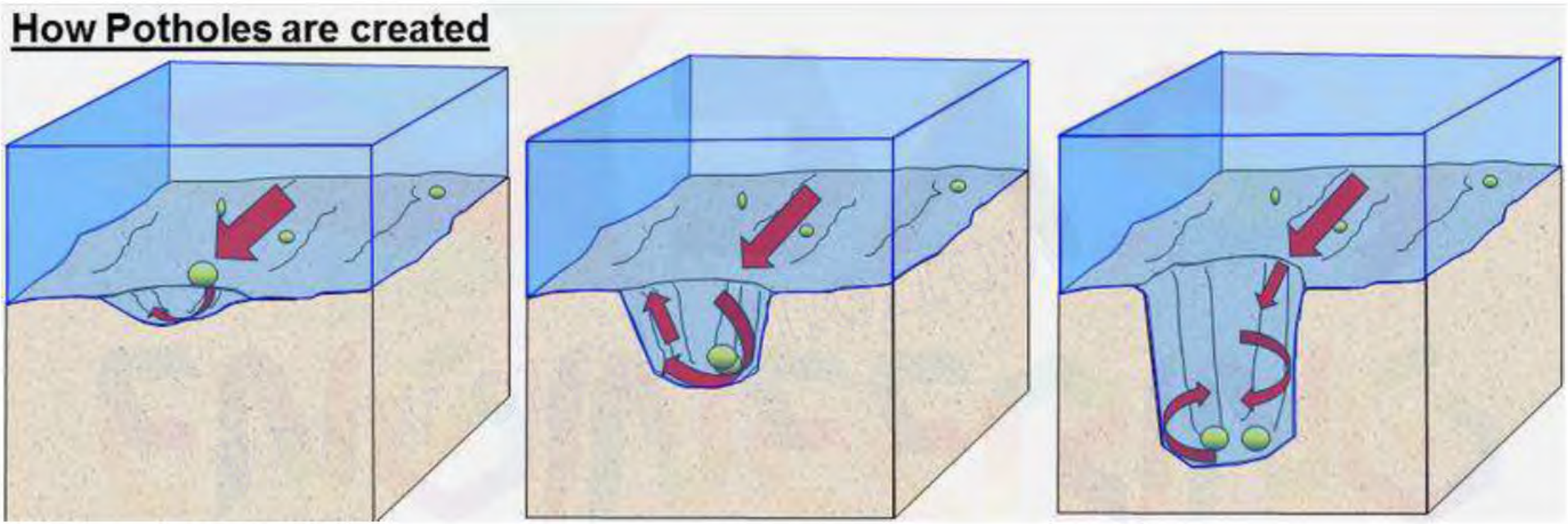
- The potholes are generally cylindrical or bowl shaped depressions developed in the river bed by excessive localized erosion by streams
- These depressions becomes the spots where pebbles and gravels of the stronger rocks are caught in eddies and thrown into a swirling or churning motion





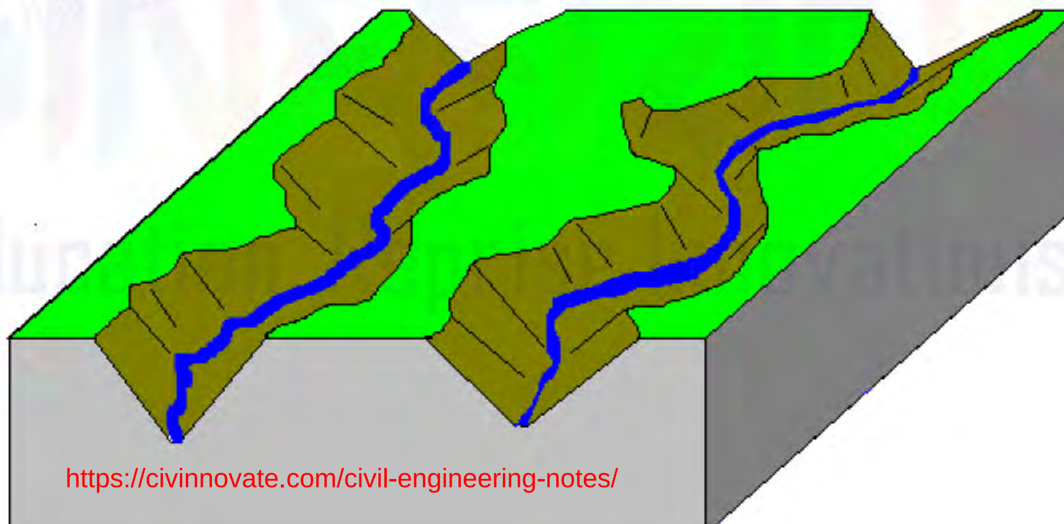
Potholes

Formation of potholes



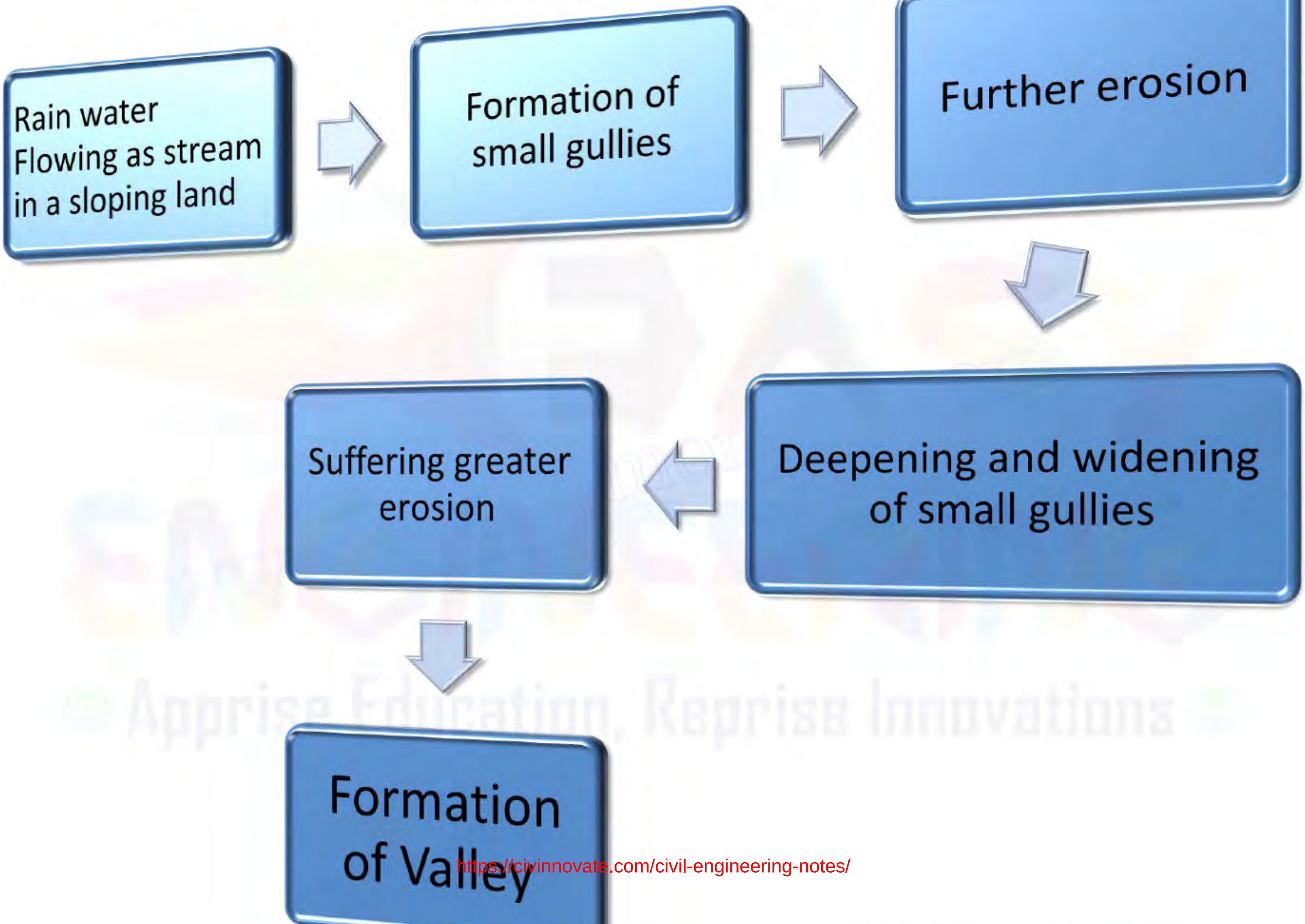
River valleys

- A valley may be defined as a low land surrounded on sides by inclined hill slopes and mountains.
- Rivers are responsible for the origin, development and modification of the valleys through well- understood processes of river erosion.



1. Origin of valley

- Rain water flowing as small streamlets produce small gullies in the gently sloping land surface.
- These gullies are incipient valleys
- Further erosion deepens and widens the original gully that can accommodate bigger volumes of water and thus suffers greater erosion which results in the formation of Valley


Rain water Flowing as stream in a sloping land
Formation of small gullies
Further erosion
Deepening and widening of small gullies
Suffering greater erosion
Formation of Valley

2. Valley Deepening

- Valley Deepening – Cutting down of the river bed
- It is achieved by cooperative action of all the processes involved in erosion: hydraulic action, abrasion and chemical action or corrosion.
- Lowest level up to which a river can erode its channel is called base level of erosion.

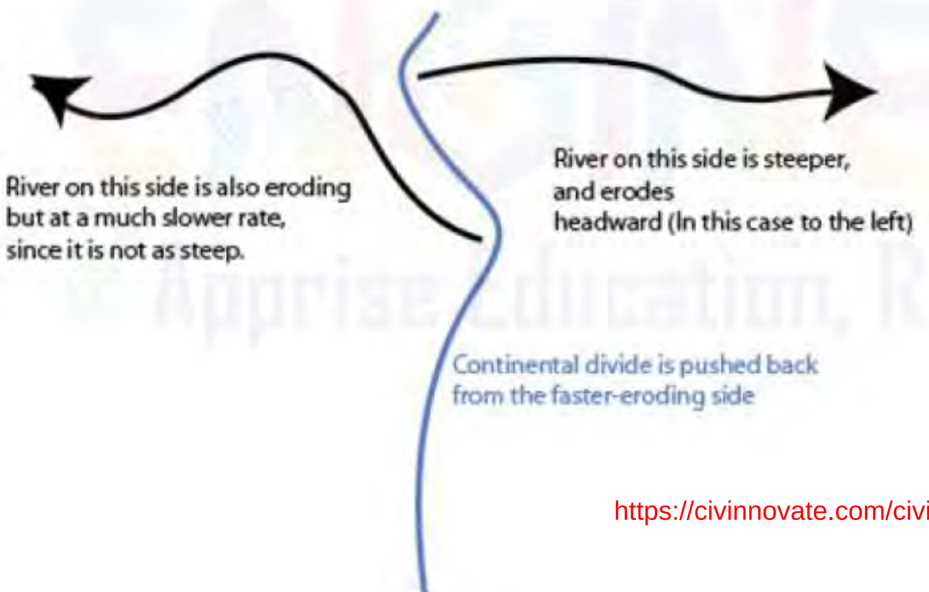
3. Lengthening of river valley

- Each main stream has its tributaries , the rate of erosion in the main stream is much higher than in the tributaries.
- The tributaries are merged completely with the main valley which results in the extension of main valley.

River Capture

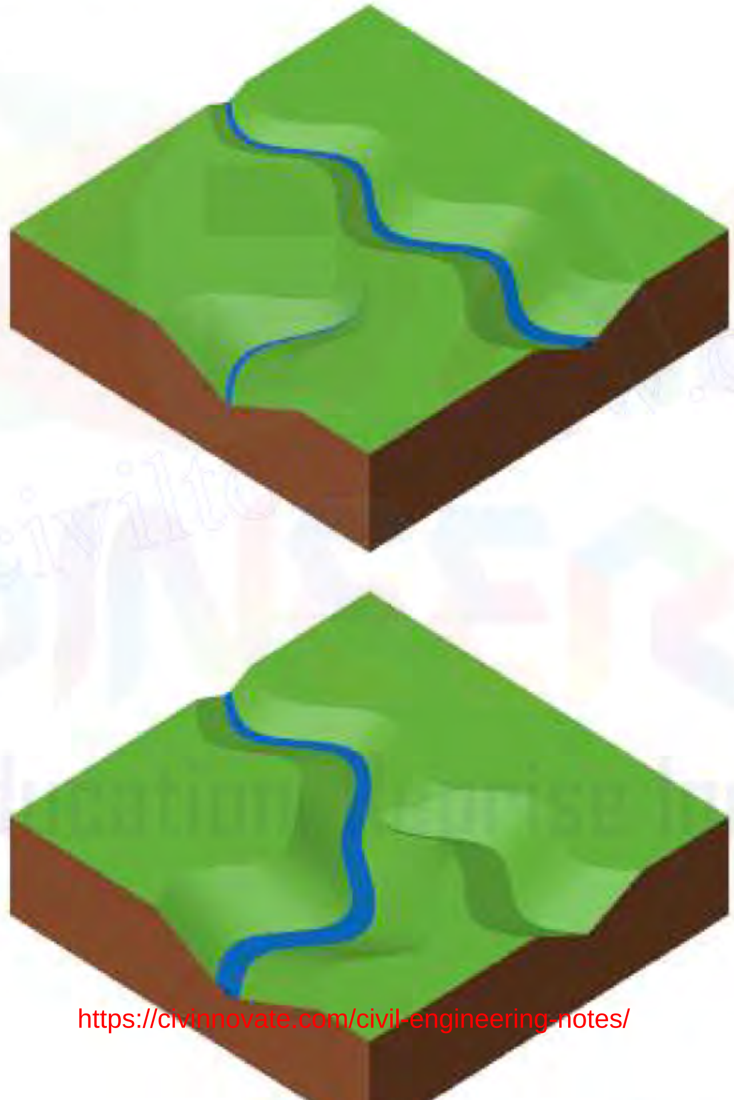
River capture is a geomorphological phenomenon occurring when a stream or river is diverted from its own bed, and flows down into the bed of a neighbouring stream.

1



2

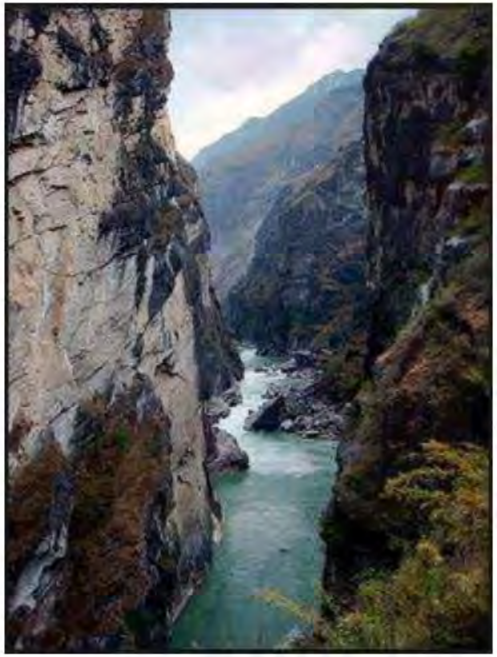
River capture



4 . Gorges and Canyons

- Gorges are very deep and narrow valleys with very steep and high walls on either side.
- Length varies from few meters to several kilometres.
- Canyon is a specific type of gorge where layers cut down by a river are stratified and horizontal in attitude.
- Example : Grand canyon of Colorado (depth 900 to 1800 mts , width – 60 to 60 mts , length – 300 km.)

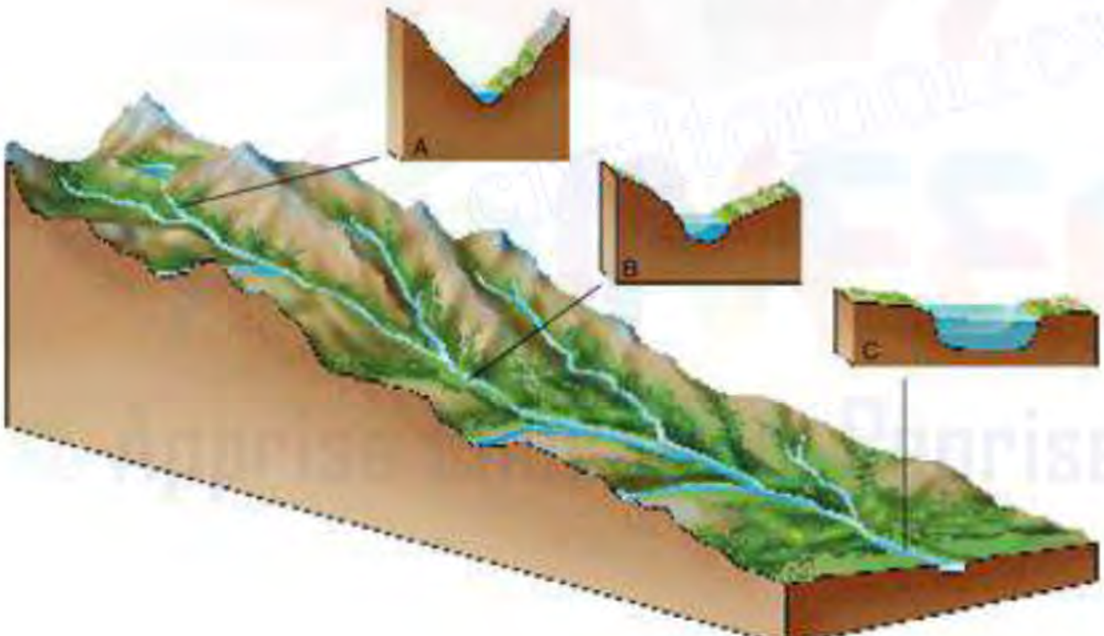
Gorges and Canyons



Canyon

Valley profile

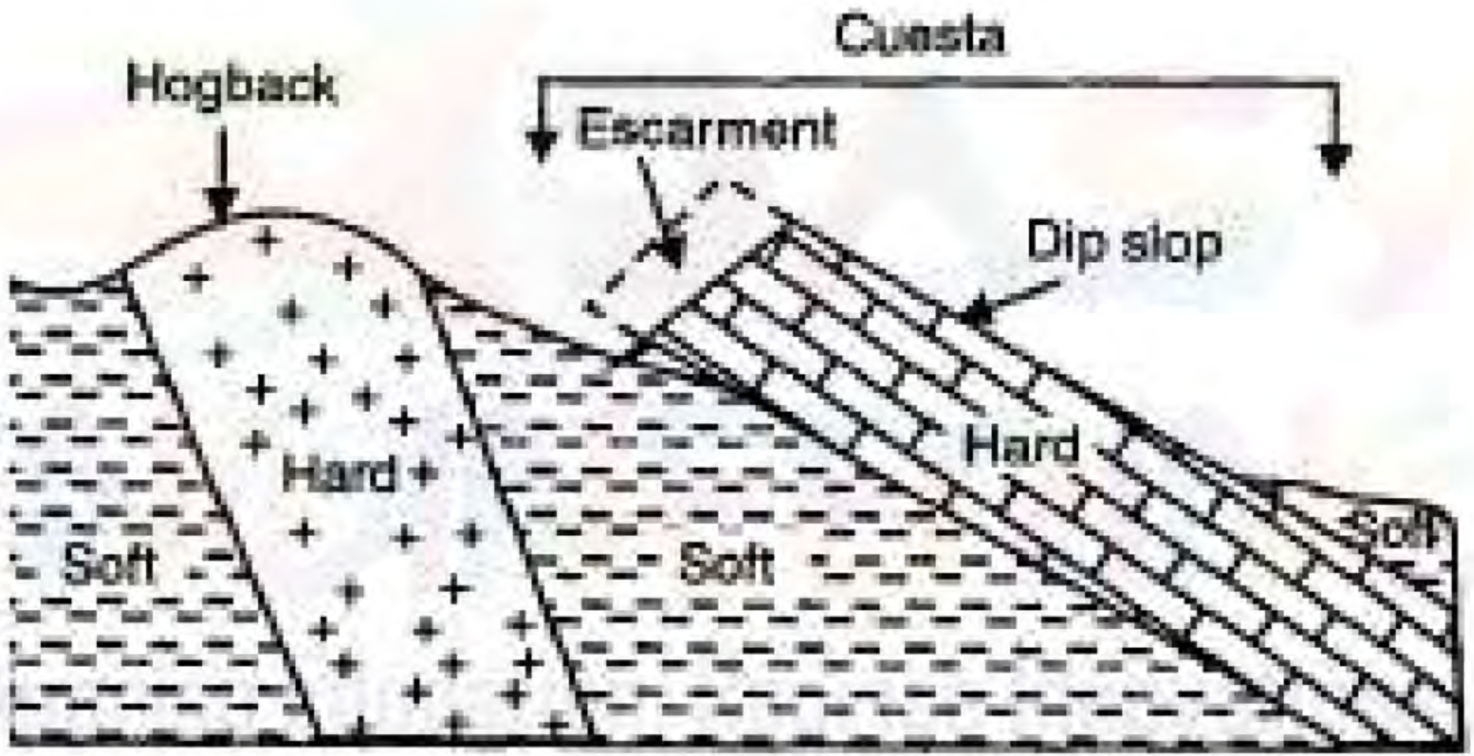
1 . Mountainous Tract
2. Semi mountainous tract
3. Plain tract



5. Escarpments and Features

- Escarpments are erosional features produced by rivers in regions composed of alternating beds of hard and soft rocks.
- Stream erodes the overlying softer rock , fully exposing the underlying hard layer. The resulting slope (angle of inclination of layer with horizontal) is called a dip slope.
- CUESTA is known as the combined set of escarpment and dip slope occurring adjacently in an escarpment topography.
- Hog back – It is an outcrop of hard rock having erosional slopes on either side.

Escarpments and related features

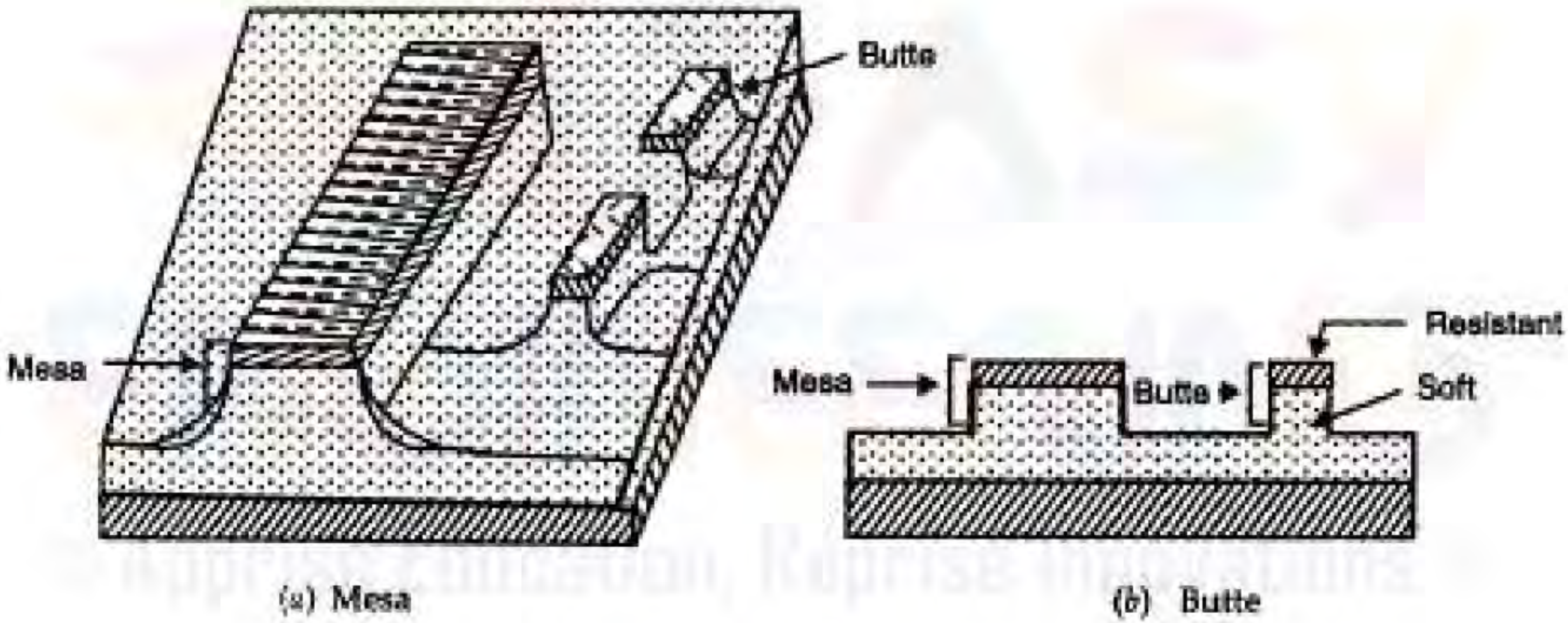


Escarpments and related features

Mesa and Butte

- These are horizontally layered rocks, having a cap of hard and resistant rocks that have escaped erosion.
- Large sized caps are called Mesa and small sized isolated patches are called butte.
- These features result in areas of alternating hard and soft layers exposed to river erosion.

Mesa and Butte



Mesa and Butte

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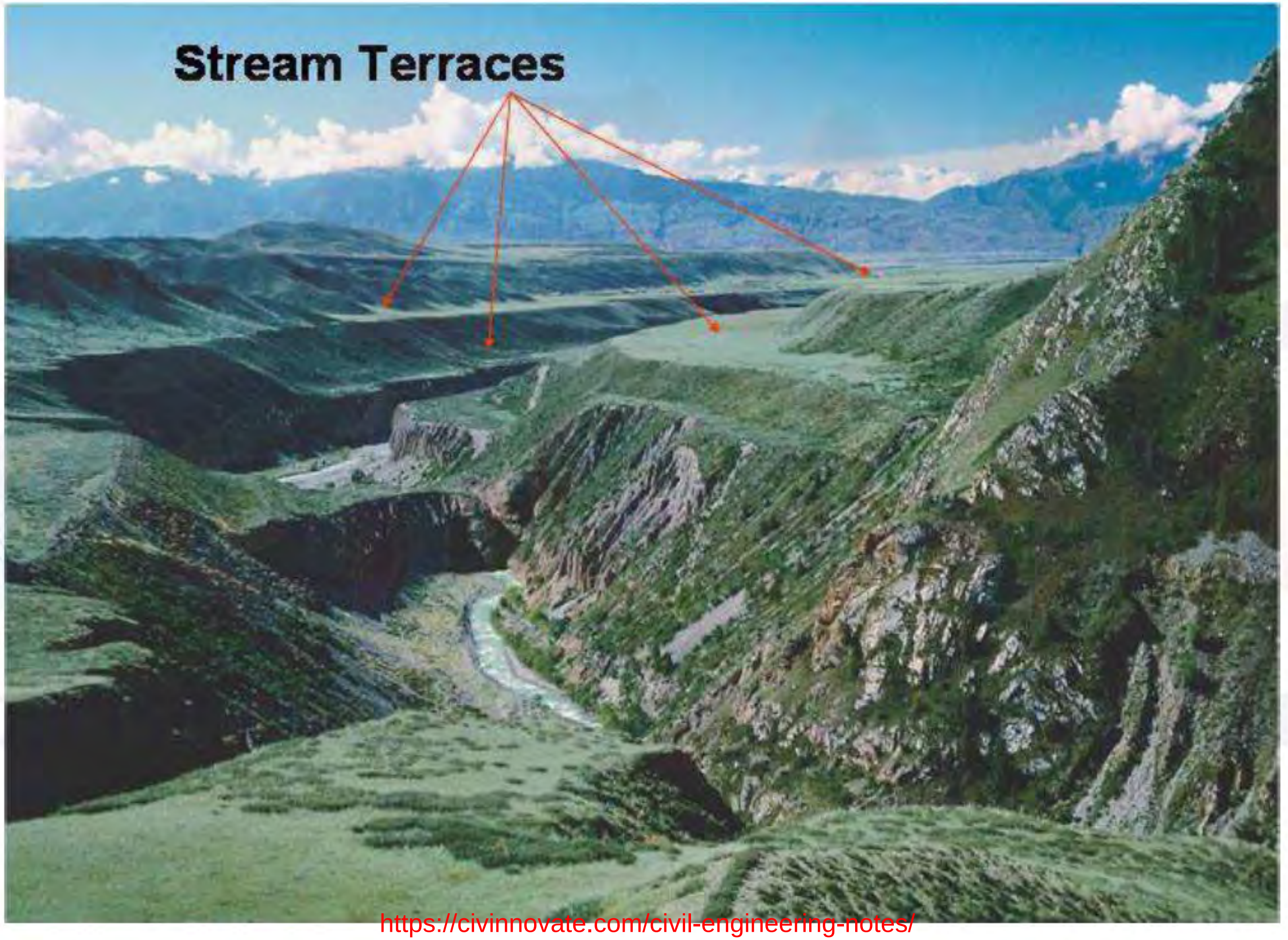
Water falls

- These are defined as magnificent jumps made by stream or river water at certain specific parts of their course where there is a sudden and considerable drop in the gradient of the channel.
- In a waterfall, the stream literally falls (instead of flowing) from a considerable height before acquiring normal flow again at a lower level.
- Obviously, the velocity of water at the point of fall increases tremendously.
- Successive falls of smaller heights are sometimes referred as rapids and cascades.

Stream Terraces

- These are bench like ledges or flat surfaces that occur on the sides of many river valleys. From a distance, they may appear as succession of several steps of a big natural staircase rising up from the riverbank.
- They may be made up of hard rock or of soft rock, but the essential thing is that they look like steps.


Stream Terraces

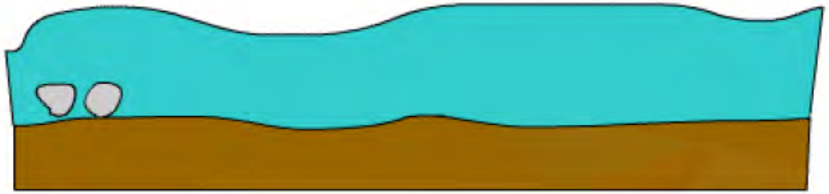
Sediment Transport by Rivers

Types of load

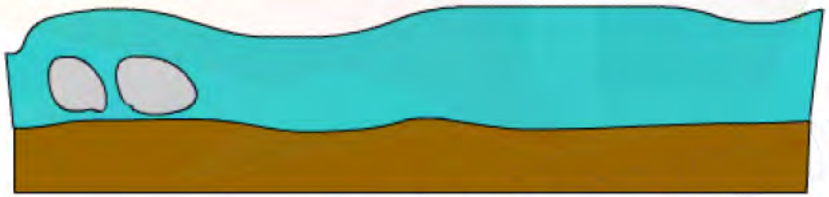
The load being transported in running water of stream or river are

- The Suspended Load
- The Bed Load
- The Dissolved Load

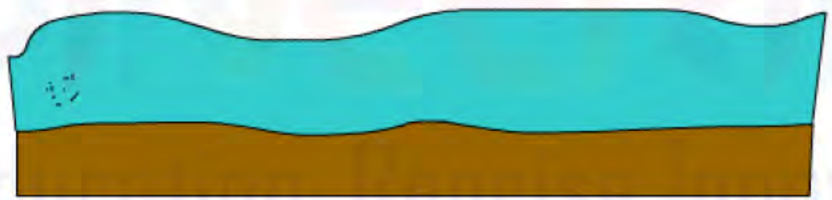
saltation



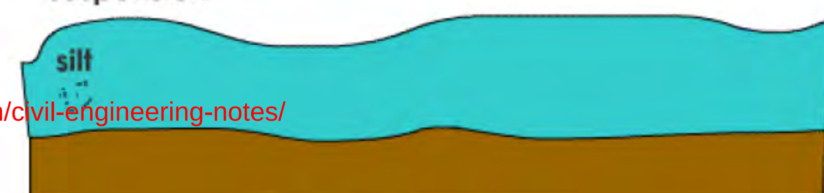
traction



solution



suspension



Suspended Load

- Fine sand , silt and clay sediments are transported in a state of suspension
- Load lifted up in stream are not allowed to touch the base due to eddies caused by turbulence

Bed Load

- Heavier particles of sand , pebbles gravels ,cobbles are transported by the method of saltation
- Sediment transport method carried out in a series of jumps

Dissolved Load

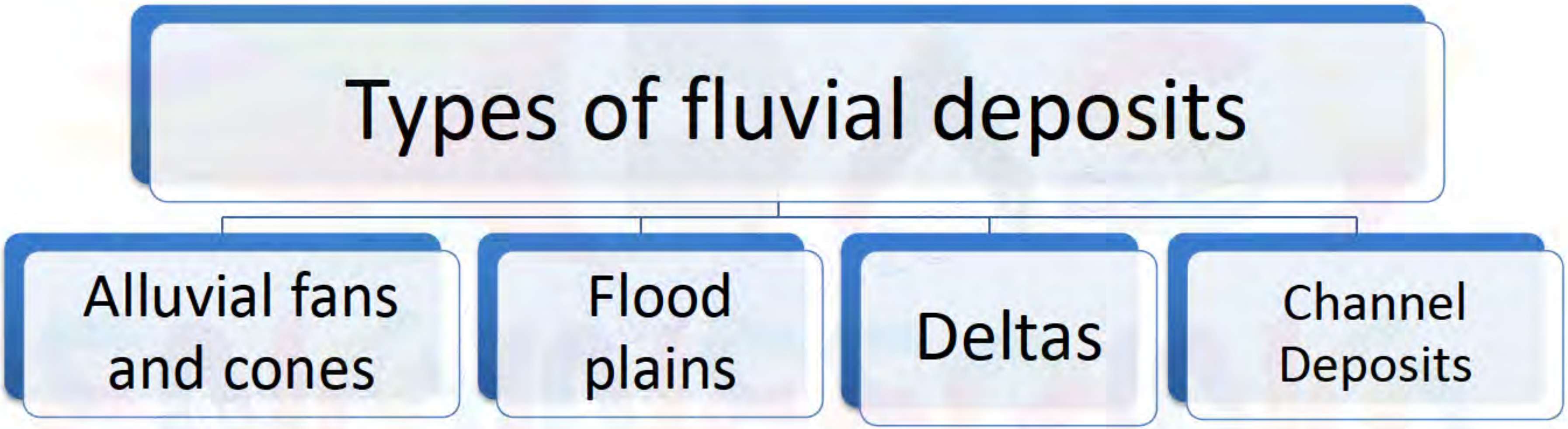
- Materials soluble in water are transported
- Limestone , gypsum , anhydrite , rock salt

Deposition by Rivers

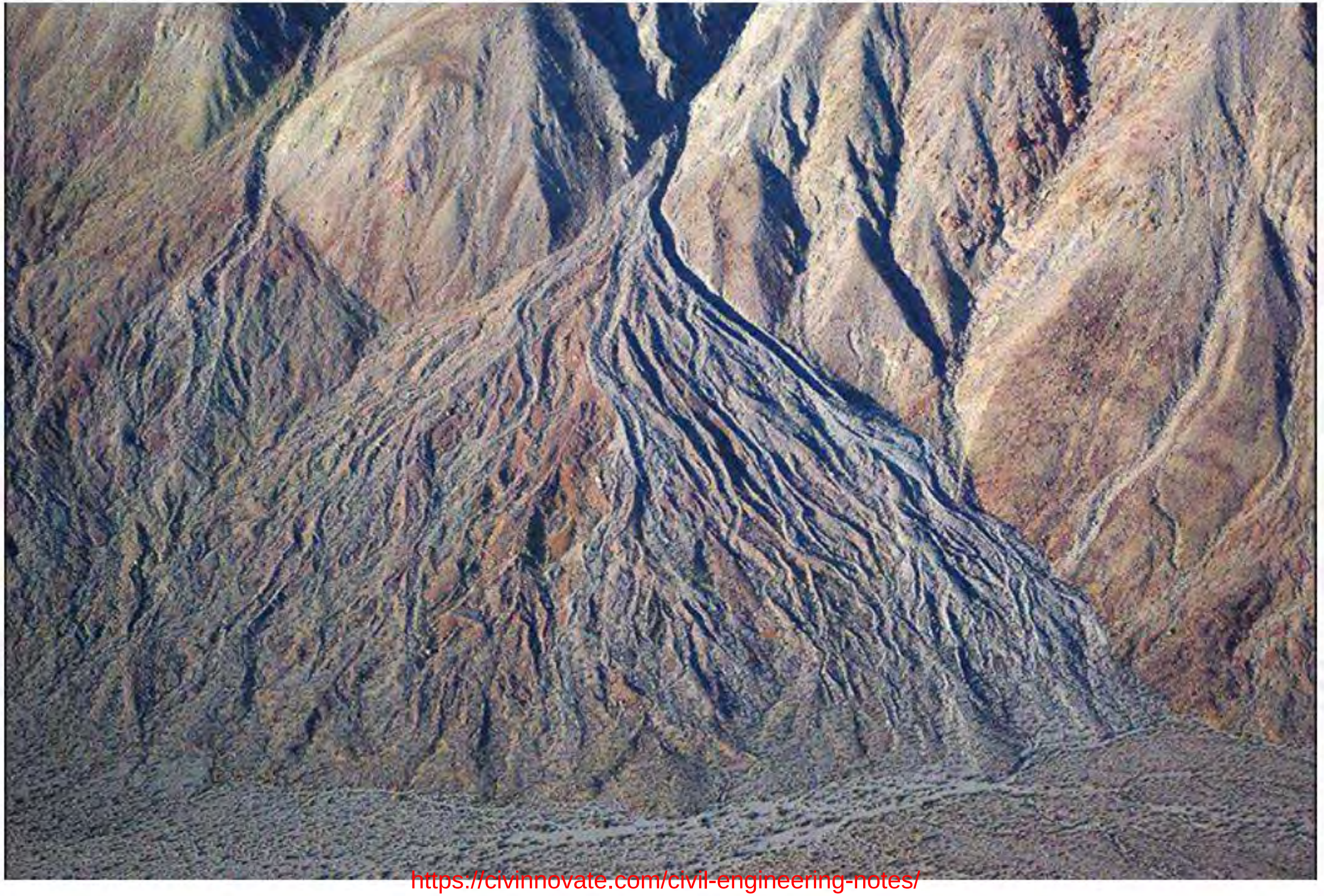
- The entire load of a stream or a river will normally remain in transport.
- when there is a decrease in the load carrying capacity of stream due to whatsoever reason, a part or whole of the load will be dropped down.
- This process is called deposition of rivers

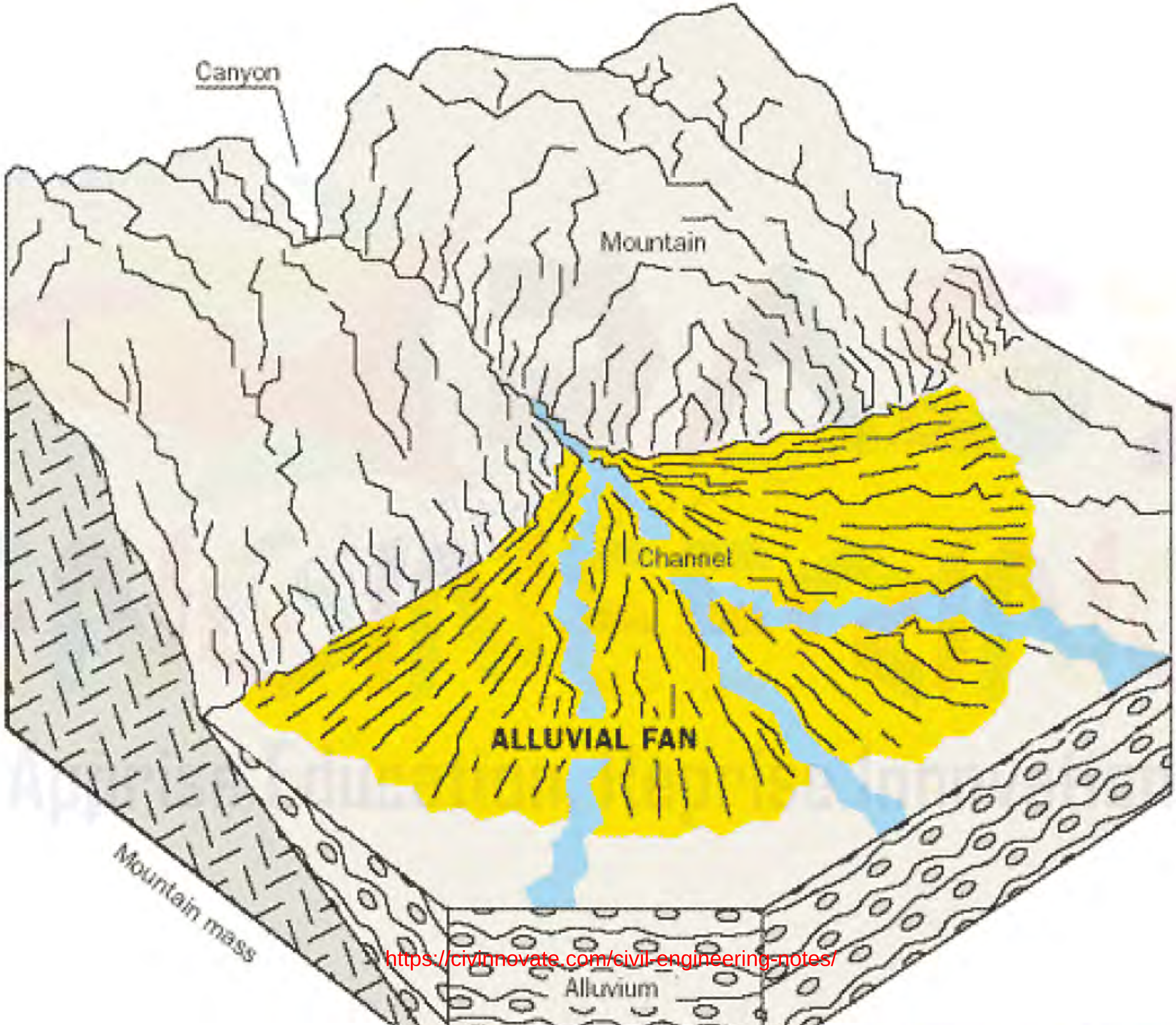
EX : Fluvial Deposits

Types of fluvial deposits



Alluvial fans and cones




Canyon
Mountain
Channel
ALLUVIAL FAN
Mountain mass
Alluvium

Alluvial fans and cones

- These are cone shaped accumulations of stream deposits found at places where stream rushing down from hill slopes with enormous debris to the low land area.
- Most of the load is spread out in all directions.
- Slope of deposit is below 10° - Alluvial fan
- Slope of deposit 10° to 50° - Alluvial cone

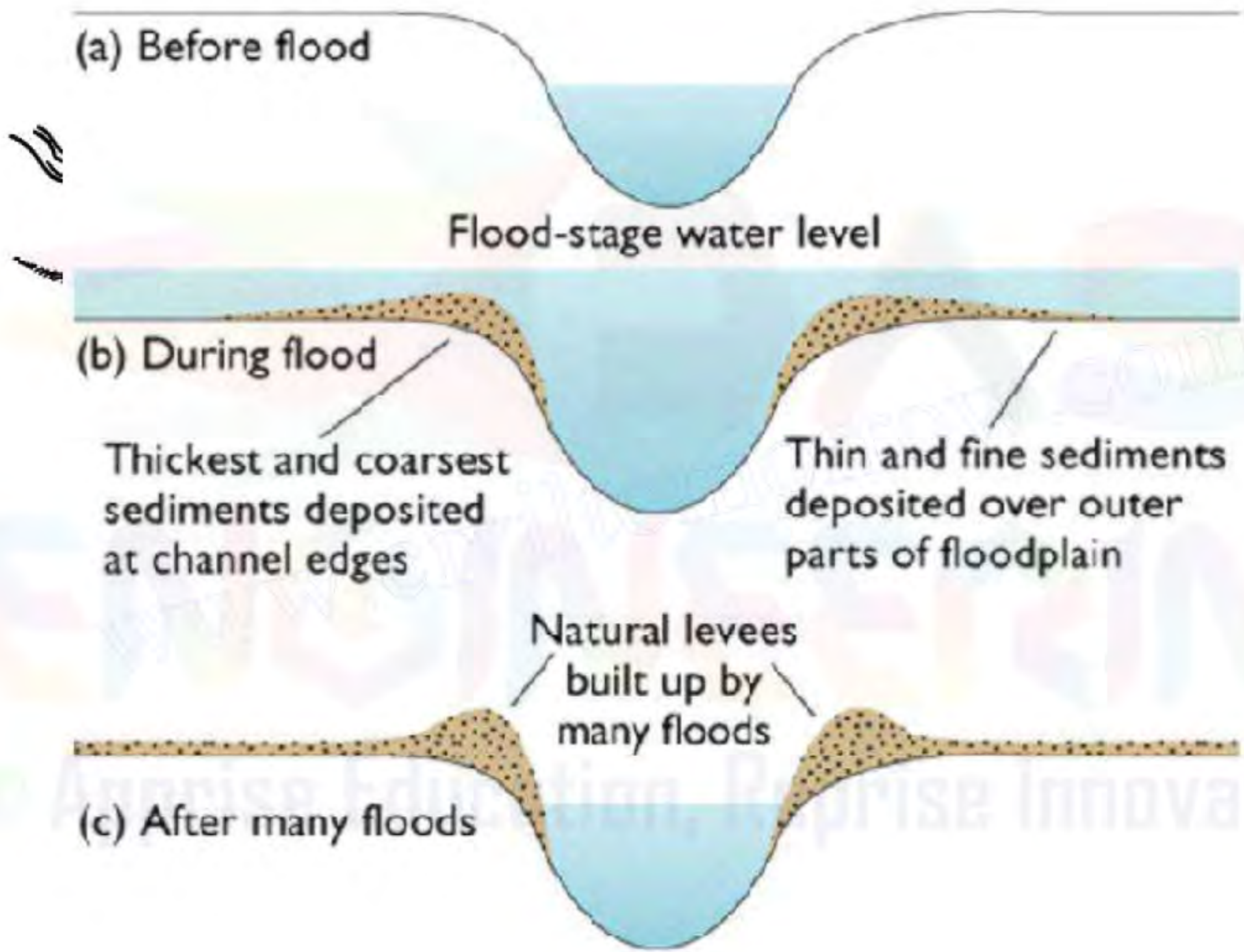
Flood plains

- Floodwaters are invariably heavily loaded with sediments of all types.
- When these waters overflow the river banks and spread as enormous sheets of water in the surrounding areas, their velocity soon gets checked everywhere due to inequalities of the ground, absence of a well defined channel and many other obstructions.
- As a consequence, they deposit most of the load as a thick layer of mud, so commonly seen after every major flood.

Flood plains

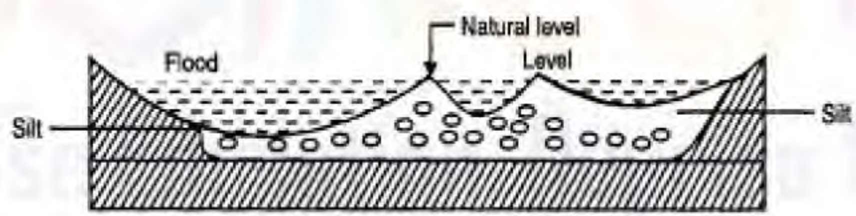
- Since such a process may get repeated after intervals, the low lying areas surrounding major rivers are actually made up of varying thickness of flood deposits.
- These are generally level or plain in nature and extensive in area; hence they are aptly called Flood Plains
- Two major types of flood plains are

1. Convex Flood plains
2. Flat flood plains



(a) Before flood
Flood-stage water level
(b) During flood
Thickest and coarsest sediments deposited at channel edges
Thin and fine sediments deposited over outer parts of floodplain
Natural levees built up by many floods
(c) After many floods

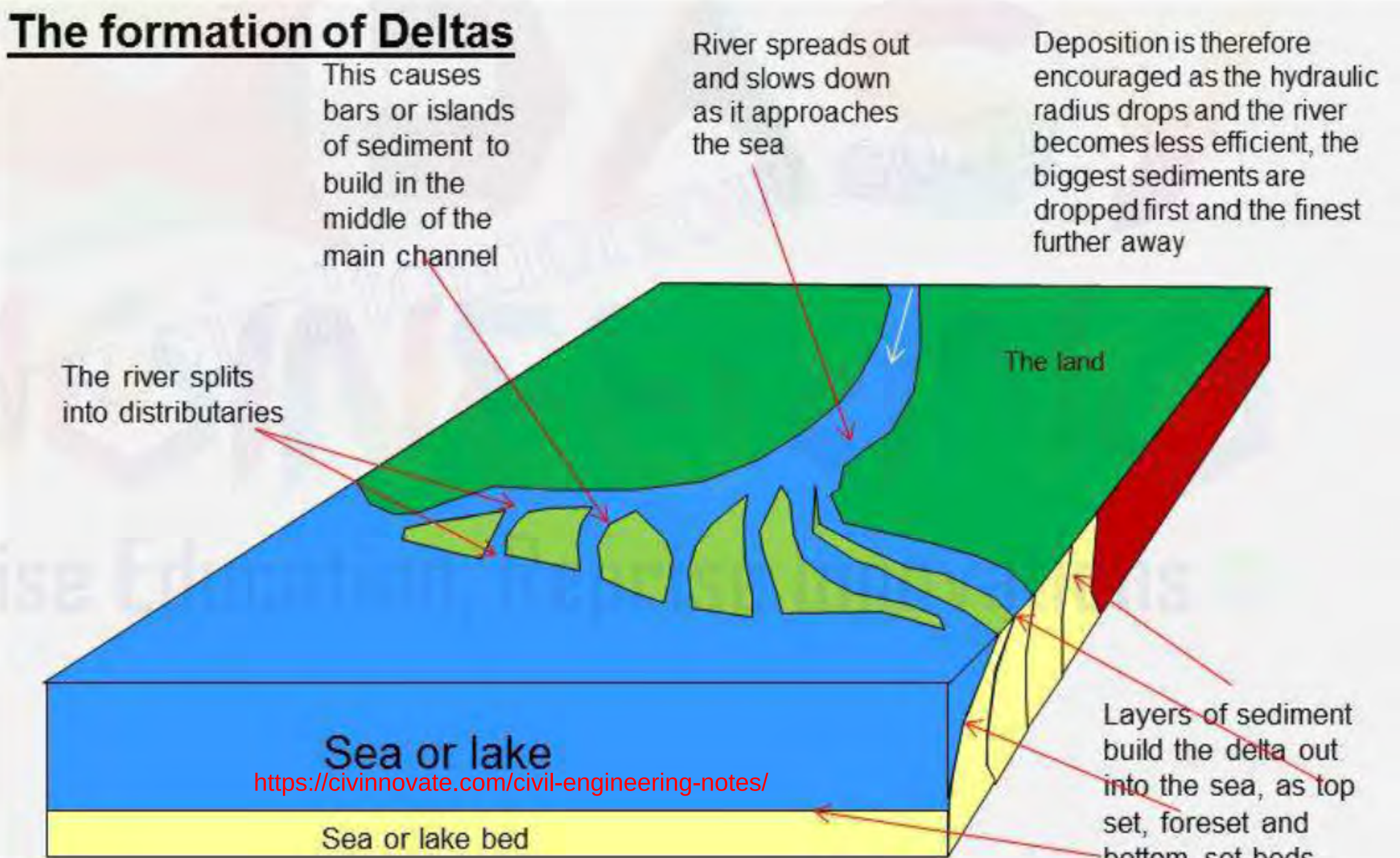
- Convex flood plains - The surrounding areas are located at rather lower levels Compared with the river channel and hence give a convex shape to the deposit in a vertical cross section.
- Flat flood plains -These flood plains appear mostly flat in cross section and are made up mostly of sand and silt sediments

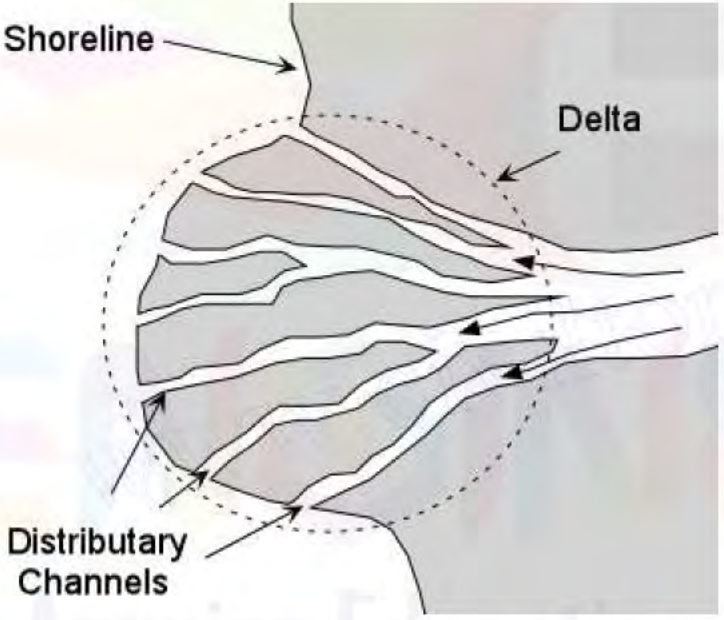


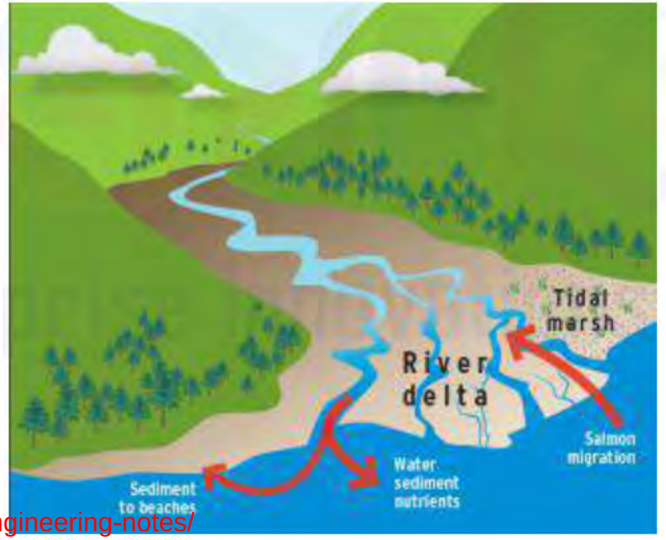
(a) Convex type.

Deltas

- Deltas are defined as alluvial deposits of roughly triangular shape that are deposited by major rivers at their mouths, i.e. where they enter a sea.
- Deltas are quite complex in their structure because of operation of a number of factors during their formation, evolution and modification with passage of time.


The formation of Deltas
This causes bars or islands of sediment to build in the middle of the main channel
River spreads out and slows down as it approaches the sea
Deposition is therefore encouraged as the hydraulic radius drops and the river becomes less efficient, the biggest sediments are dropped first and the finest further away
The river splits into distributaries
The land
Sea or lake
Sea or lake bed
Layers of sediment build the delta out into the sea, as top set, foreset and


Shoreline
Delta
Distributary Channels


Tidal marsh
River delta
Salmon migration
Water sediment nutrients
Sediment to beaches

Channel Deposits

- Many streams are forced by some natural causes to deposit some of their load along their river –beds.
- They are called as channel deposits .
- Channel deposits includes varied mixture of clays, silts , sand and gravels and occassional boulders.

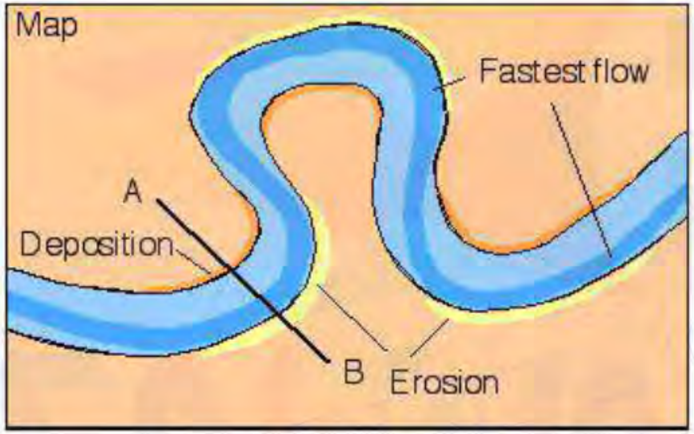
River Meandering

- When a stream flows along a curved , zig zag path acquiring a loop – shaped course ,it is said to meander. The process of development of zigzag type of channel for itself is called river meandering.
- Meanders are developed mostly in the middle and lower reaches of major streams where lateral erosion and deposition along opposite banks occur.

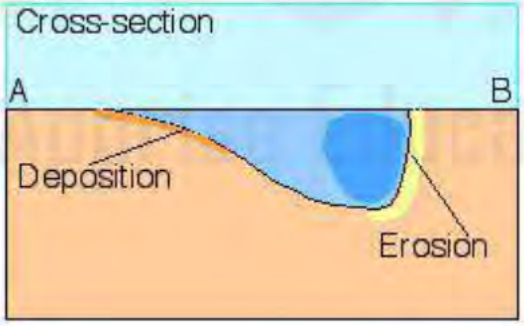
River Meandering

Erosion and Deposition along opposite banks

Meanders:



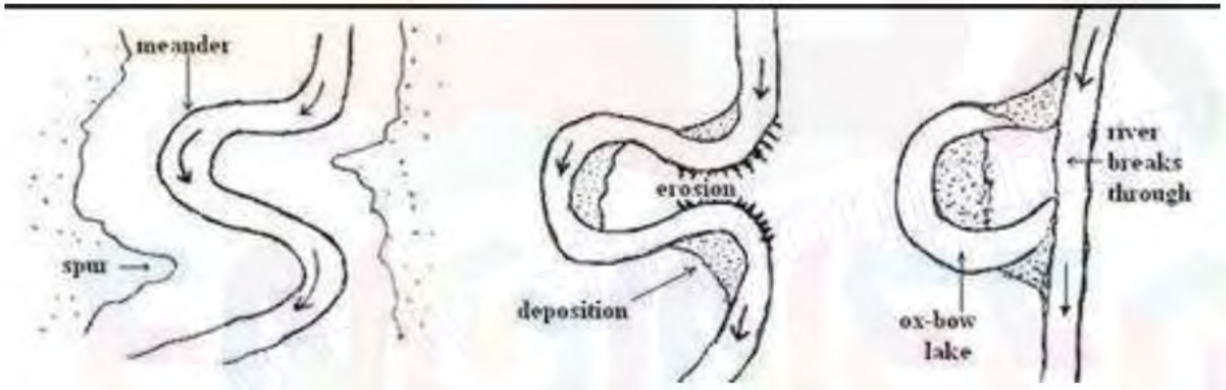
Velocity of stream at the convex bank may be little less than the velocity of the stream on the concave side

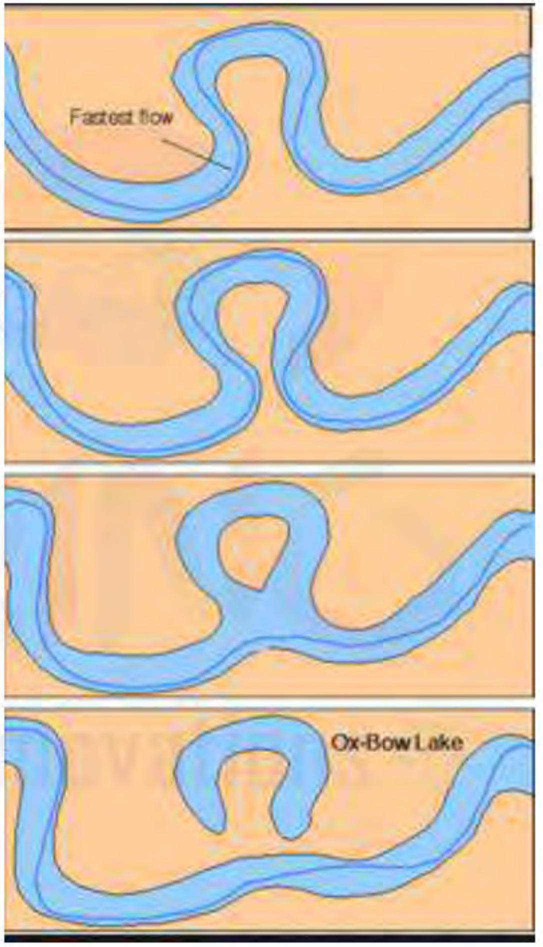


Concave bank – Erosion occurs (high Velocity)

Convex bank – Deposition occurs (low velocity)

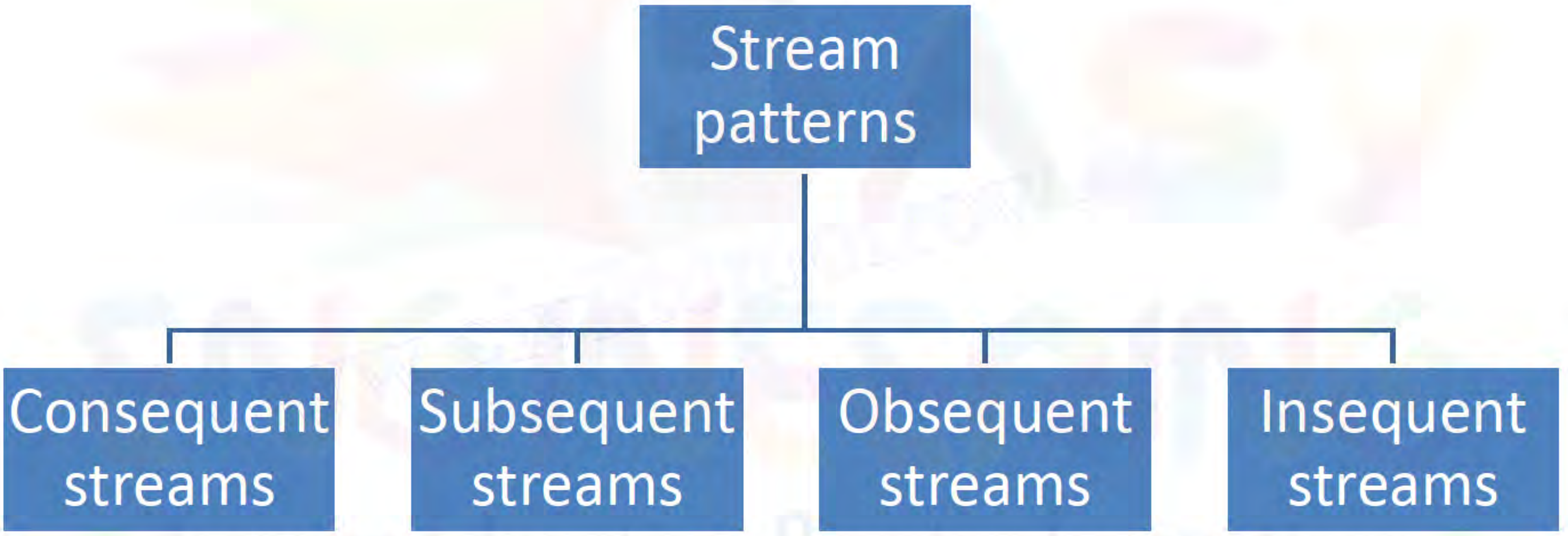
Formation of Ox bow lakes





Stream and drainage patterns

Stream patterns



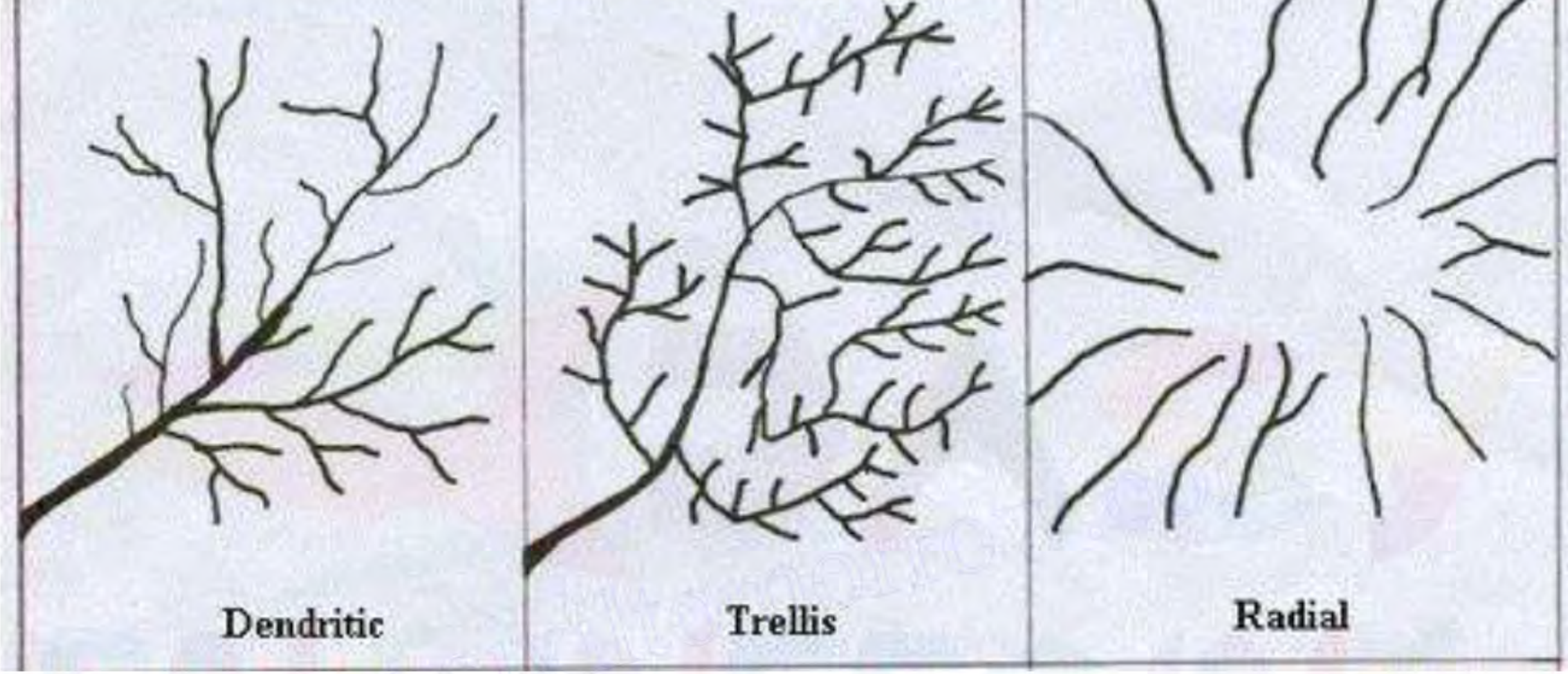
Stream patterns

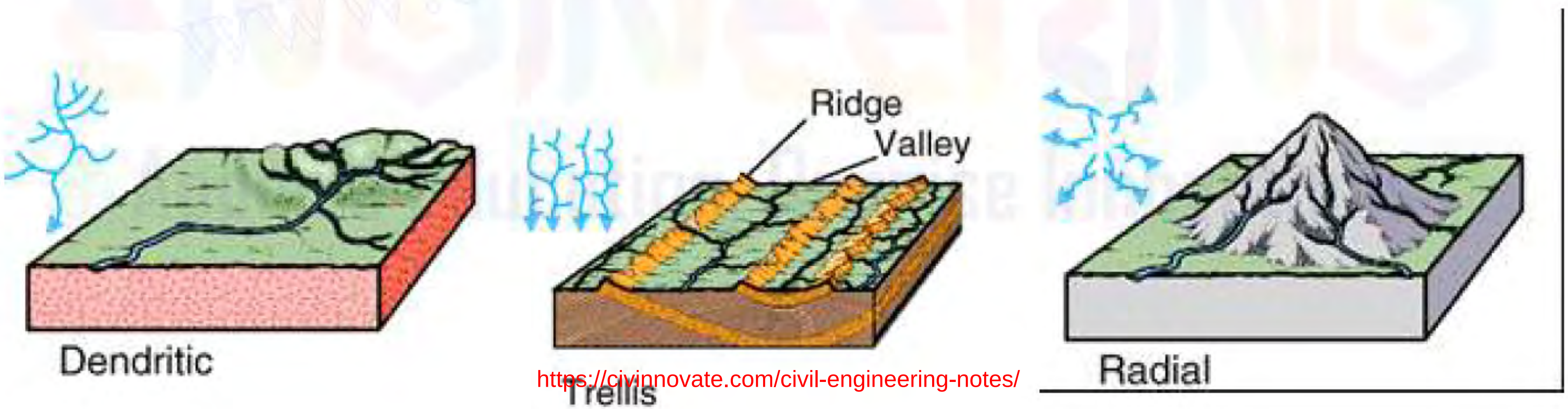
- Consequent streams – First streams developed based on the topography of the area.
- Subsequent streams – These are tributaries of consequent streams
- Obsequent streams – Tributaries of subsequent streams
- Insequent streams – They are called as irregular streams found to flow in channels

Drainage patterns

- The relationship of all these streams with each other and with the region as a whole give rise to the drainage pattern of that area.

1. Trellis drainage
2. Dendritic drainage
3. Radial drainage
4. Superimposed drainage
5. Antecedent drainage

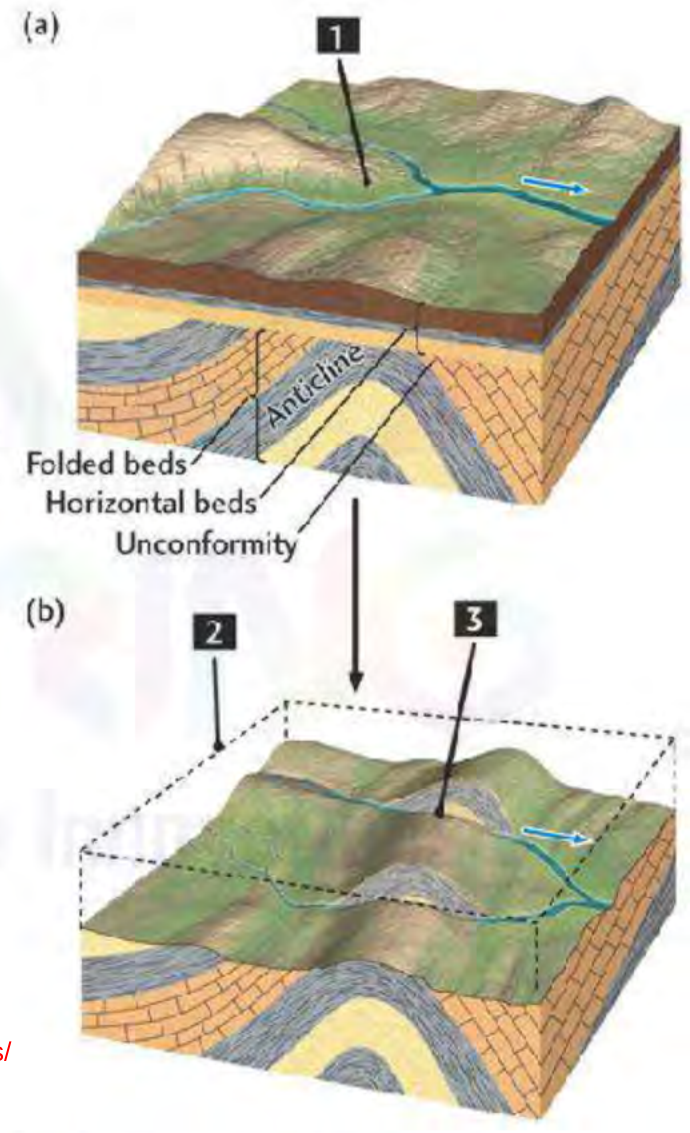

Dendritic
Trellis
Radial


Ridge
Valley
Dendritic
Trellis
Radial

- Trellis drainage – when consequent stream receives a number of subsequent streams from right and left approximately at right angles to its direction of flow.
- Dendritic drainage – when streams of different types (consequent , subsequent , obsequent) are all fairly common in a region
- Radial drainage – This pattern develops in region which are elevated or depressed with reference to topography.

- Superimposed drainage – it is developed in geologically old and complex folded regions.

- Antecedent Drainage - streams flowing over a gradually rising block of crust of the earth form the antecedent drainage



Geological work of sea

- A sea is an extensively developed continuous body of salt water .
- It is well known that about 71 % of the surface of the earth is covered by the oceans and seas.
- The oceans and seas cover an area of about 361 million square kilometer out of 510 million square kilometer of the surface of the entire globe.
- Average depth of sea is generally less than four Km.
- The greatest known depth in the ocean is 11022 meters at the Mariana Trench in the pacific.

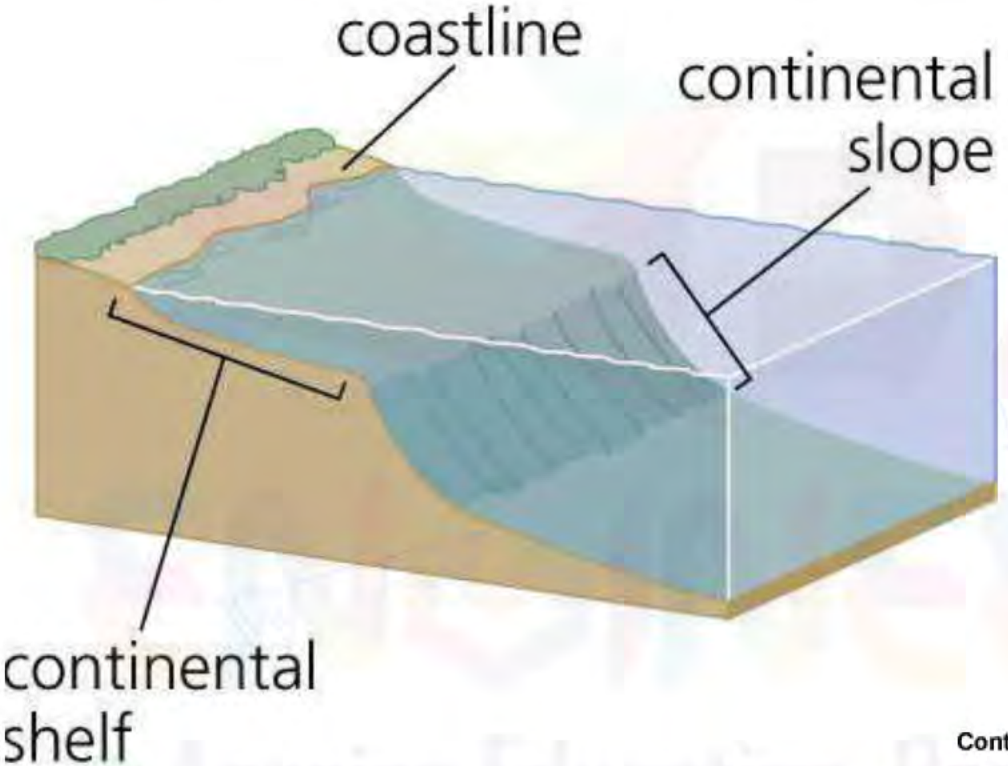
- On the basis of available bathymetric maps, the ocean is divided into definite regions as indicated below:

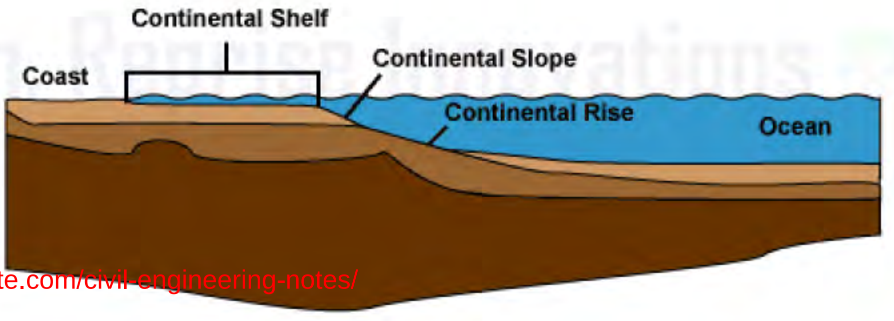
1. Continental shelf
2. Continental slope
3. Abyssal plain
4. Submarine canyons

Terminologies

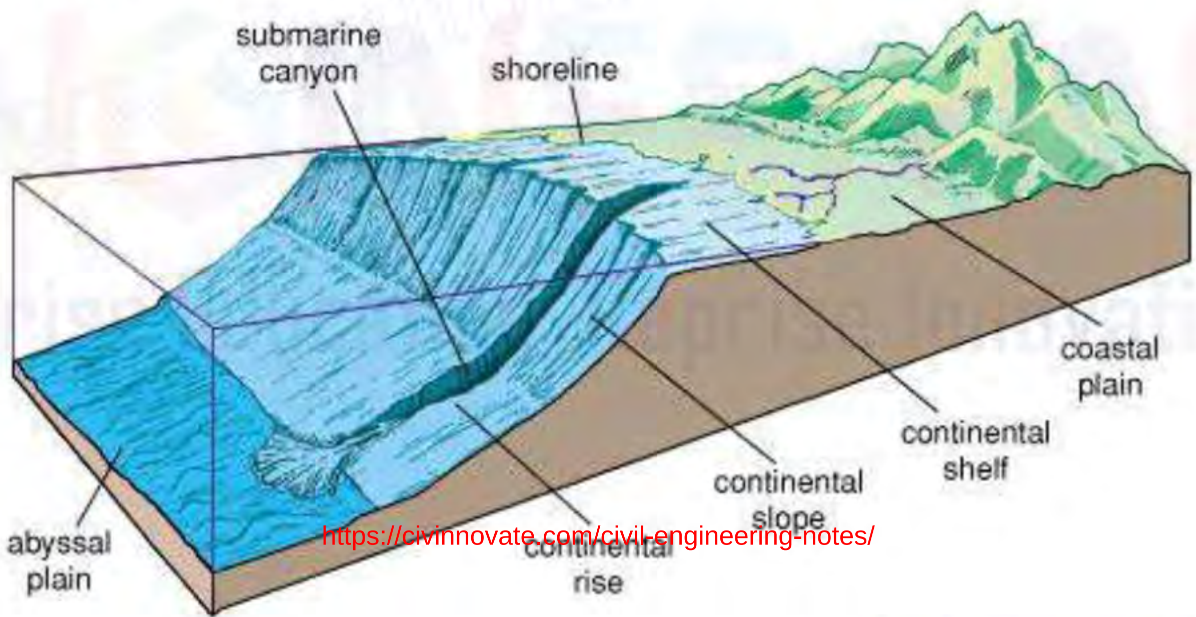
- Continental shelf – Gently sloping land that remains partly submerged under sea water. The slope in a continental shelf is of the order of 1 in 1000 or less.
- Continental slope – Slope starting from the farthest end of the continental shelf and continues up to the sea floor . The gradient varies between 1 in 4 to 1 in 6.

Continental shelf and Continental slope





- Abyssal plain – each ocean is normally characterized with an abyssal plain . It has a gradient of 1 in 1000
- Submarine canyons – These are deep narrow –walled v shaped structures found on slopes of many continental shelves.



The Sea waves and currents

- Waves - Undulatory disturbances on the surface of the seawater due to strong rushing winds, earthquake, attraction of seawater by the sun and the moon, and other similar reasons.
- Two principal types of sea waves distinguished on the basis of shape of orbit are:

1. Oscillatory waves
2. Translatory waves

- Oscillatory waves -These are characteristics of deeper portions of the sea .In such waves, each particle moves in a circular orbit.
- In shallow depths, these particles find it impossible to describe a perfectly circular motion.
- Consequently an oscillatory wave rushing towards the shore breaks at the crest region, giving rise to the so well known **surfs.**

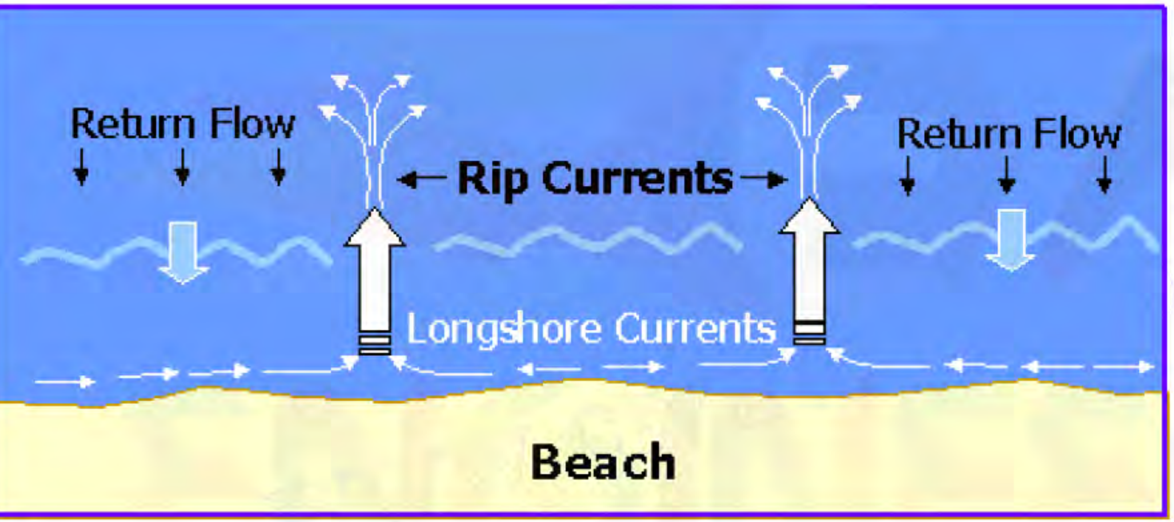
- Translatory Waves: These are typically of shallower depths in the sea and abound along the seashore. They are commonly produced after the oscillatory waves break and rush forward.

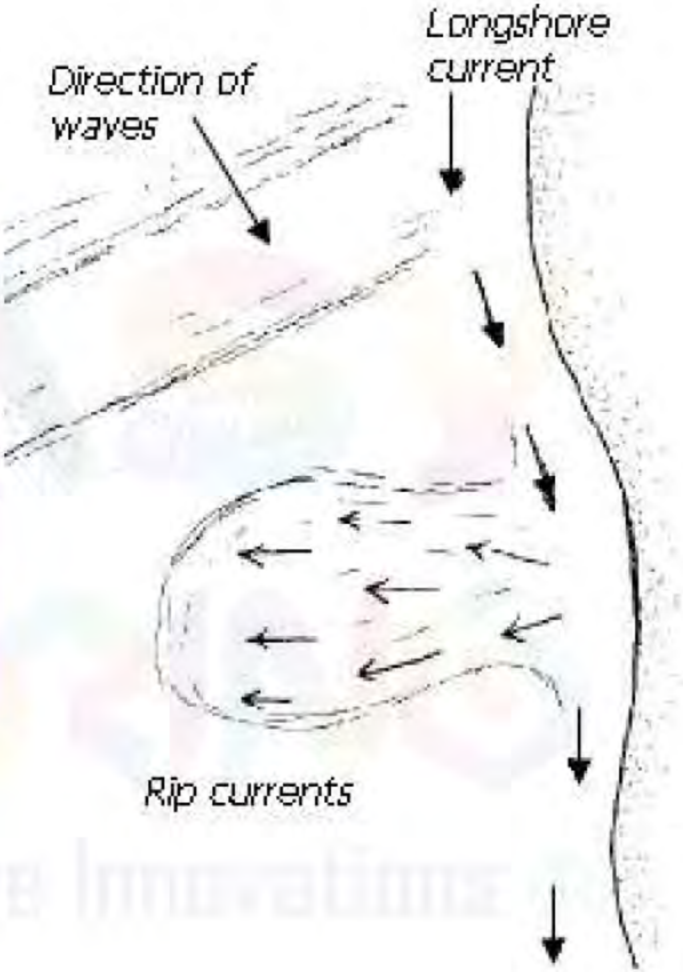
Currents

- These are layers or strips of seawater that are actually pushed forward in any particular direction. Two types are more important in the geological work of sea:

a) Littoral currents: These are bodies of seawater of considerable volume moving along and parallel to the shore.

(b) Rip currents: These are bodies of seawater moving backwards to sea after having reached and struck the seashore. They often move below the surface of the sea and reach varying distance up to the middle of the sea.


Return Flow
Rip Currents
Return Flow
Longshore Currents
Beach


Longshore current
Direction of waves
Rip currents

Marine erosion

- The work of erosion accomplished in three ways: Hydraulic action, Marine abrasion, Corrosion.

  Hydraulic action: This is the process of erosion by water involving breaking, loosening, and plucking out of loose, disjointed blocks of rocks their original places by the strong forces created by the impact of sea waves and currents

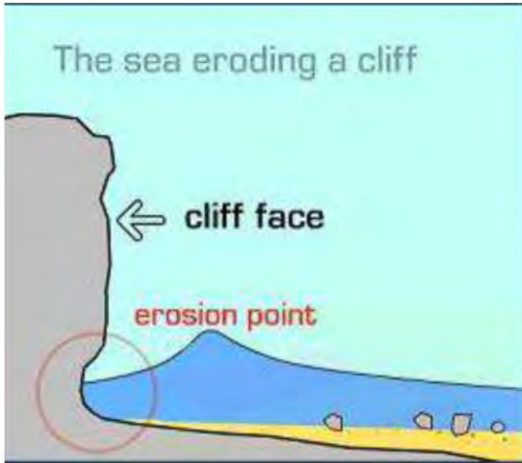
- **Marine abrasion: This involves the rubbing and grinding action of seawater on the rocks of** the shore with the help of sand particles and other small fragments that are hurled up again and again against these rocks.
- **Corrosion: It is the solvent action of seawater , which is particularly strong in environment** where the shore rocks is of a vulnerable chemical composition.

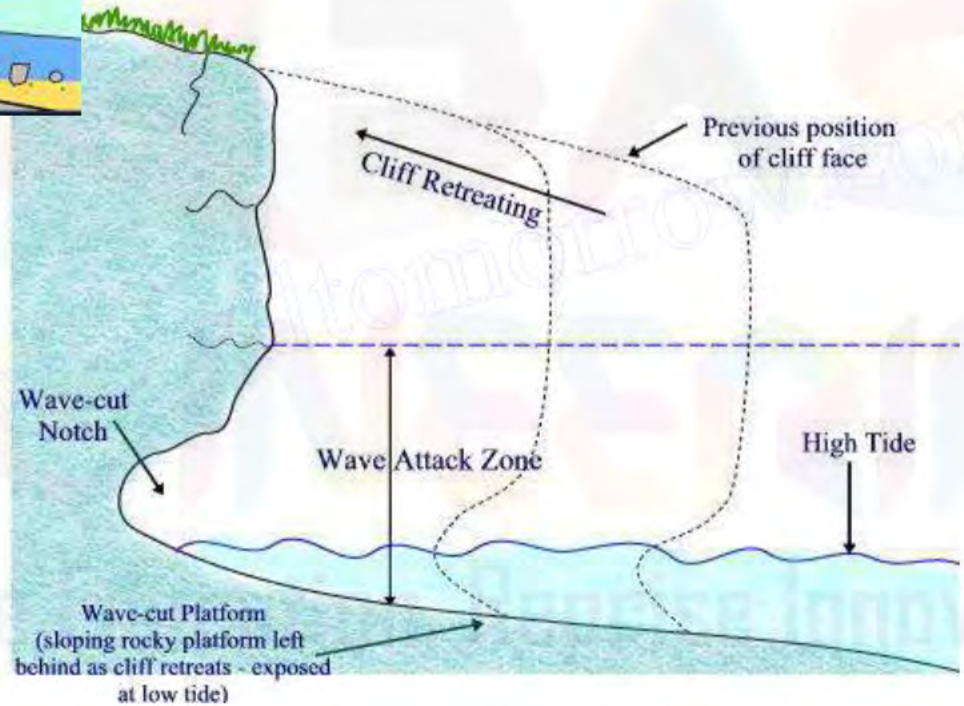
Features of marine erosion

- Headlands and bays
- Sea cliffs
- Wave cut terraces

- **Sea Cliffs**

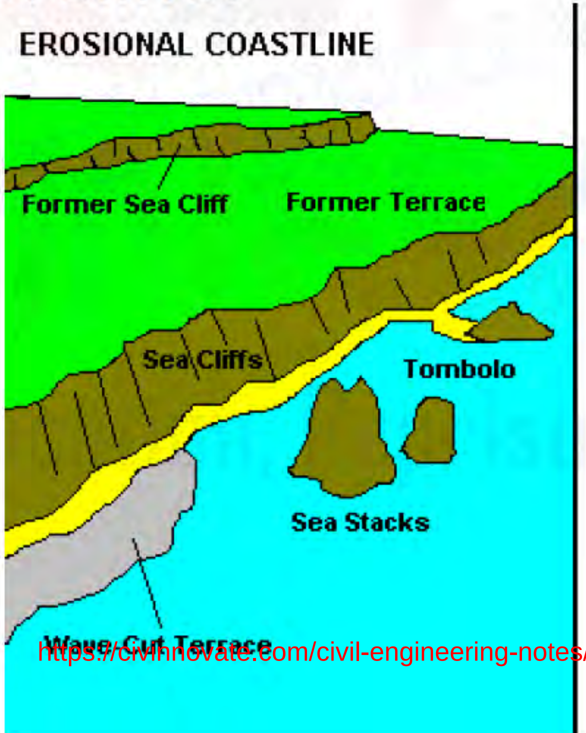
  When the sea erodes an area of high ground to create a vertical face of rock or other material a cliff is formed. The sea creates a 'notch' at the base of the cliff causing the cliff to eventually collapse.


The sea eroding a cliff
cliff face
erosion point


Previous position
of cliff face
Cliff Retreating
Wave-cut
Notch
Wave Attack Zone
High Tide
Wave-cut Platform
(sloping rocky platform left
behind as cliff retreats - exposed
at low tide)

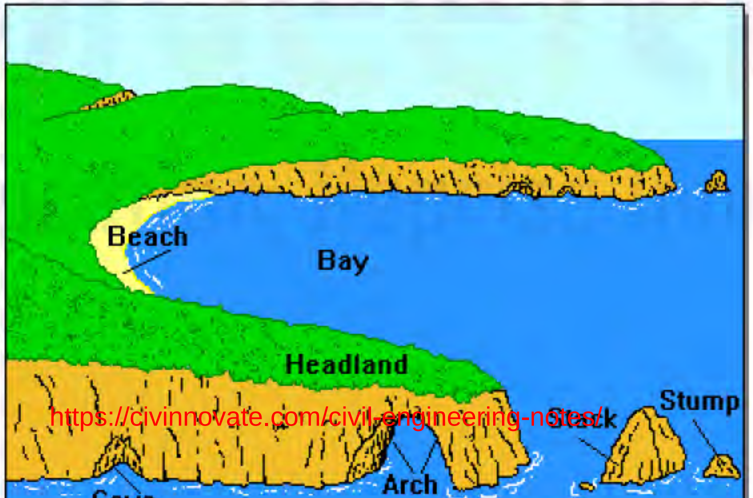
Wave cut terraces

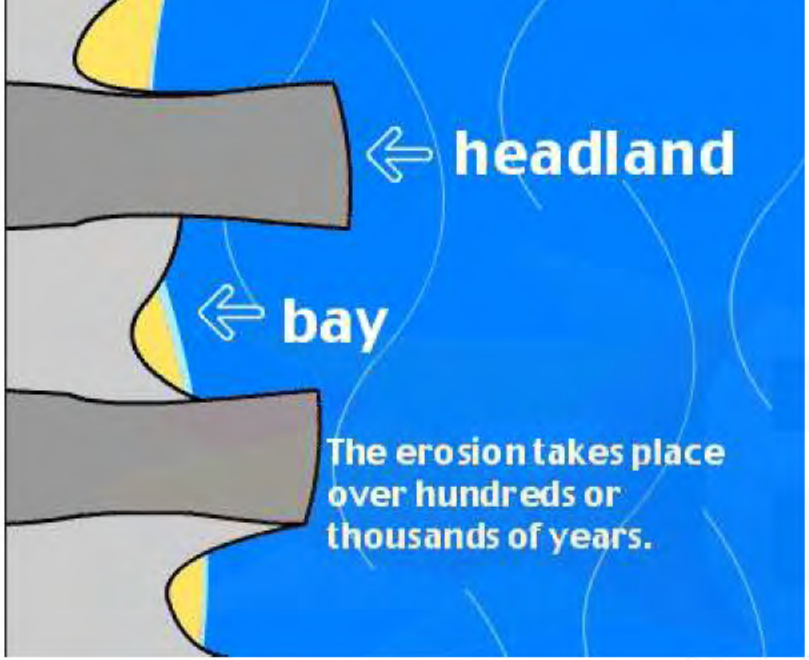
- This is an area of relatively flat rock at the base of the cliff which has been created by the retreating shoreline.



Head lands and bays

- If there are areas of soft and hard rock along the coastline the sea erodes the softer rock more quickly than the harder rock. This creates a wide inlet known as a bay. The harder rock is less affected by the erosion of the sea and remains as a headland.




headland
bay
The erosion takes place
over hundreds or
thousands of years.

Marine Deposition

Marine deposits are classified into two groups

1. Shallow water deposits – Marine deposits laid down in neritic zone of sea. Common examples of neritic deposits are : beaches ,spits and bars , tomboles
2. Deep water deposits – These deposits consists mostly of mud and oozes.

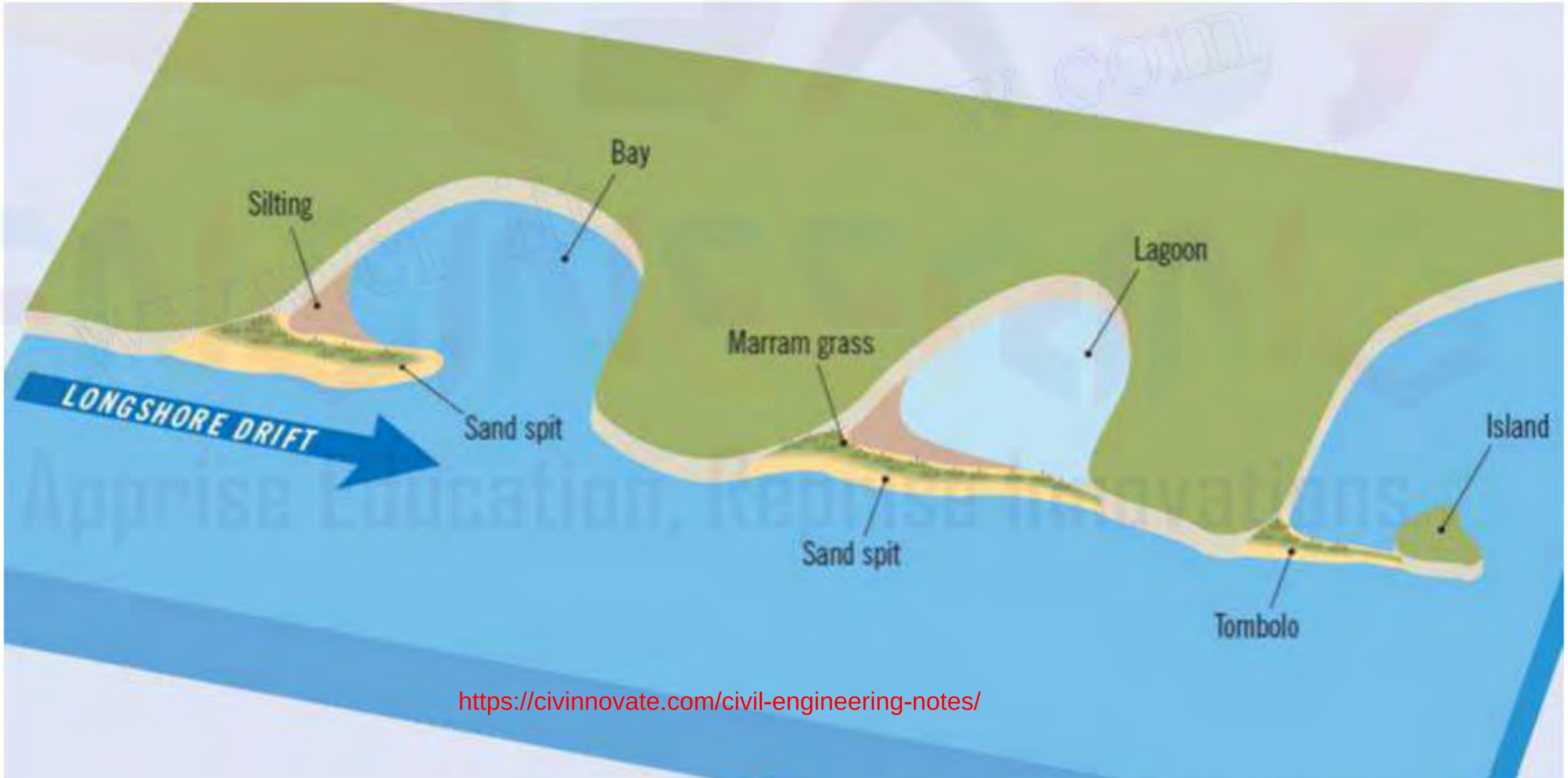
Beaches

- A beach is an accumulation of sand, shingle or rock between the high tide mark and low tide mark. A beach forms if the incoming wave (Swash) is stronger than the out-going wave(Backwash)

Spits and bars

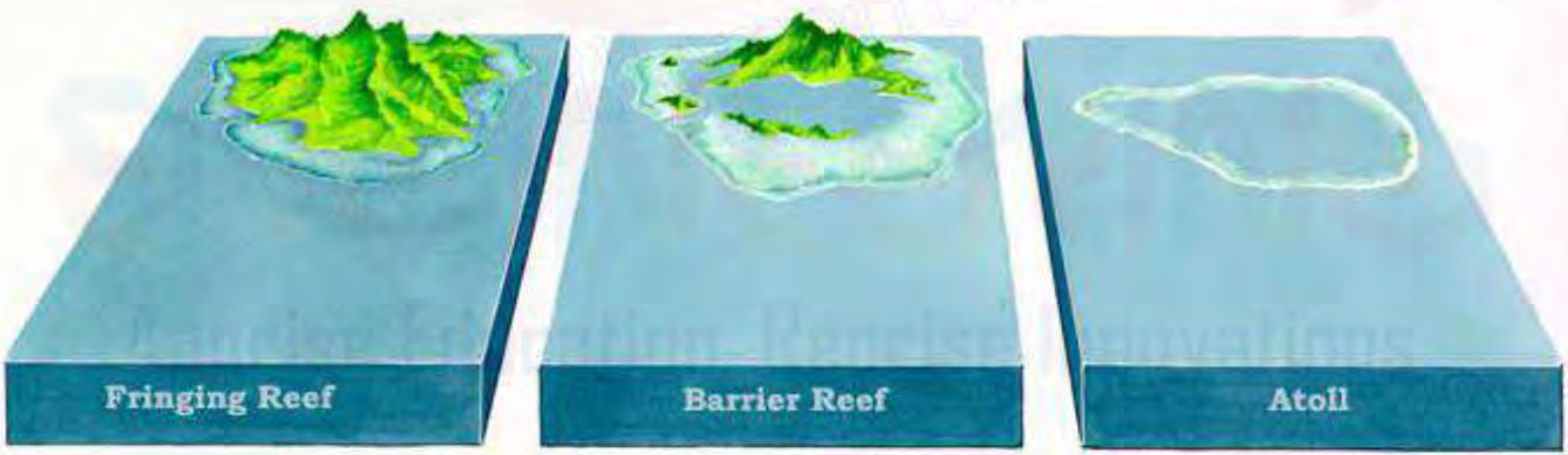
- A spit is a finger of land which grows out from the mainland, it is formed from sand and mud and other material deposited by the waves.
- A sand bar is formed when a sand spit grows across the mouth of a bay and cuts it off from the sea. The area of enclosed water becomes known as a lagoon.
- A tombola is formed when a sand spit links an off-shore island to the mainland.


Bar
Spit
Tombolo
Cuspate
foreland


Bay
Silting
Lagoon
Marram grass
LONGSHORE DRIFT
Sand spit
Island
Sand spit
Tombolo

Coral reefs

- These are deep water deposits ,Formed due to accumulation of dead parts of sea organisms.



Shore control problems

- Areas close to seashore are always subject to continued action of sea water.
- Some of the areas have to be protected from damaging action of the sea water.
- Sea beaches are most attractive tourist spots , they have to be maintained in their natural shapes for retaining their attraction.
- Ports are established at the sea shores are in close contact with marine waters and open to damaging action from them.

- Two main aspects of shore control problems are

1. Rehabilitation and stabilization of beach areas
2. Control of water traffic difficulties

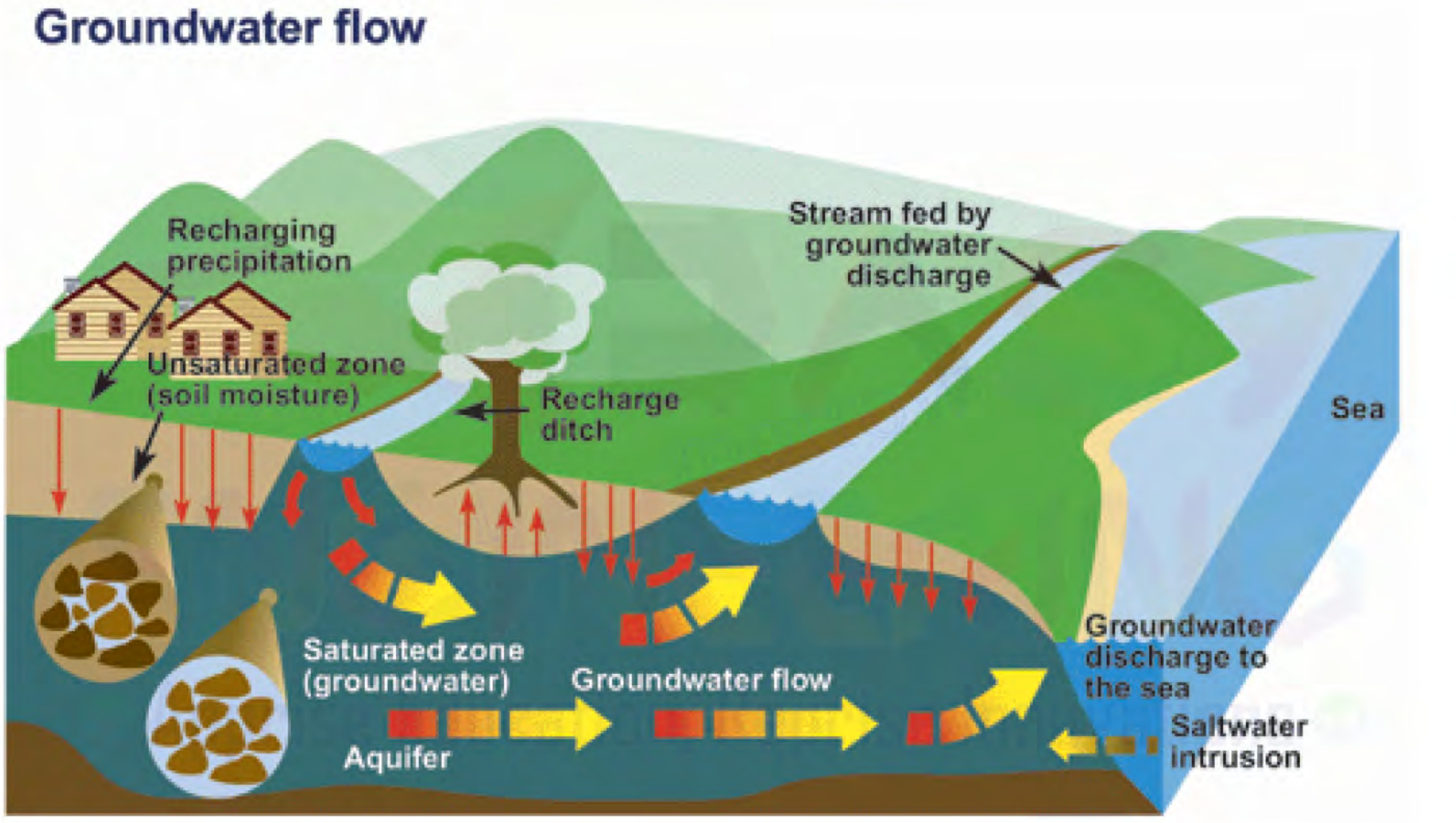
For arriving a satisfactory solution of such problems , a thorough knowledge of marine geology of area is necessary.

1. Source and nature of beach materials
2. Rate of supply and loss of sediments from the area under investigation
3. Mechanism of transport of material from the source to the beach and from beach to the adjacent areas.

Geological work of ground water

Ground water

- Ground water is the under ground water that occurs in the saturated zone of variable thickness below the earth surface.
- Ground water is also a very powerful natural agent responsible for modifying and creating many geological features on and below the surface of the earth.



https://civinnovate.com/civil-engineering-notes/

Geological work of ground water

1. Chemical work (important)

2. Mechanical work

Chemical work of ground water

- Water is a great solvent
- It can dissolve many rocks – lime stone , dolomite , gypsum , rock salt during its downward journey below the surface.
- Carbonated water dissolves upto 150 mg / l of limestone
- Gypsum – 2 to 3 g /l

Factors controlling dissolution of soluble rocks

1. Climate
2. Geological structure
3. Topography
4. Porosity
5. Permeability of rocks
6. Composition of rock
7. Composition of ground water
8. Flow velocity
9. Temperature
10. Pressure
11. Depth at which water comes in touch with the rocks

- The features resulting from this type of action of ground water are complex in nature.
- These collective effects were best studied first in the KARST region of YUGOSLAVIA which was named as **Karst Topography**.

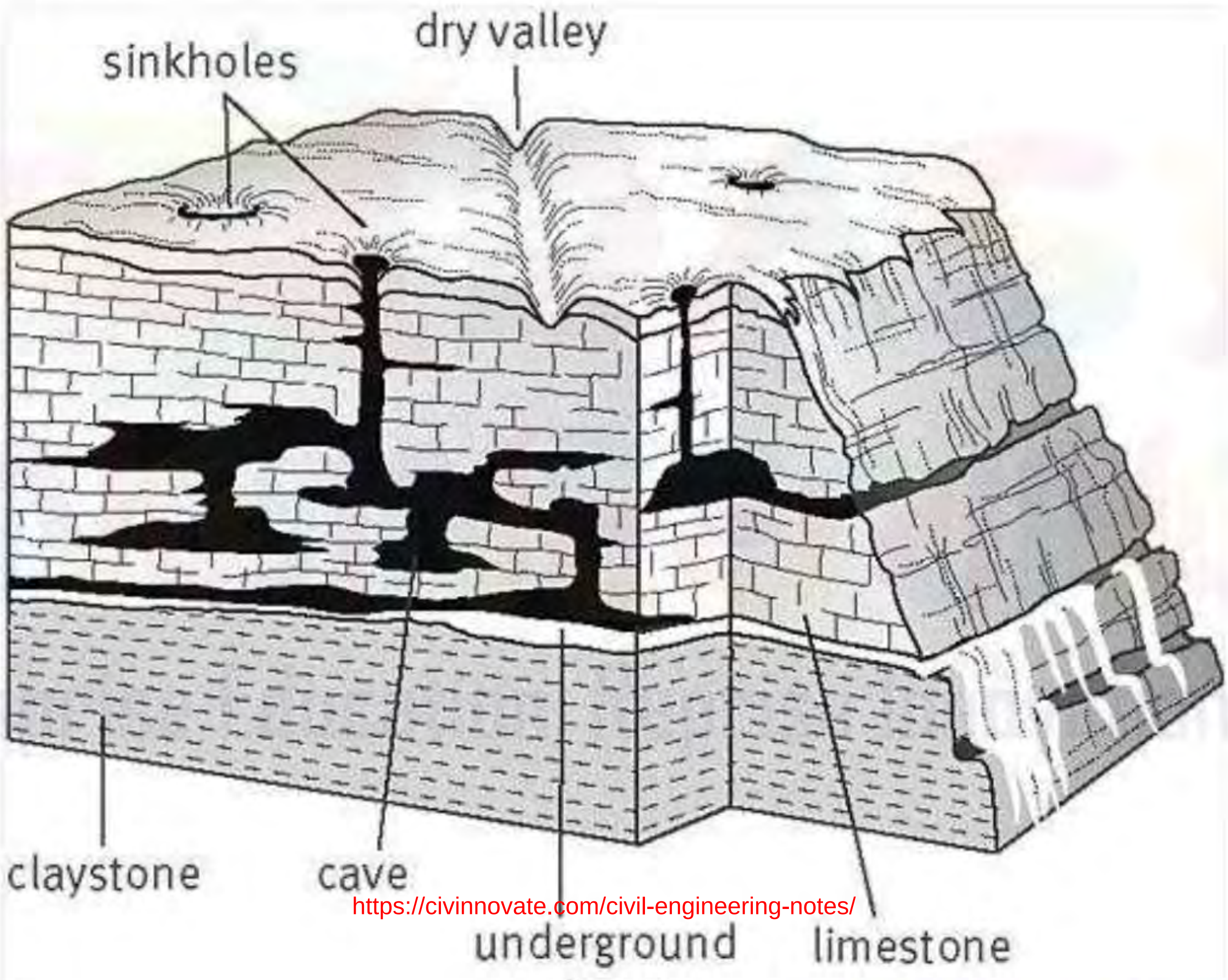
Typical features of Karst Topography

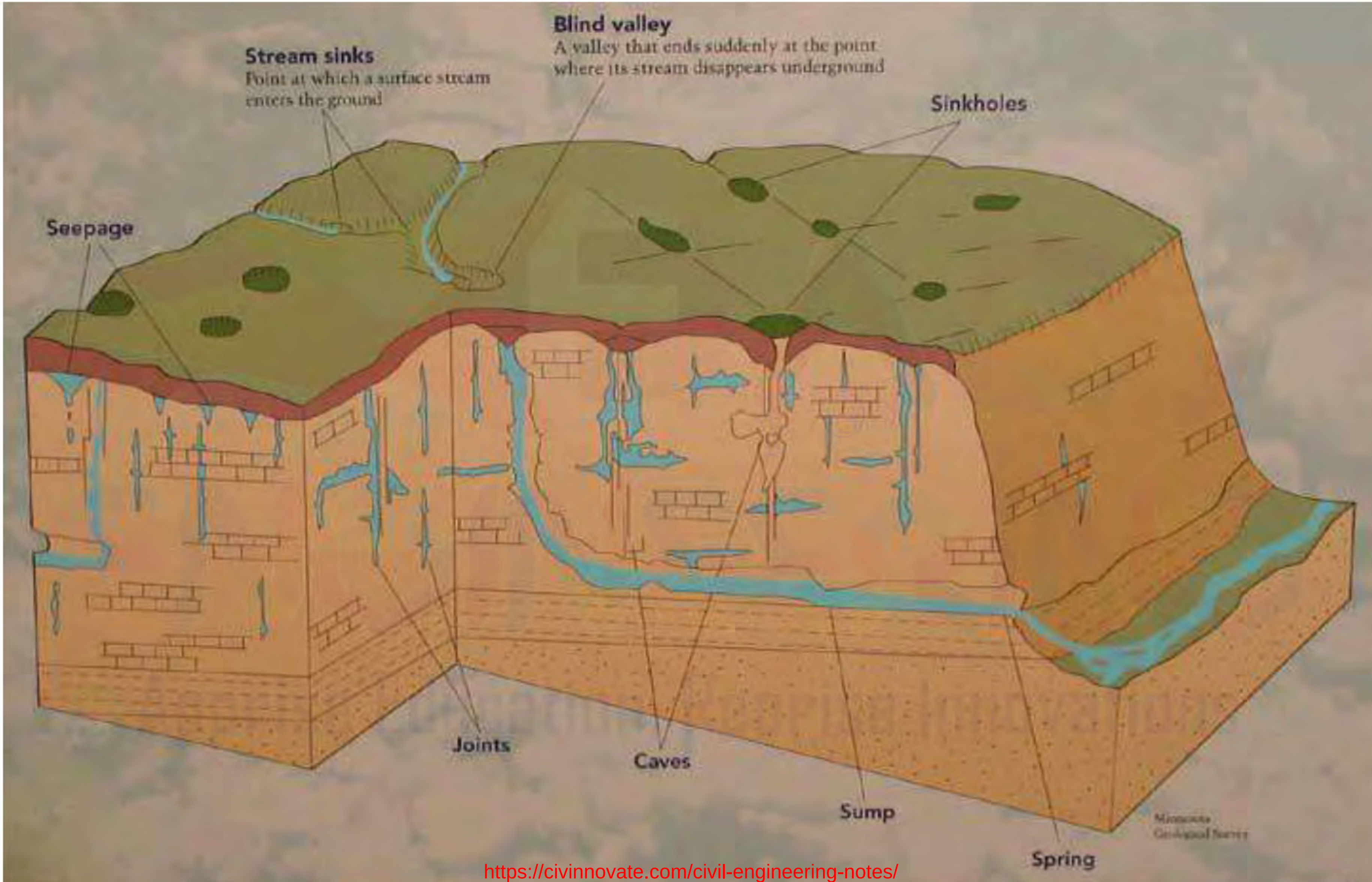
- Disorderly distribution of landforms
- Highly irregular and intermittent stream flows (frequently disappearing and often reappearing at different places)
- Abundance of dry valleys , Marshy and swampy low lands

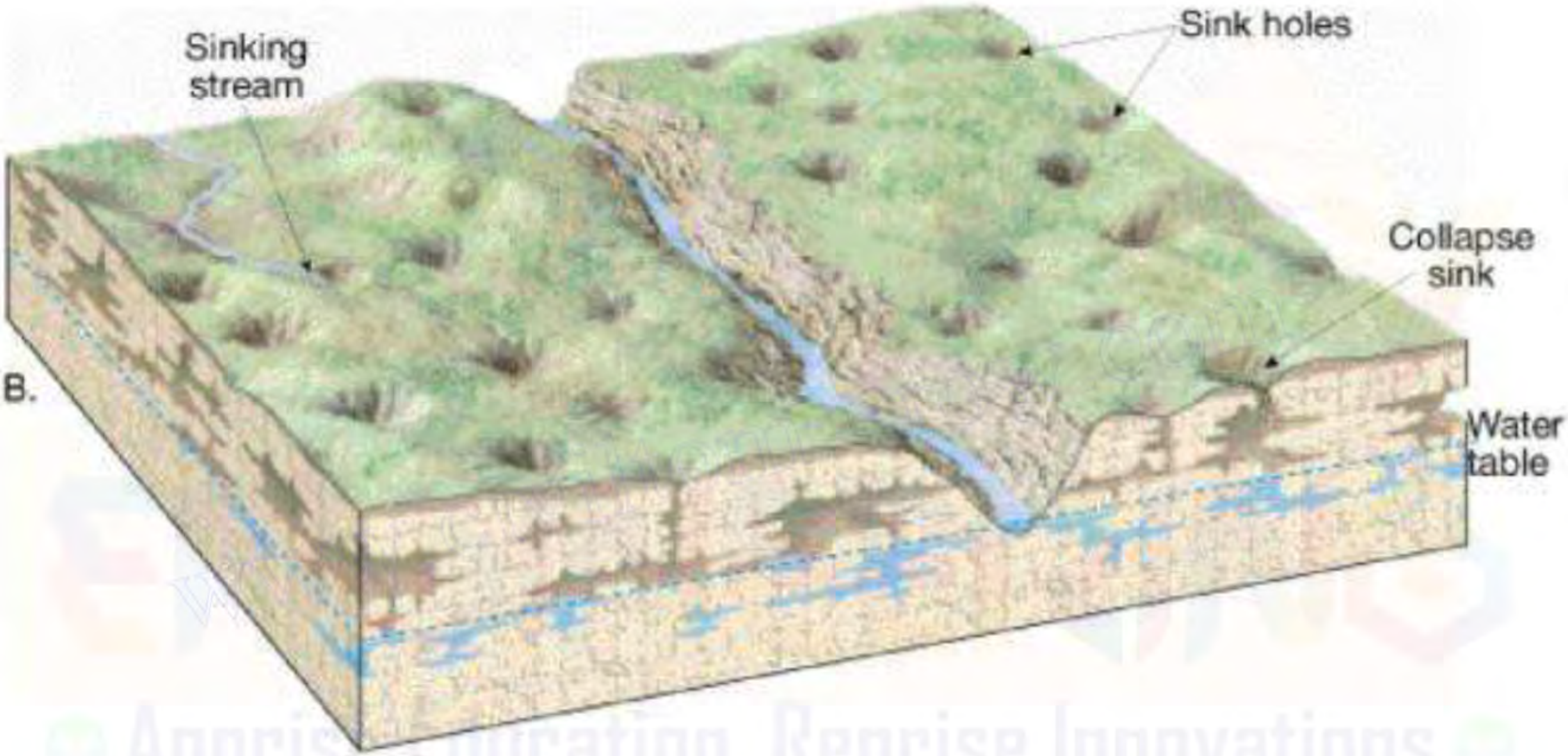
- Numerous depressions , hollows , openings , caves , natural tunnels and basins some of which may be containing water.

- A **centripetal drainage** (streams from different directions flow towards a common central basin)

Karst Topography




Blind valley
A valley that ends suddenly at the point where its stream disappears underground
Stream sinks
Point at which a surface stream enters the ground
Sinkholes
Seepage
Joints
Caves
Sump
Spring


Sinking stream
Sink holes
Collapse sink
B.
Water table

- Karst is distinguished as

1. Bare karst – solution forms are exposed on the surface
2. Covered karst – rocks affected by solvent action are under a thin cover of insoluble rock
3. Subjacent Karst – cover over the affected rocks is thick.

Forms developed due to solvent action of water in Karst region

1. Dolines

2. Caves

3. Blind valleys

Dolines

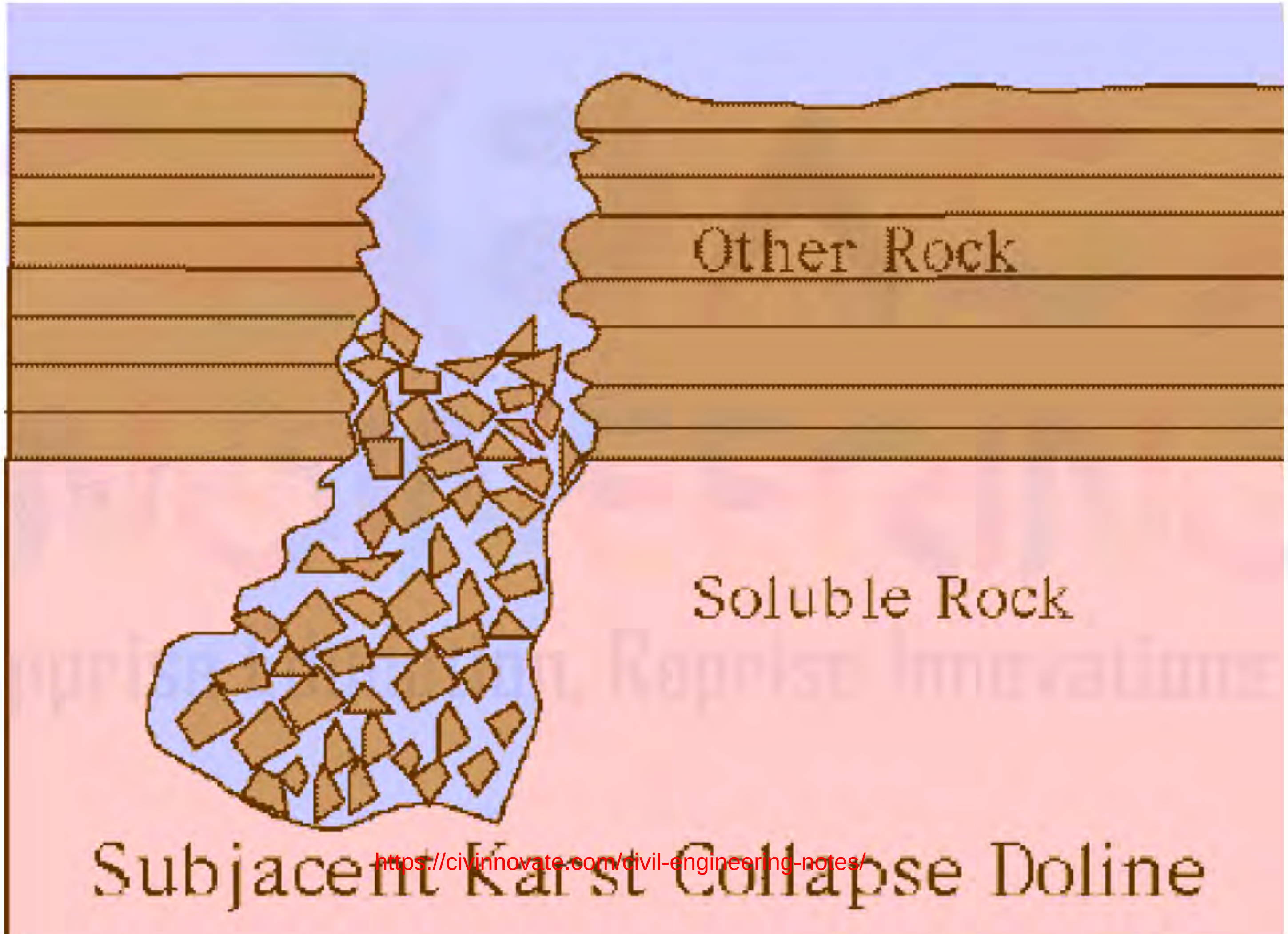
- They are also termed as swallow holes , sink holes.
- It has **circular or oval depression**, which in depth becomes bowl –shaped or cylindrical in cross section.
- These depressions are very often dry but may form **temporary lakes** in other cases.

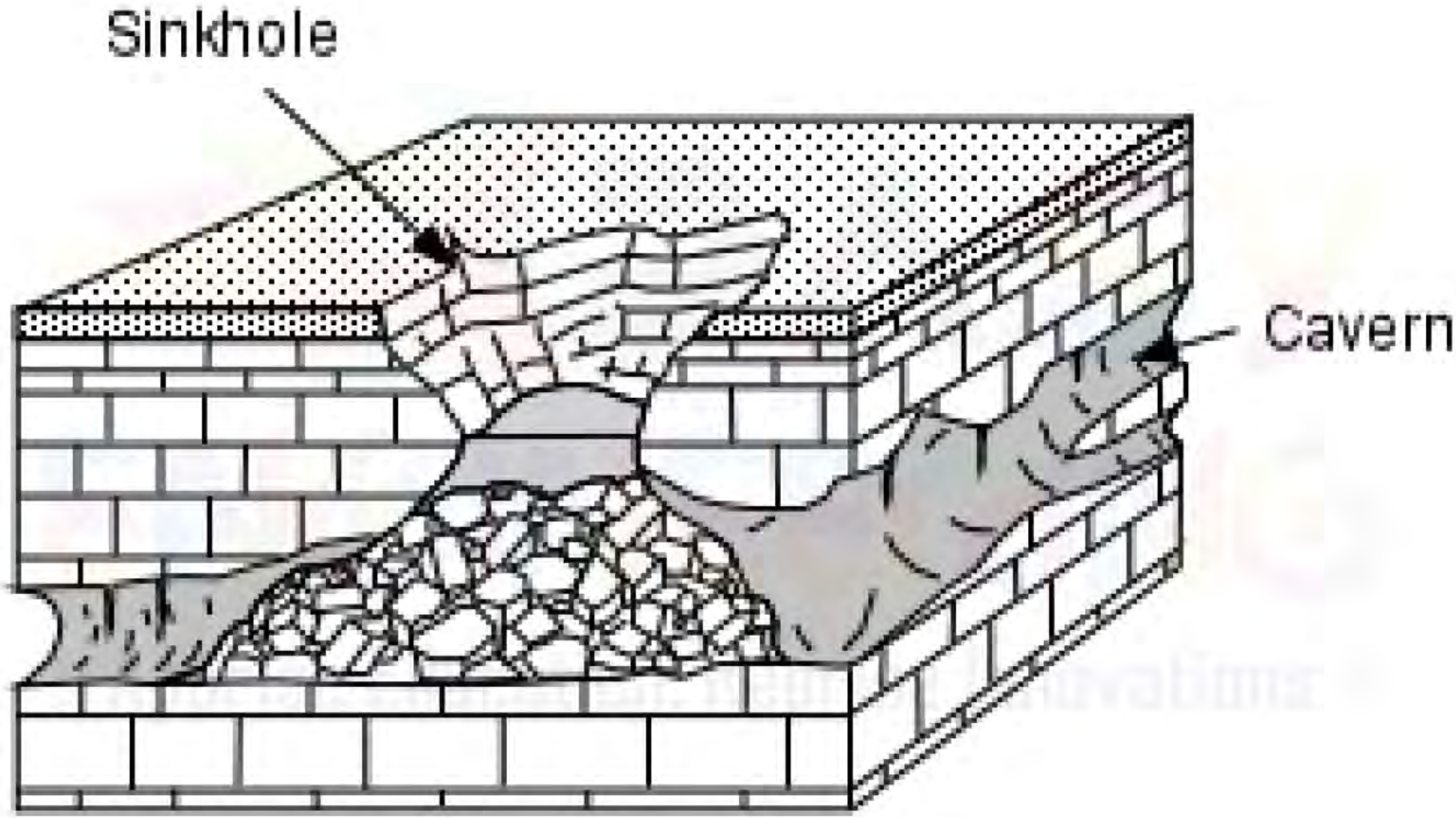
- Dolines may be formed by two causes :

1. **Due to solvent action of water** ; in this process the rock is gradually dissolved and removed part by part , leaving a depression

2. **Due to collapse of surface rocks** ; they are obviously called as collapse dolines. Roofs of caves will collapse when all the support below has been dissolved by ground water.

Surface collapse of rocks – collapse doline




Sinkhole
Cavern

Dolines in clusters

Caves

- Naturally carved out underground cavities of various dimensions.
- Caves are similar to tunnels
- Caves do not have an exit where as tunnels has an entry at one end and exit on the other end.
- In caves entry point is much smaller and narrower

- The cavity inside the cave extends from a meter to hundreds of kilometers.
- Most caves are single chambered , they have only one cavity
- Multi chambered caves – all chambers being generally interconnected.

Examples of caves

- Most famous cave of the world – Mammoth cave in Kentucky , United states
- Its length is 250 kms and has 200 chambers
- In India , natural caves of shri Amar nath cave in Kashmir and Vaishnodevi cave in jammu are famous

- Favourable conditions for formation of caves are

1. Thick formations of soluble rocks like limestones
2. Sufficient supply of ground water for long time
3. Adequate natural drainage for the water.

Blind valleys

- Blind valley is a valley like feature where a stream flowing through it in the upper reaches suddenly disappears in the lower reaches.

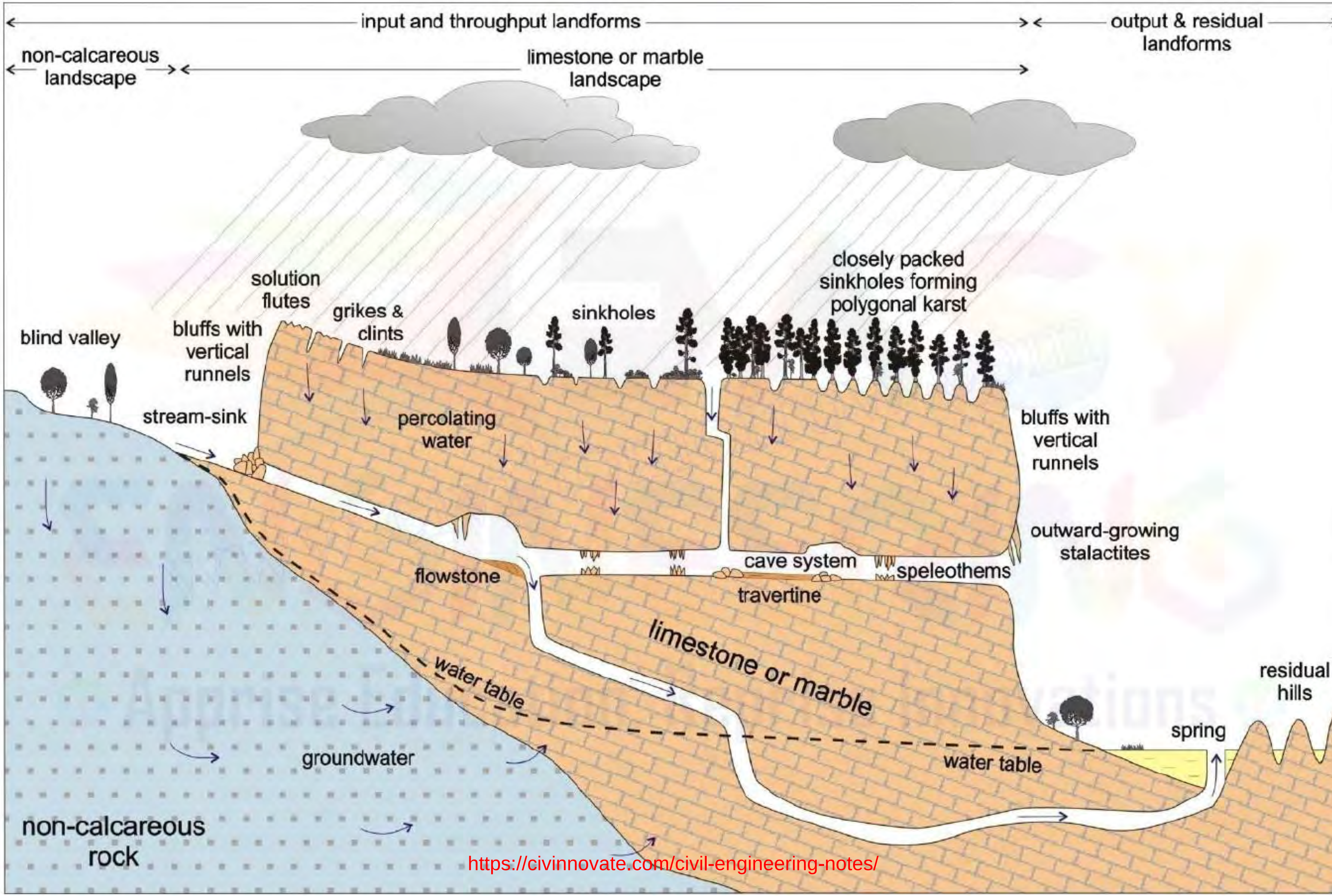
- This happens when the stream takes a dip into an underground channel at a particular place along its course.

rainwater
carbon dioxide dissolves into water
cracks in limestone
soil
limestone
volcanic rock
disappearing stream
limestone
cave
spring
volcanic and sedimentary rock

- That particular place may be a partly collapsed roof of a cave

- Stream flow downwards in cave and then reappear far down from the place of disappearance.

- Formation of blind valley is by the presence of **caves , do lines , underground channels**


input and throughput landforms
output & residual landforms
non-calcareous landscape
limestone or marble landscape
solution flutes
grikes & clints
sinkholes
closely packed sinkholes forming polygonal karst
blind valley
bluffs with vertical runnels
stream-sink
percolating water
bluffs with vertical runnels
outward-growing stalactites
cave system
speleothems
flowstone
travertine
limestone or marble
water table
water table
residual hills
spring
groundwater
non-calcareous rock

Replacement Action

- when ground water percolates through the rocks , the rocks loses some of their constituents to the ground water molecules taking in return some component from the ground water.

Example of replacement action

- When **ground water percolates over a fossil wood** , wood cells may be replaced by silica molecules converting the fossil wood into silicified wood. This process is called **petrification**

Deposition by Ground water

- Ground water is an active agent of deposition
- Deposits are found to occur in caves & other underground openings.
- Minerals very often deposited from ground water are calcite , silica , fluorite , barite

- Two commonly known cave deposits are

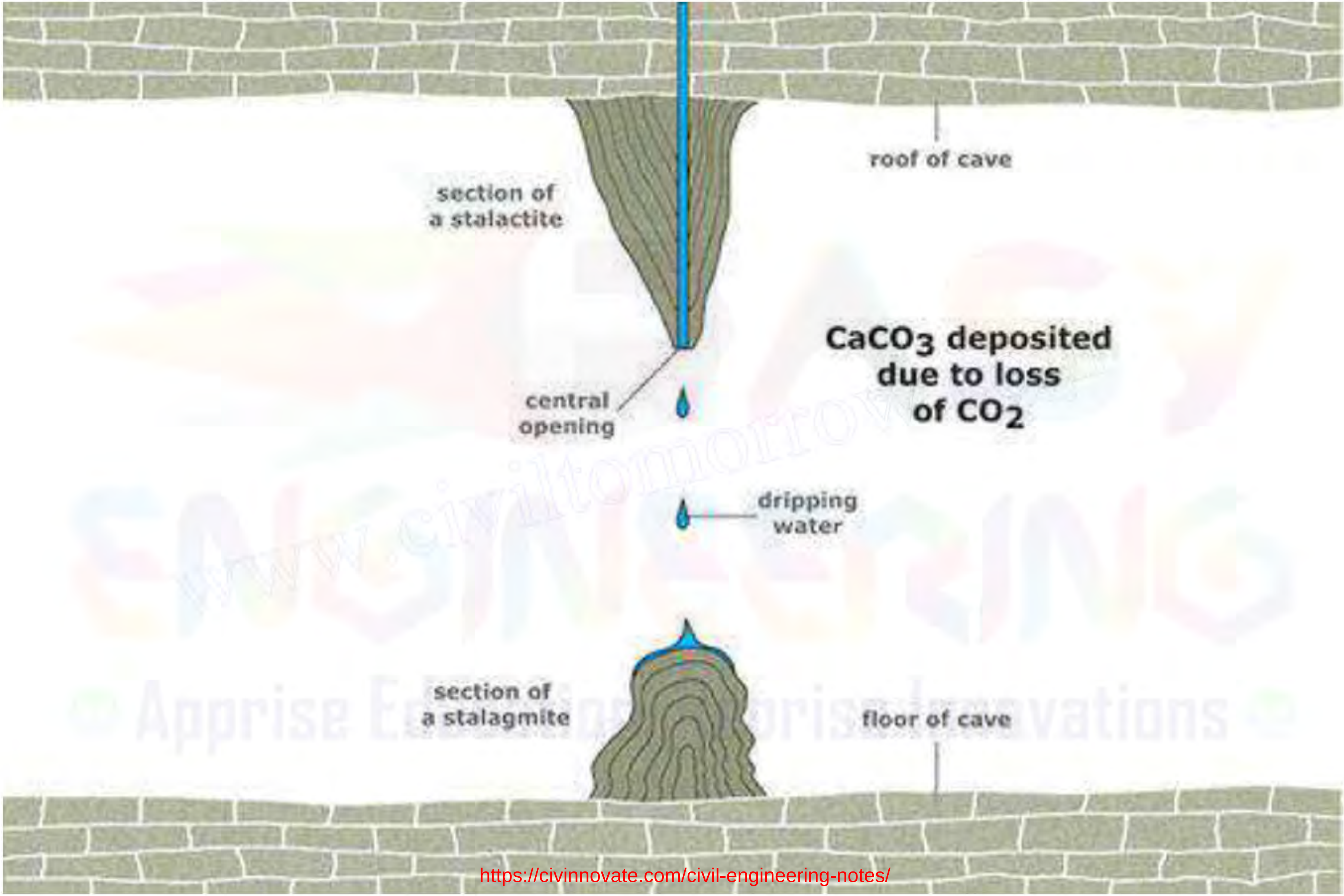
1. Stalactites
2. Stalagmites

Stalactites

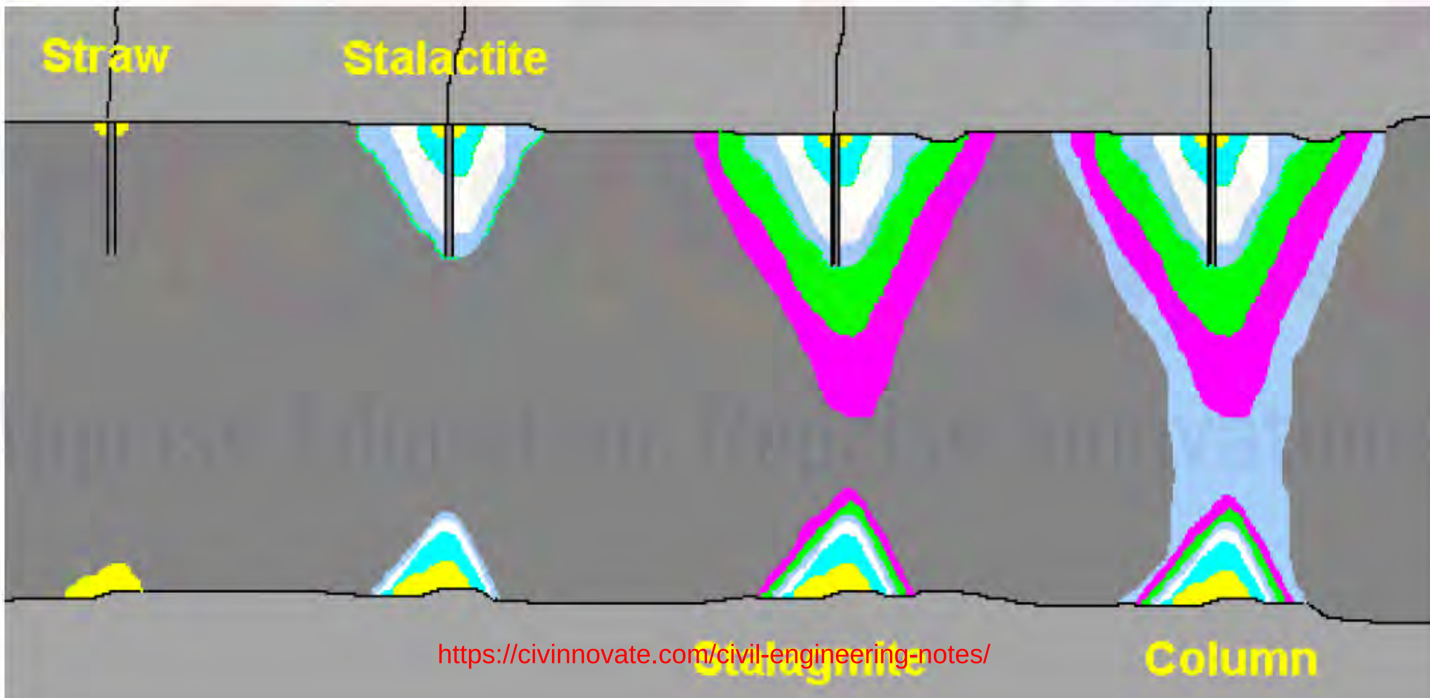
- They are carbonate projections that hang down from the roof of cave
- They acquire shapes like slender rods and cones with flattened bases attached firmly with roof
- It may project for any length even almost touching the floor of cave

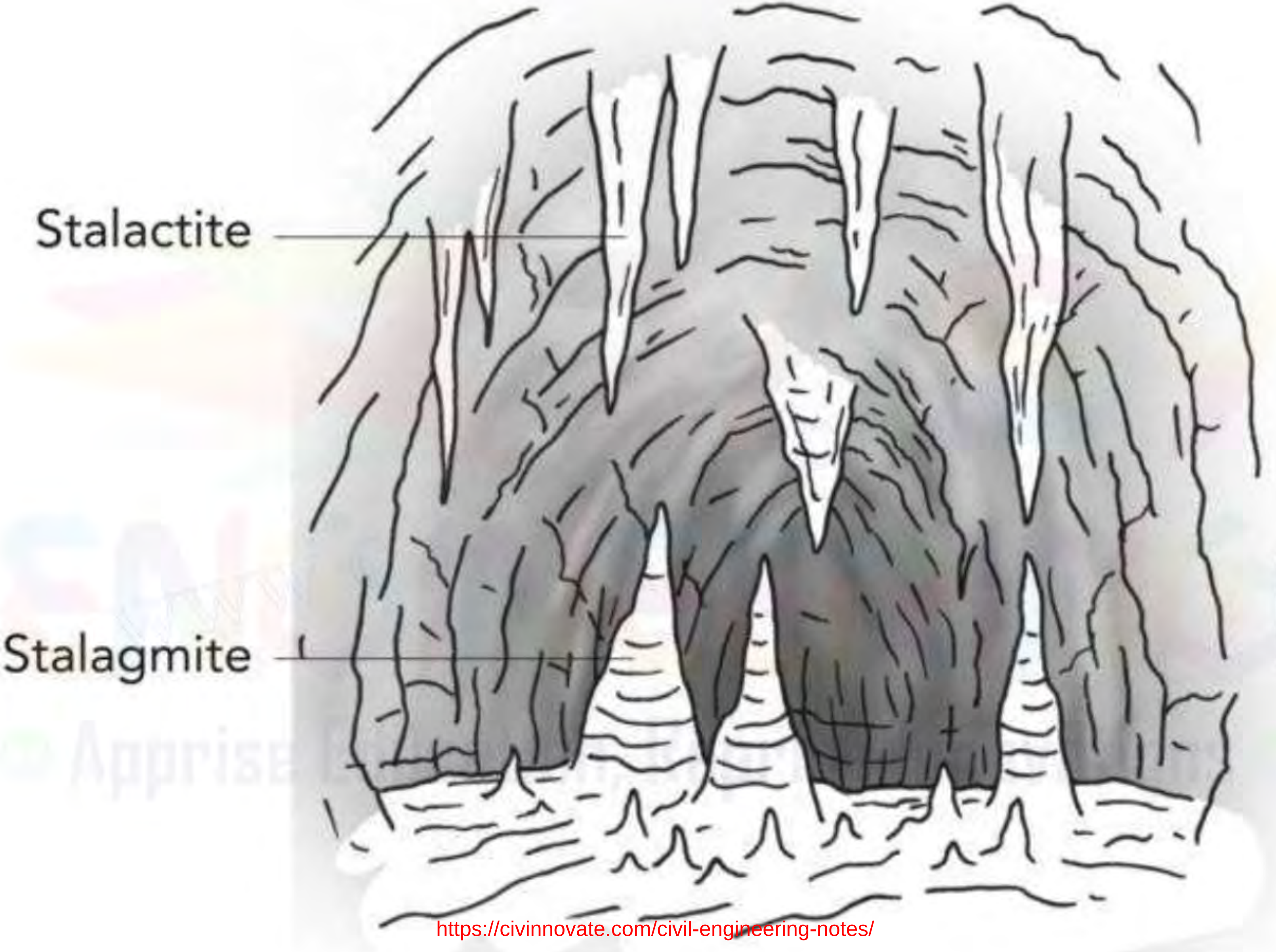
Stalagmites

- These are also ground water deposits formed by deposition from carbonate rich droplets from ground upwards.
- The **dripping water loses dissolved carbon dioxide** when it falls down and it deposits calcium carbonate at the floor of the cave.
- The deposit grows upwards getting **thicker** and it may touch the roof of the cave


roof of cave
section of
a stalactite
CaCO$_3$ deposited
due to loss
of CO$_2$
central
opening
dripping
water
section of
a stalagmite
floor of cave

- In some cases, stalactites and stalagmites join together anywhere in the cave forming pillar & slender columns of these deposits.




Stalactite
Stalagmite

- Ground water emerging on the surface as springs & geysers may be actually deposit salts.
- Two common examples are

1. Travertine (precipitated calcium carbonate)

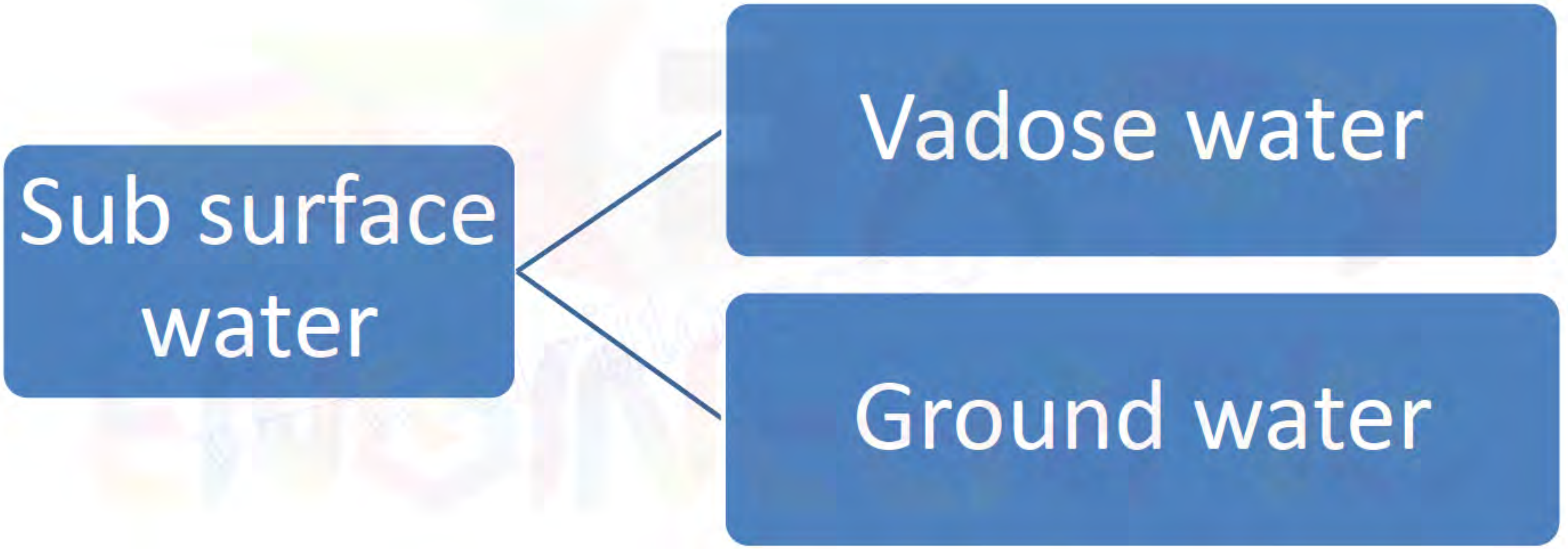
2. Siliceous sinter (Precipitated silica)

Mechanical work

- Velocity of sub surface water flow is much less compared to surface water.
- When the flow is in the form of gliding droplets, moving along the rocks it may lubricate the surfaces and it decreases the strength parameters resulting in **sliding & failure , ground subsidence.**

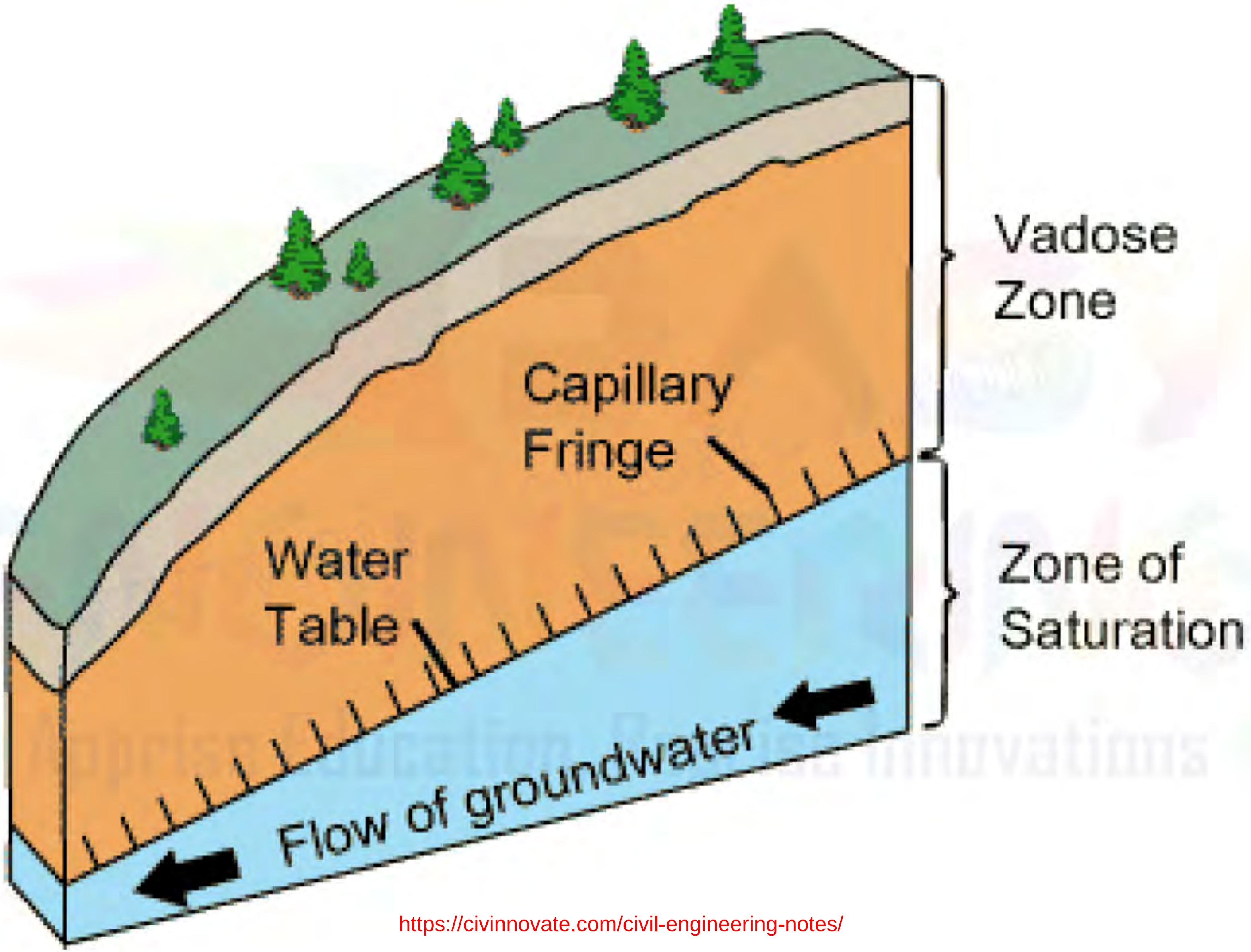
- While flowing in sub surface channels , **water behaves almost the same way as on the surface** in its mechanical work.

Ground water Occurrence


Sub surface water
Vadose water
Ground water

Vadose water

- The water which occurs in the zone of aeration or unsaturated zone is called vadose water.
- In the zone of aeration , the soil and rocks remain unsaturated with water.
- Water moves to the zone of aeration by **Infiltration**



Vadose
Zone
Capillary
Fringe
Water
Table
Zone of
Saturation
Flow of groundwater

Groundwater

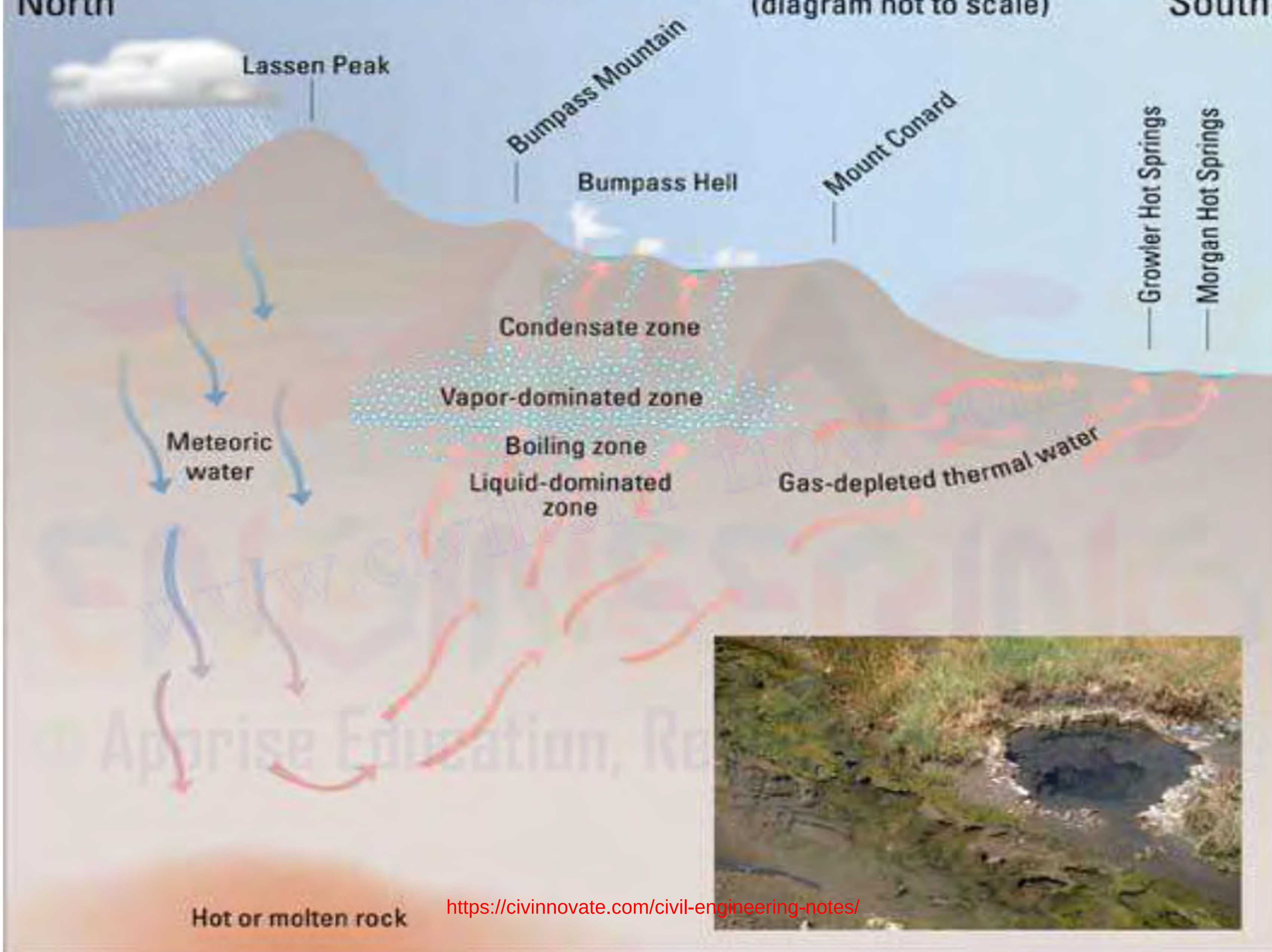
- Water which occurs in the fully saturated rock bodies (aquifers) is called ground water.
- The water moves to the saturated zone by the process of **percolation.**
- Water table is the upper surface of the saturated zone.

Sources of ground water

- Meteoric water
- Connate water
- Juvenile water

Meteoric water

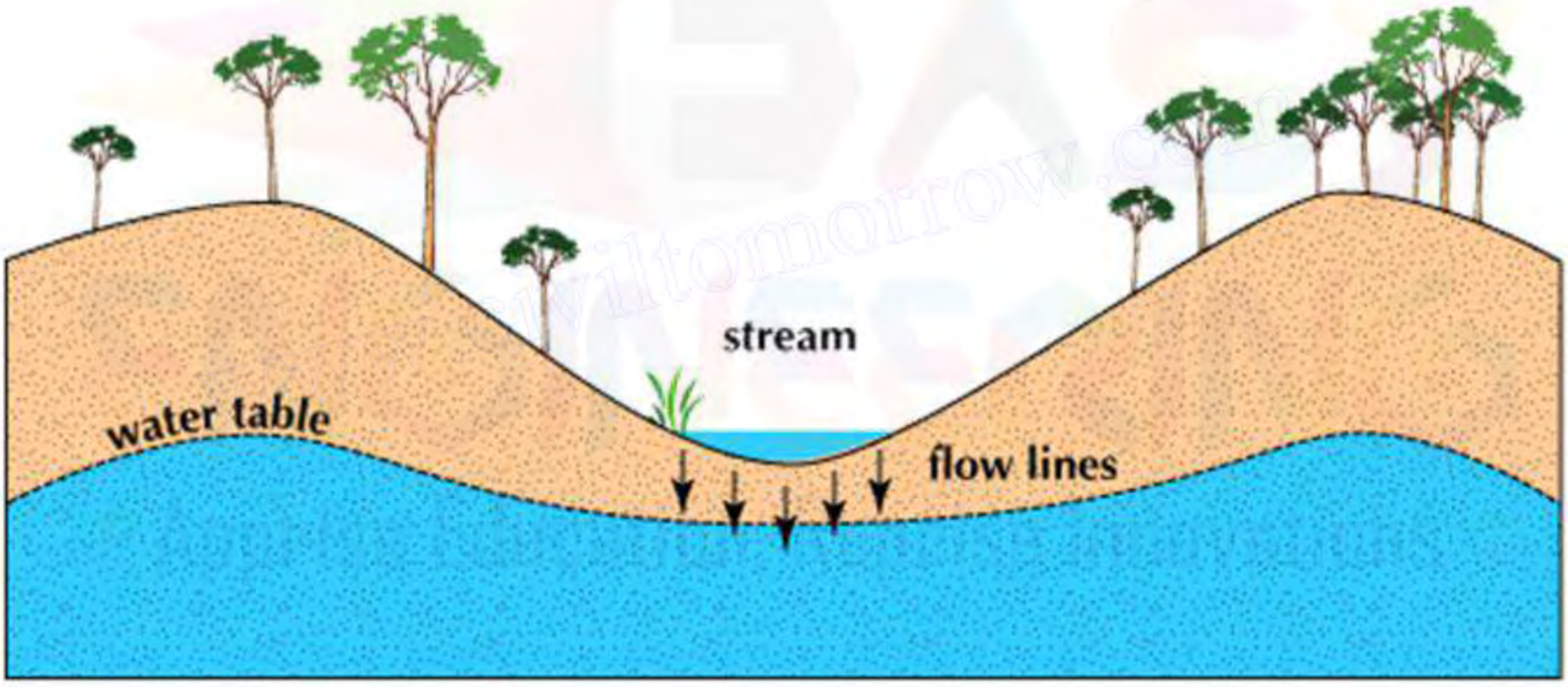
- It is the water derived from the precipitation (rain and snow)
- Meteoric water includes water from **lakes, rivers, and ice melts**, which all originate from precipitation indirectly.

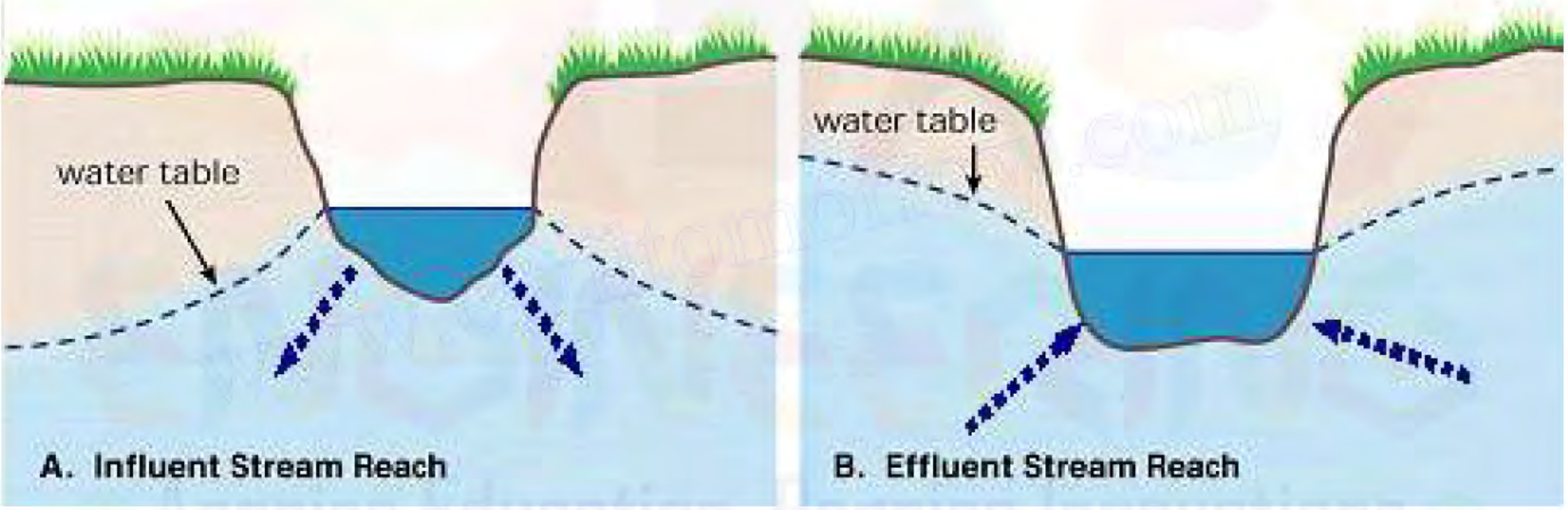

North
(diagram not to scale)
South
Lassen Peak
Bumpass Mountain
Bumpass Hell
Mount Conard
Growler Hot Springs
Morgan Hot Springs
Condensate zone
Vapor-dominated zone
Boiling zone
Liquid-dominated zone
Meteoric water
Gas-depleted thermal water
Hot or molten rock

- **Influent streams** – when the water table is lower than the water level in the stream. They are known as Influent streams.

- **Effluent streams** – When the water table is higher than the level of water in the stream . It is known as Effluent stream

Influent streams




water table
A. Influent Stream Reach
water table
B. Effluent Stream Reach

Connate water

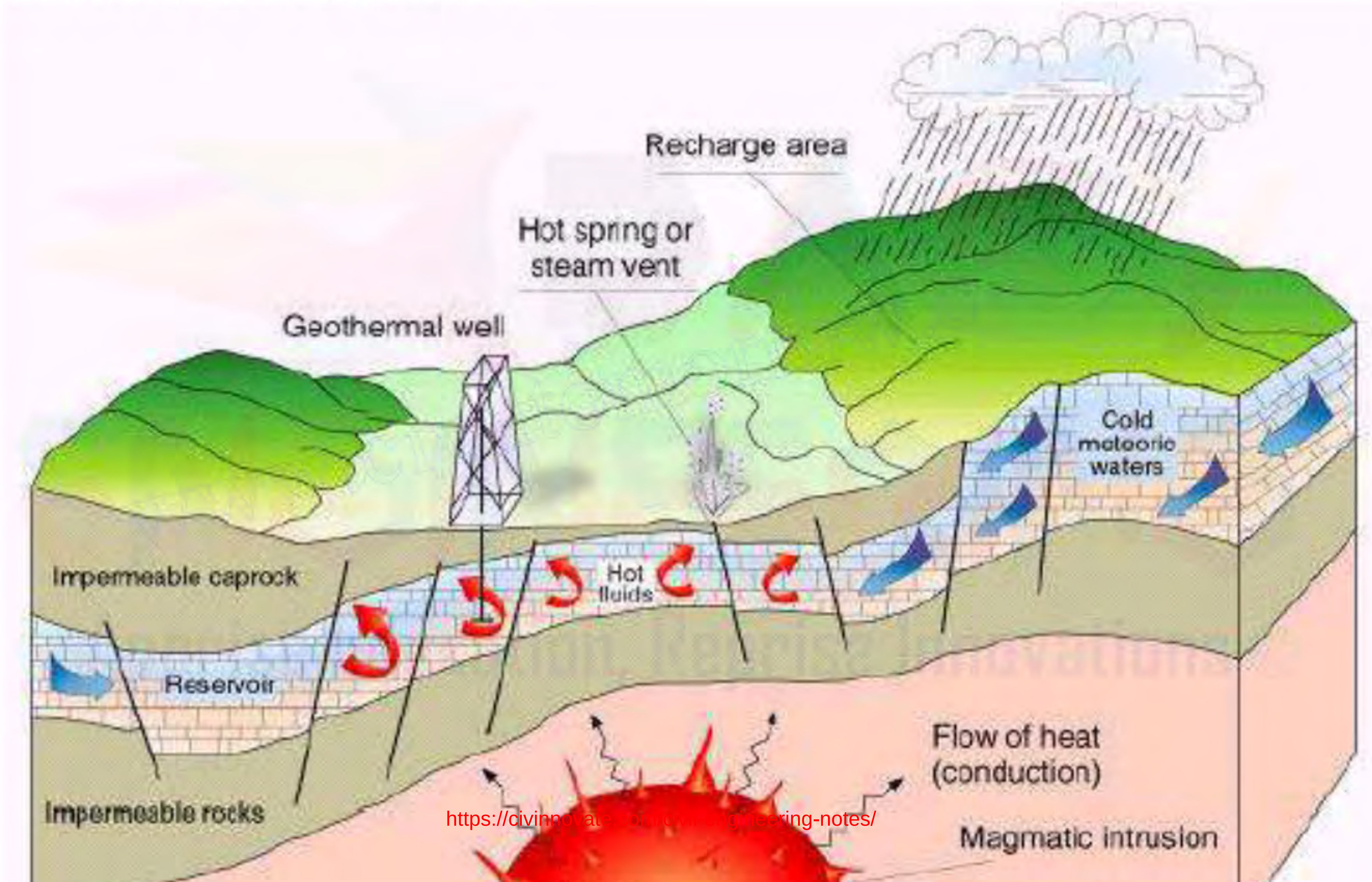
- Water present in the rocks right from their deposition.
- Formation of sedimentary rocks is by **deposition of minerals and Compaction**
- **Compaction** leads to **squeezing out of water** present between the sediment deposits

- **Incomplete compaction** may cause retention of water between the rocks.
- EX : Lime stones , sand stones
- Connate waters are saline in nature

Juvenile water

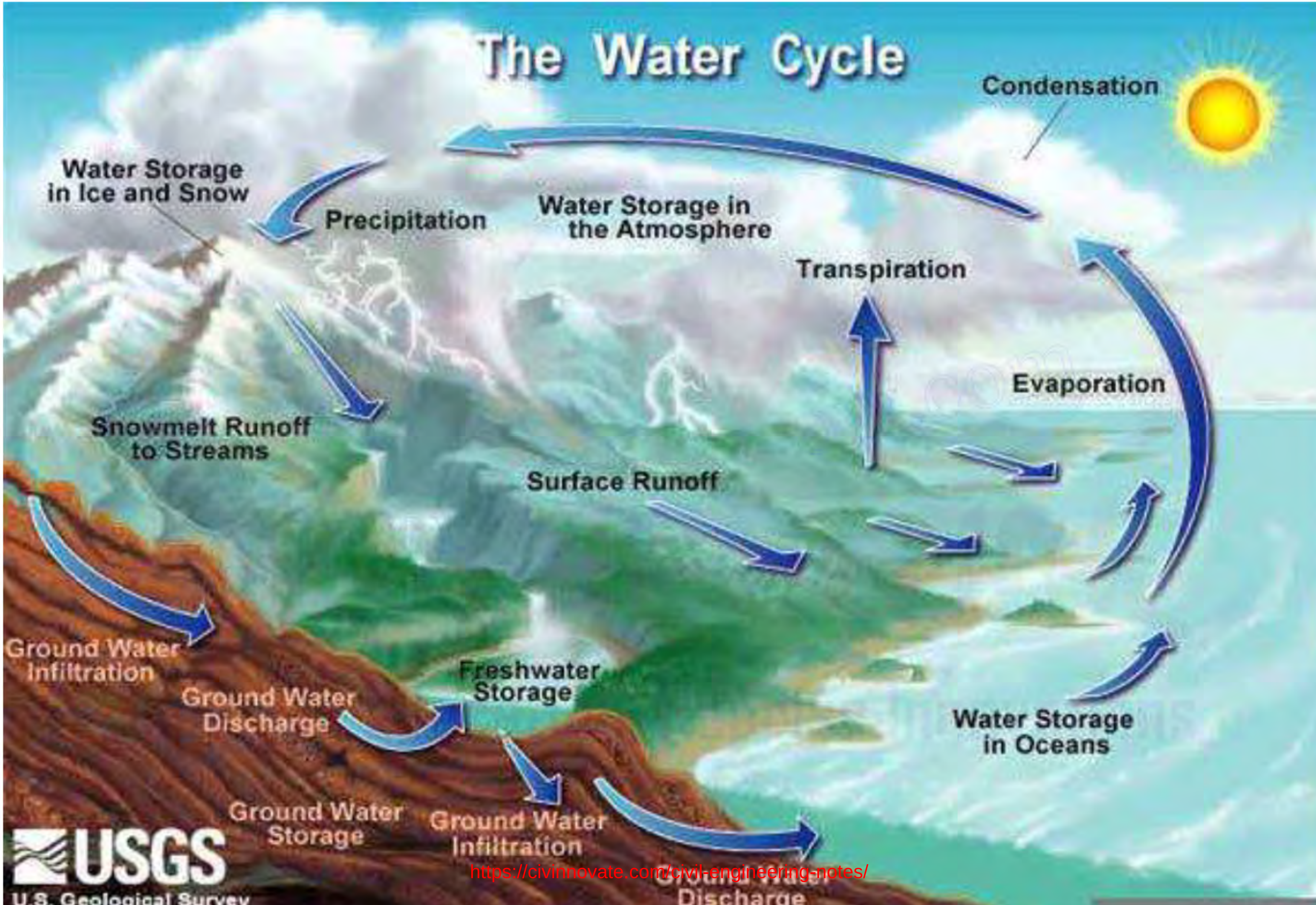
- It is also called as **Magmatic water**.
- Water formed in the cracks or pores of rocks due to condensation of steam emanating from hot molten masses or magmas existing below the surface of earth.
- Hot springs and geysers are derived from juvenile water.

Juvenile water

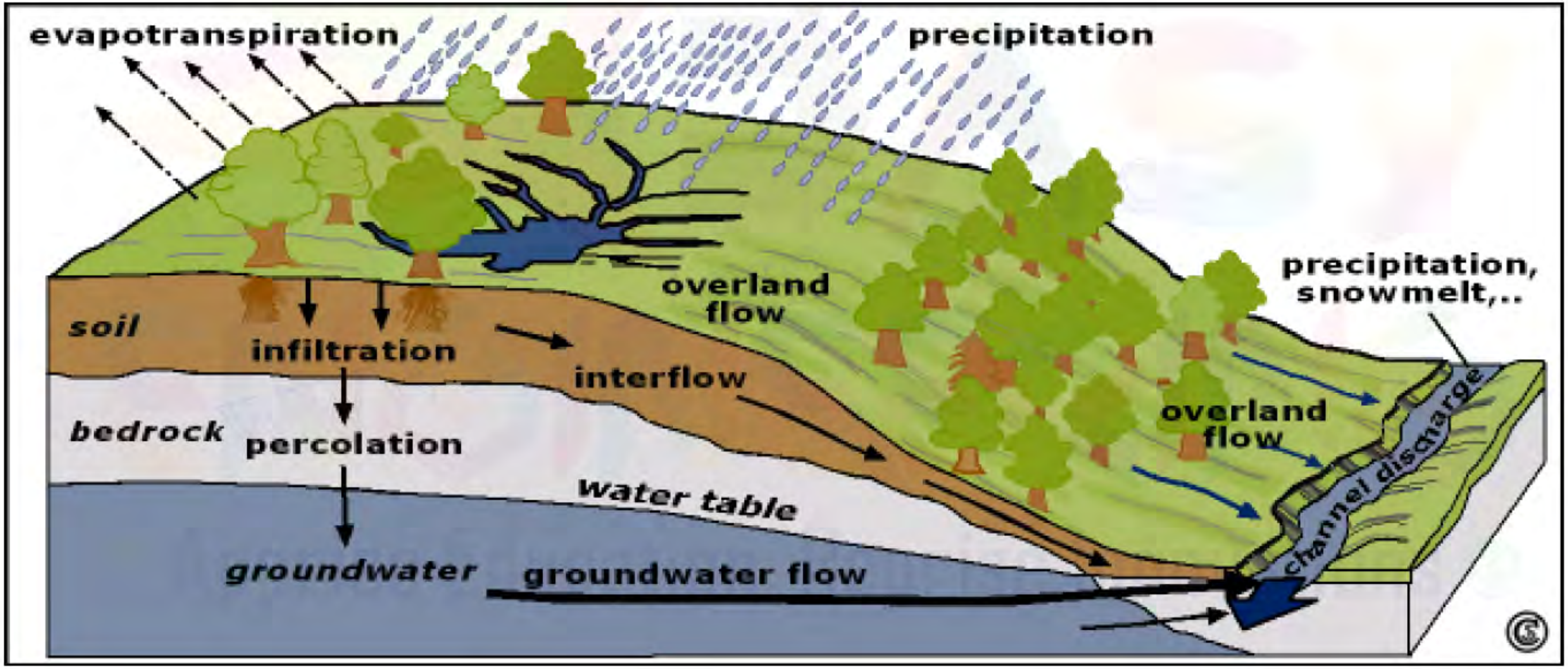


Hydrological cycle

- The water cycle, also known as the hydrologic cycle, describes the continuous movement of water on, above and below the surface of the Earth
- Water can change states among liquid, vapour, and ice at various places in the water cycle.


The Water Cycle
Condensation
Water Storage in Ice and Snow
Precipitation
Water Storage in the Atmosphere
Transpiration
Evaporation
Snowmelt Runoff to Streams
Surface Runoff
Ground Water Infiltration
Freshwater Storage
Ground Water Discharge
Water Storage in Oceans
Ground Water Storage
Ground Water Infiltration
Discharge
USGS
U.S. Geological Survey

Hydrological cycle

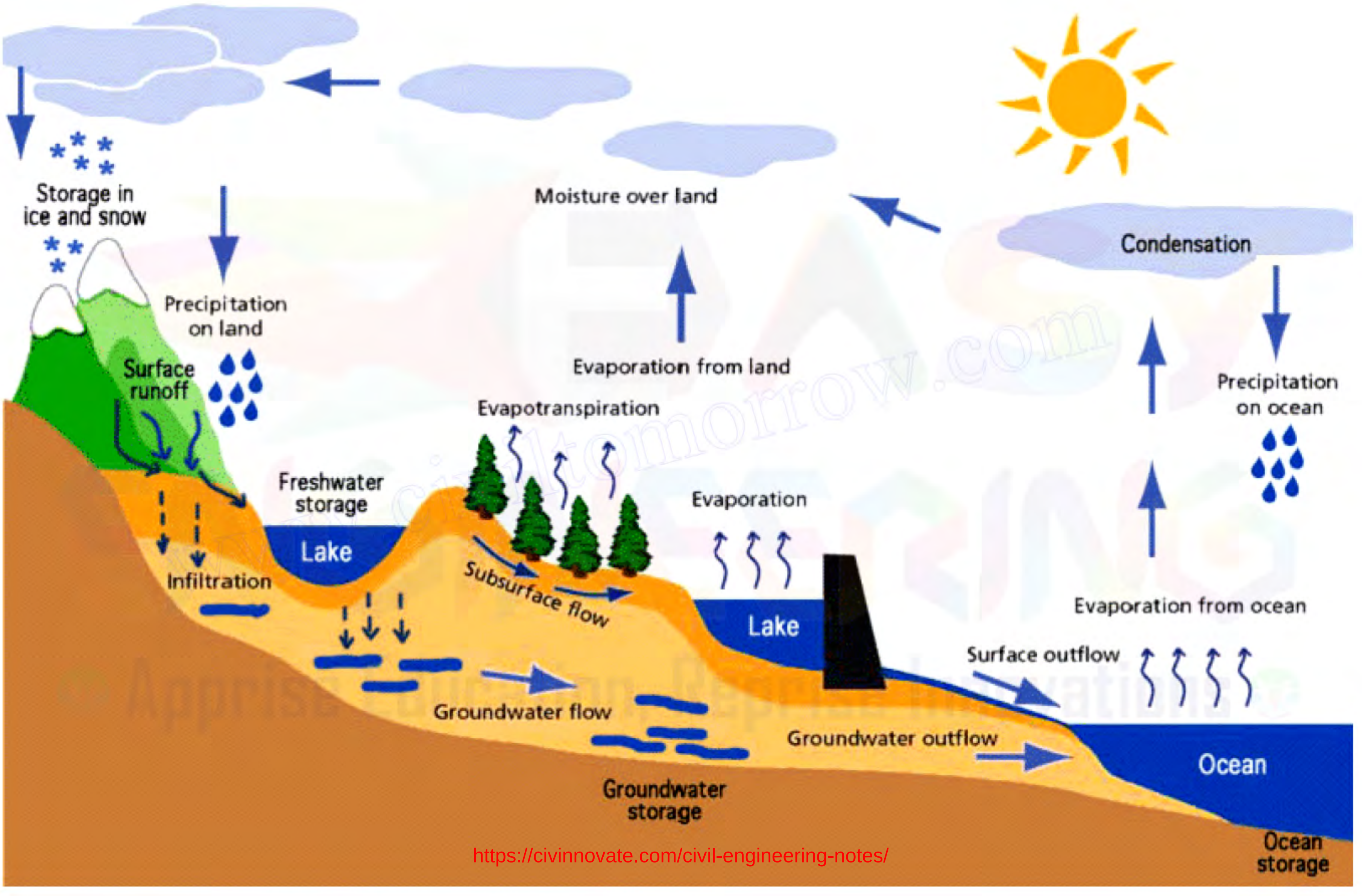


https://civinnovate.com/civil-engineering-notes/

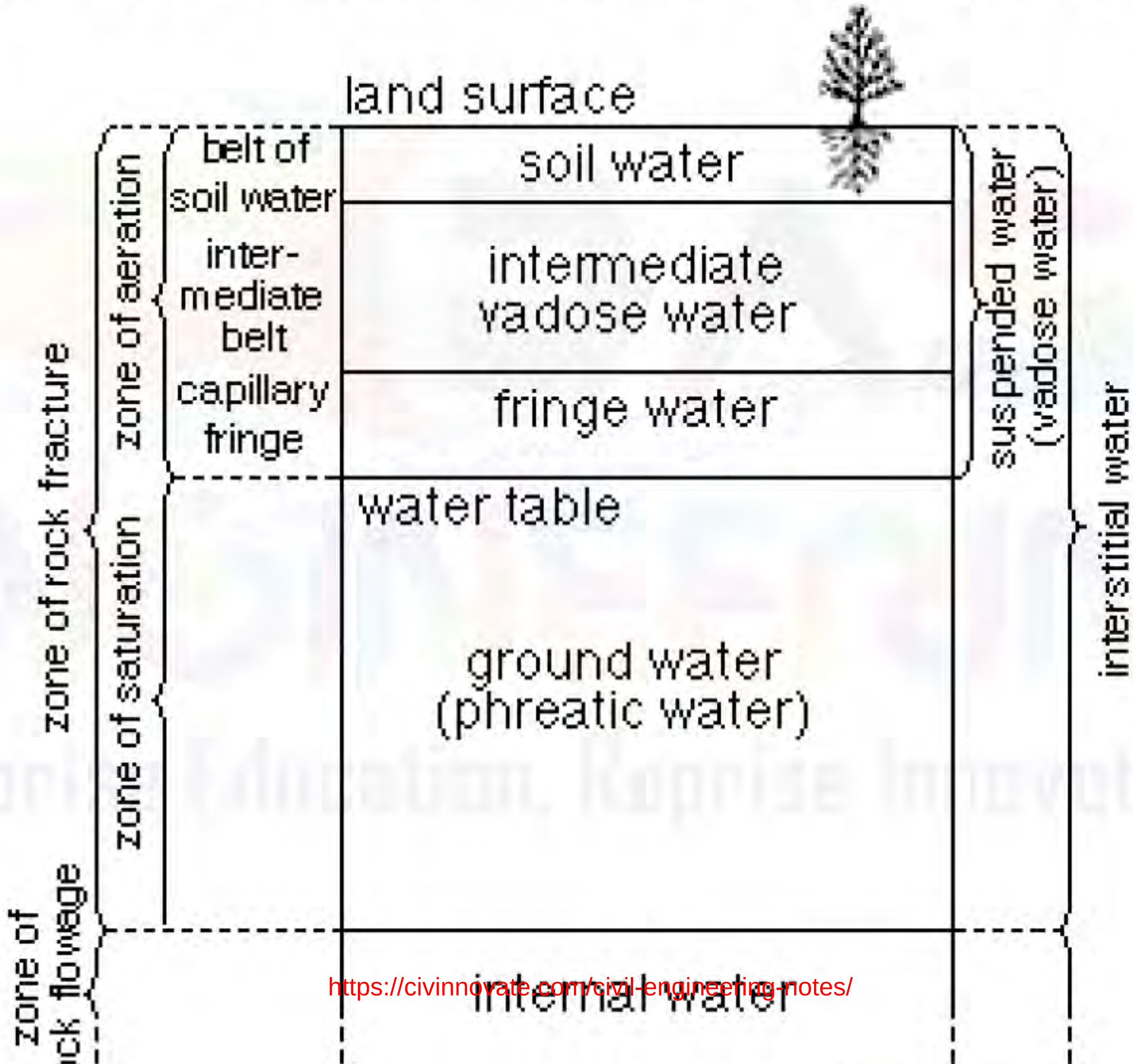
- In the hydrological cycle , water evaporates from the surface water bodies and is lost from **vegetation** by **transpiration**.
- These water vapours condense into clouds and gets precipitated in the form of rain , snow , sleet and hail.

- Essential features of water cycle are

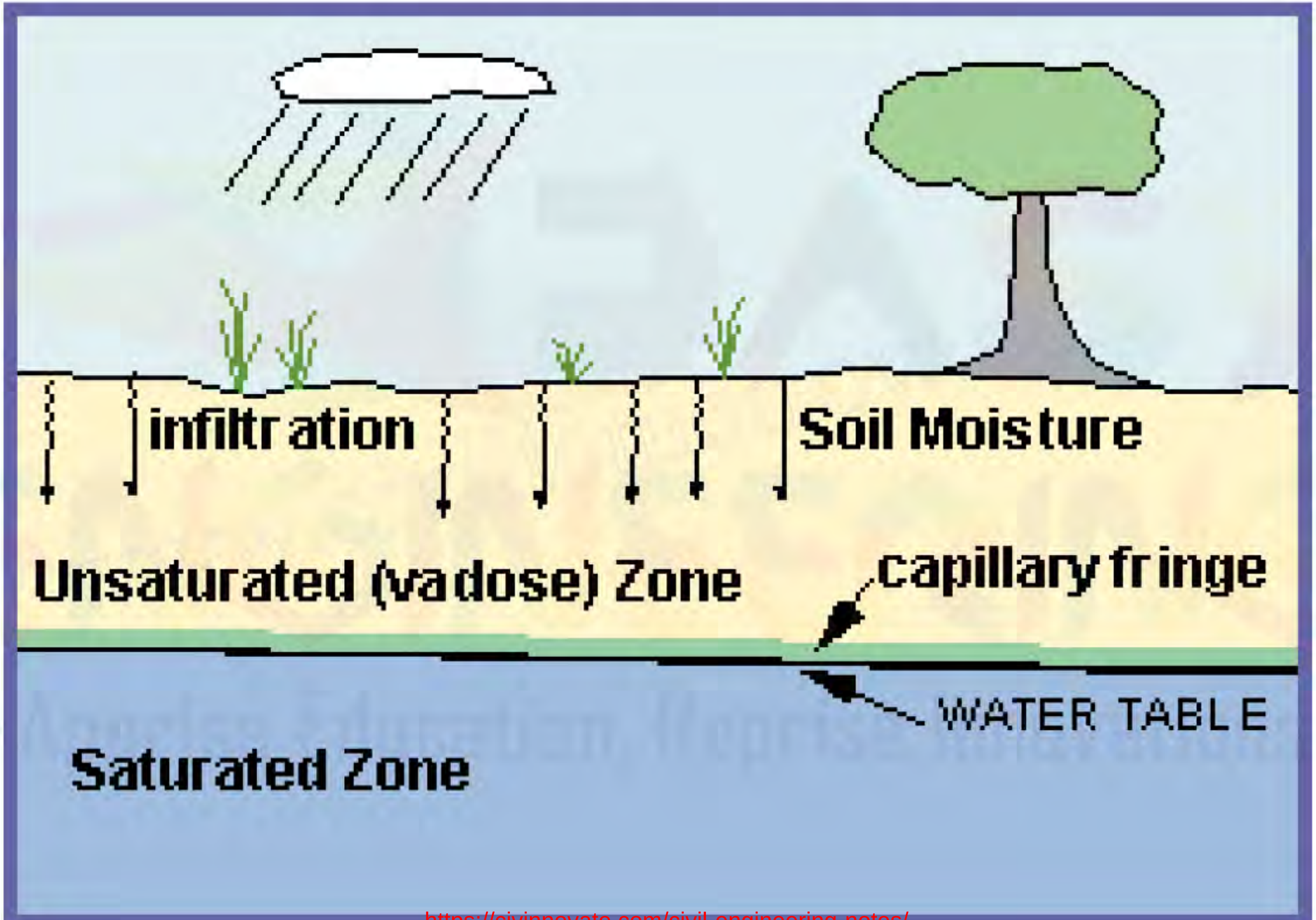
1. Evaporation (from land and oceans)
2. Condensation and precipitation
3. Return to land and oceans through interception , runoff , infiltration, percolation

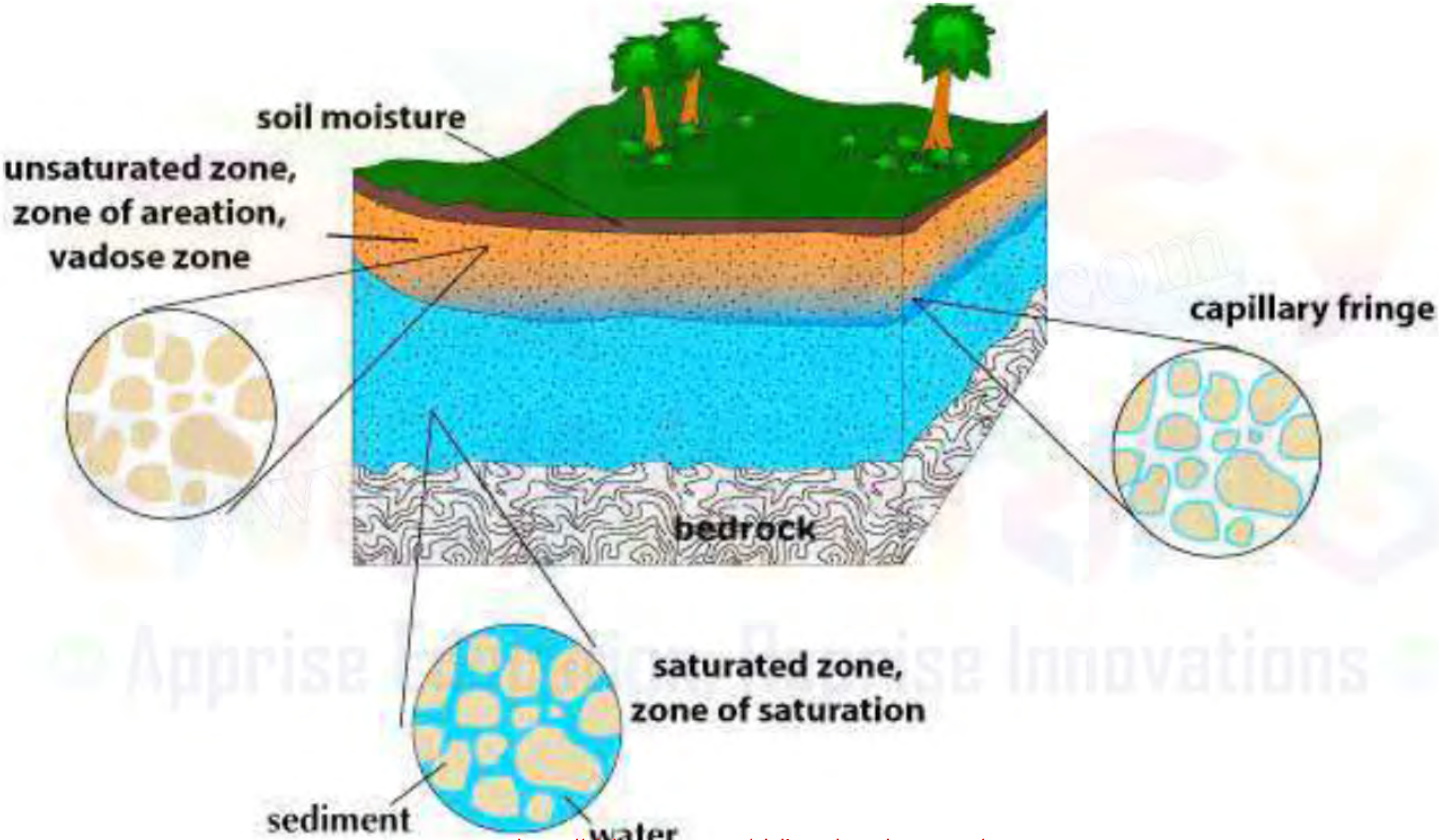

Storage in ice and snow
Precipitation on land
Moisture over land
Condensation
Surface runoff
Evaporation from land
Precipitation on ocean
Evapotranspiration
Freshwater storage
Evaporation
Lake
Infiltration
Subsurface flow
Lake
Evaporation from ocean
Surface outflow
Groundwater flow
Groundwater outflow
Ocean
Groundwater storage
Ocean storage

Zonal distribution of subsurface water



Groundwater




soil moisture
unsaturated zone,
zone of areation,
vadose zone
capillary fringe
bedrock
saturated zone,
zone of saturation
sediment
water

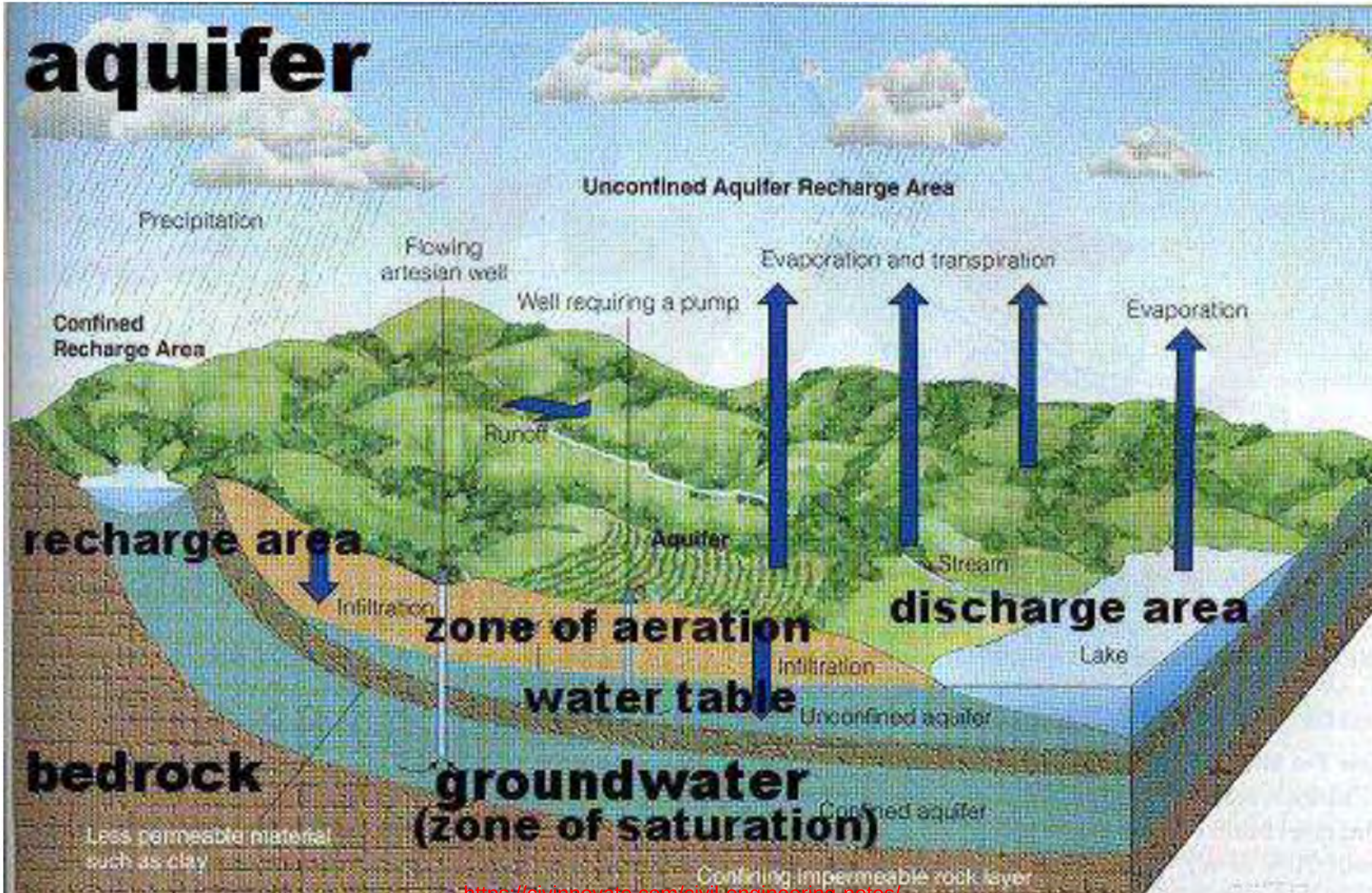
Water bearing qualities of rocks

All rocks are neither capable nor suitable for holding and transmitting groundwater

1. **Aquifer**
2. **Aquiclude**
3. **Aquifuge**
4. **Aquitard**

Aquifer

- An aquifer is an underground layer of water bearing permeable rock from which groundwater can be usefully extracted using a water well.
- An aquifer is a body of saturated rock through which water can easily move.


aquifer
Unconfined Aquifer Recharge Area
Precipitation
Flowing
artesian well
Evaporation and transpiration
Well requiring a pump
Evaporation
Confined
Recharge Area
Runoff
recharge area
Aquifer
Stream
Infiltration
discharge area
zone of aeration
Lake
Infiltration
water table
Unconfined aquifer
bedrock
groundwater
(zone of saturation)
Confined aquifer
Less permeable material
such as clay
Confining impermeable rock layer

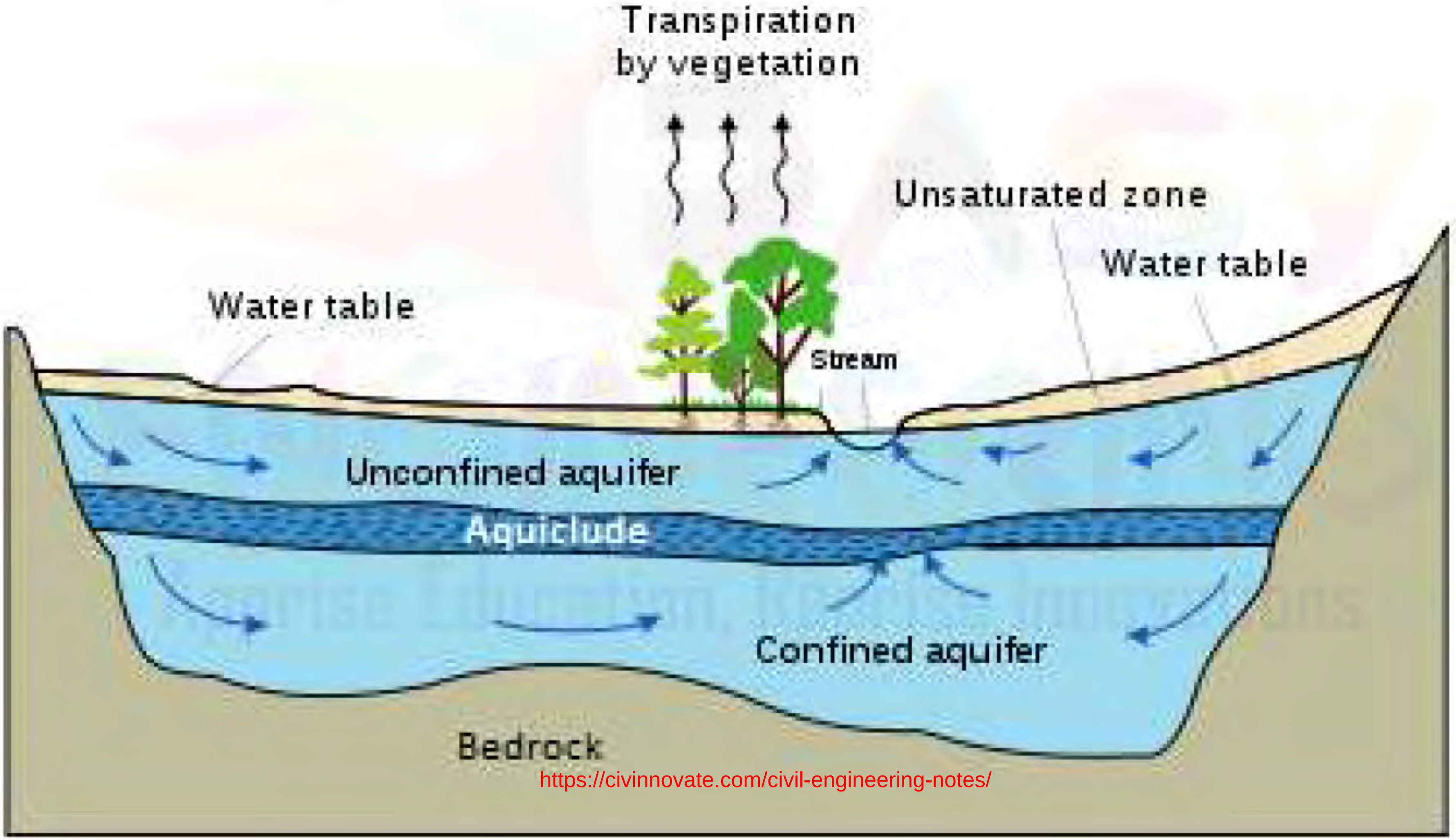
Aquifers

- Aquifers must be both **permeable and porous** and include such rock types as sandstone, conglomerate, fractured limestone and unconsolidated sand and gravel.

Aquiclude

- A rock body or formation which may be porous enough to hold enough quantity of water but due to its other properties **does not allow an easy and quick flow through it**, is called an aquiclude

Aquiclude

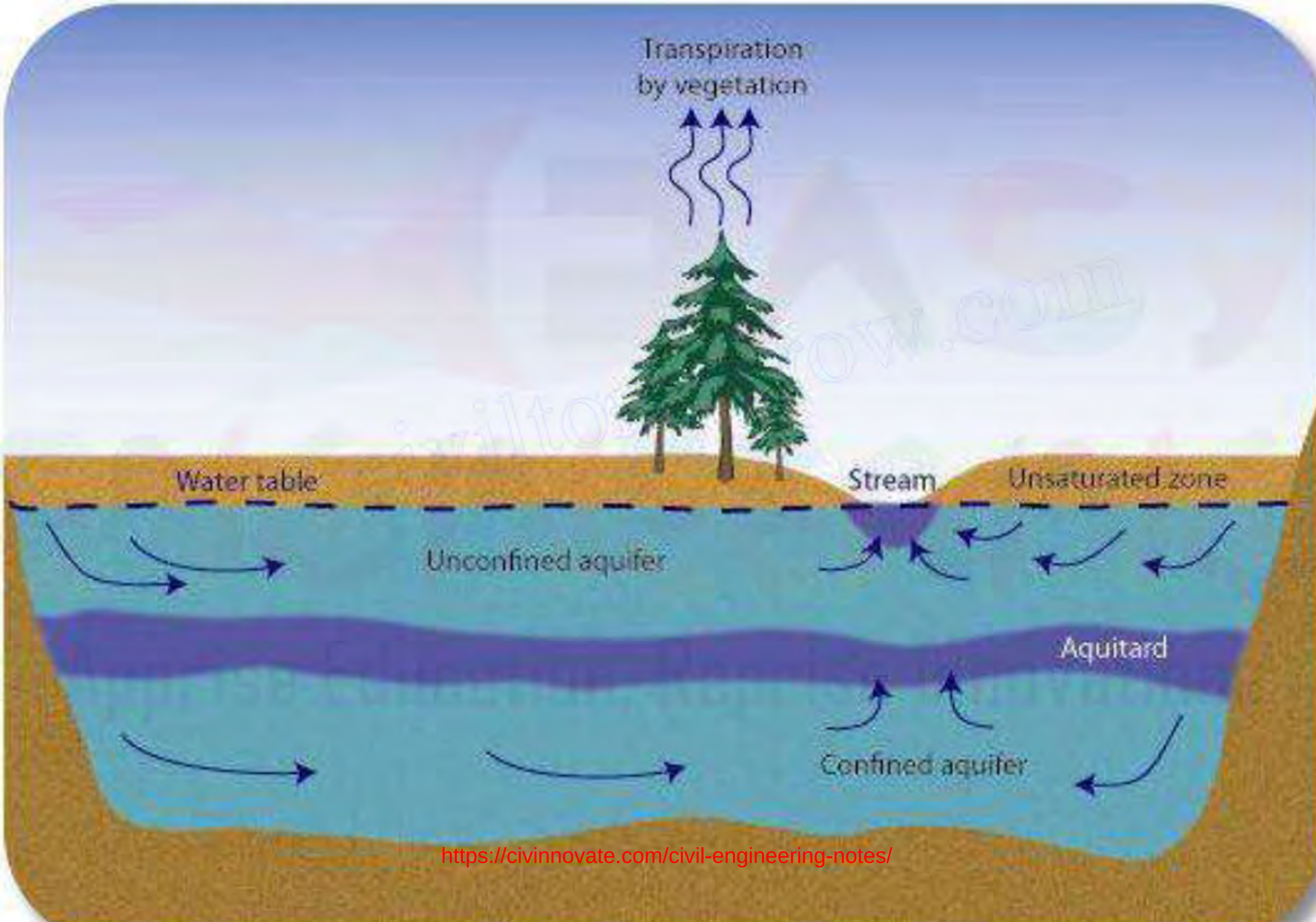


Transpiration
by vegetation
Unsaturated zone
Water table
Water table
Stream
Unconfined aquifer
Aquiclude
Confined aquifer
Bedrock

Aquitard

- A water-saturated sediment or rock whose permeability is so low it cannot transmit any useful amount of water.

Aquitard



Transpiration
by vegetation
Water table
Stream
Unsaturated zone
Unconfined aquifer
Aquitard
Confined aquifer

Aquifuge

- It is an impermeable rock formation through which there is no possibility of storage or movement of water

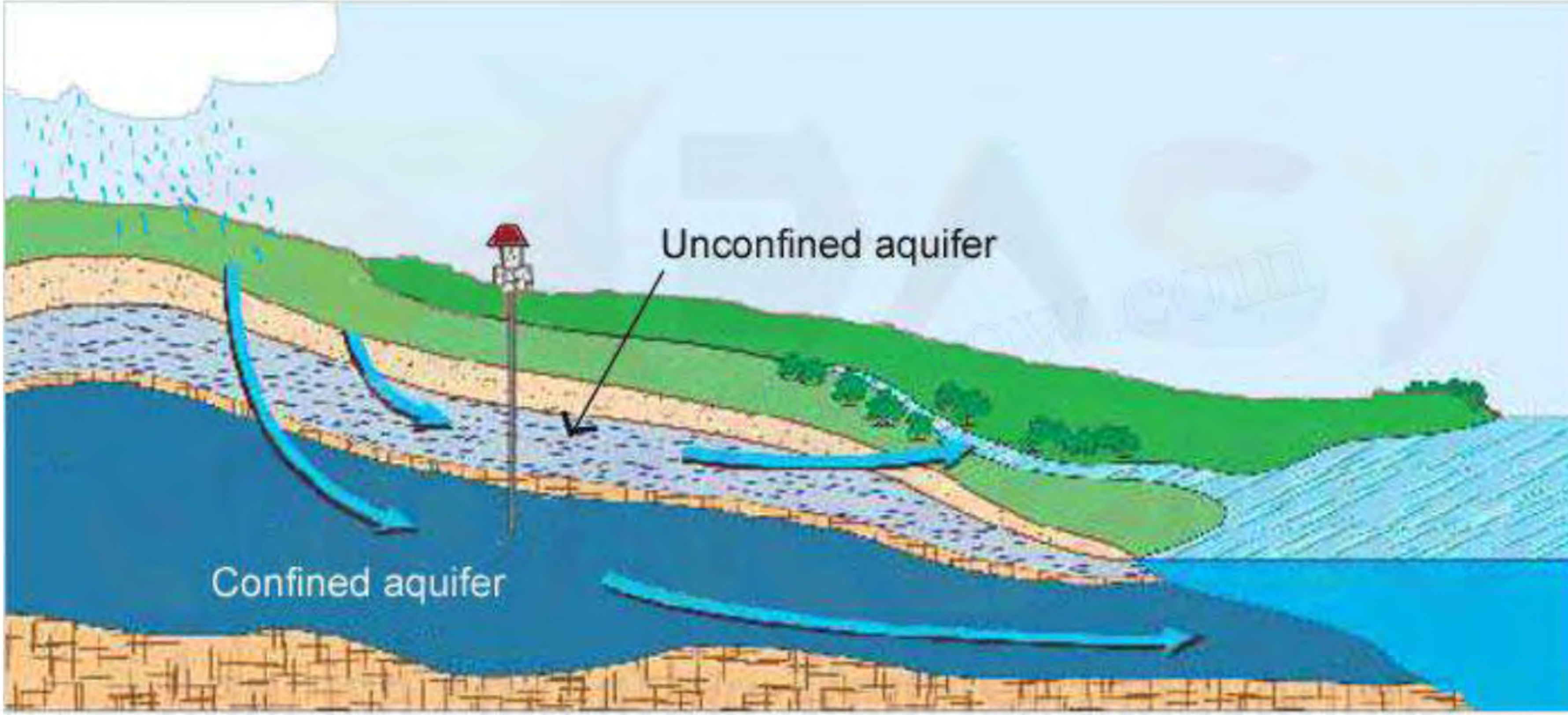
Types of aquifer

- **Unconfined aquifer**

It is also called a **water table aquifer**.

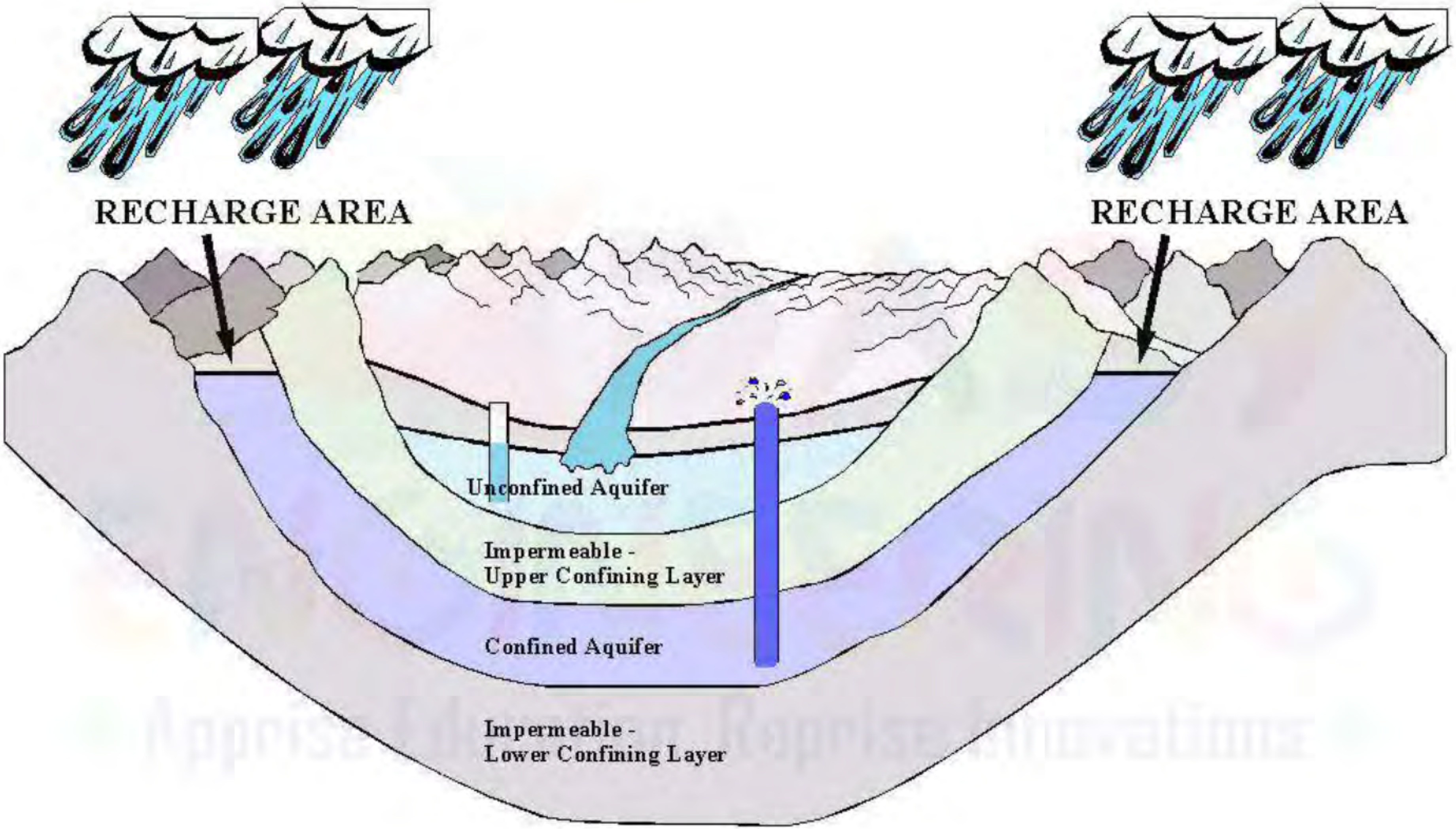
The upper surface of water or the water table is **under atmospheric pressure.**

The water occurring in this type of aquifer is called **free ground water.**


Unconfined aquifer
Confined aquifer

Confined Aquifer

- It is a rock formation saturated with water and capable of yielding water.
- It has an **overlying confining layer** (impermeable rock mass)
- Water held in this type of aquifer is not under atmospheric pressure but **under a great pressure due to confining medium.**


RECHARGE AREA
RECHARGE AREA
Unconfined Aquifer
Impermeable -
Upper Confining Layer
Confined Aquifer
Impermeable -
Lower Confining Layer

Aquifer functions

- Aquifer serves as underground reservoirs and distribution systems
- The storage capacity of aquifer depends on the porosity of the rock.

1. **Porosity**
2. **Specific yield**

Porosity

- It is defined as the volume of voids in a rock mass expressed in percentage terms of total volume of rock.

$$n = V_v/V_T$$

- Pore spaces may be formed in the rocks during the process of deposition in sedimentary rocks.

$$\text{Porosity } (n) = \frac{\text{Volume of voids } (V_v)}{\text{Total volume } (V_t)}$$

- Openings may be also caused in the rocks due to development of cracks , crevices , joints
- Sedimentary rocks are highly porous because of degree of packing and in size, shape and arrangement of grains
- Porosity is a broad measure of storage capacity of an aquifer.

Sedimentary Rocks	
Rock Type	**Porosity (%)**
Sandstone	14 - 49
Siltstone	21 - 41
Claystone	41 - 45
Shale	1 - 10
Limestone	7 - 56
Dolomite	19 - 33

Crystalline Rocks	
Rock Type	**Porosity (%)**
Basalt	3 - 35
Weathered granite	34 - 57
Weathered gabbro	42 - 45

Specific yield

- Specific yield is defined as the quantity of water that a unit volume of aquifer drains by gravity.
- **Specific yield** is defined as the volume of water released from storage by an unconfined aquifer per unit surface area of aquifer per unit decline of the water table.

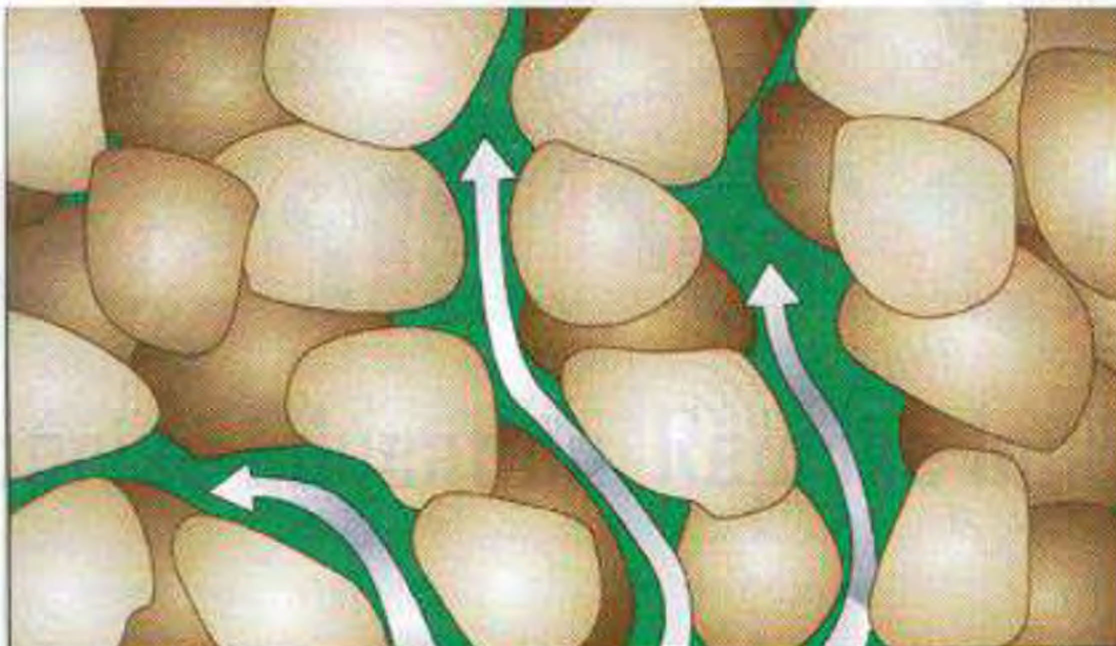
Flow in Aquifer

- Various aspects of movement of water in an aquifer are

1. **Permeability**
2. **Hydraulic conductivity**
3. **Transmissivity**

Permeability

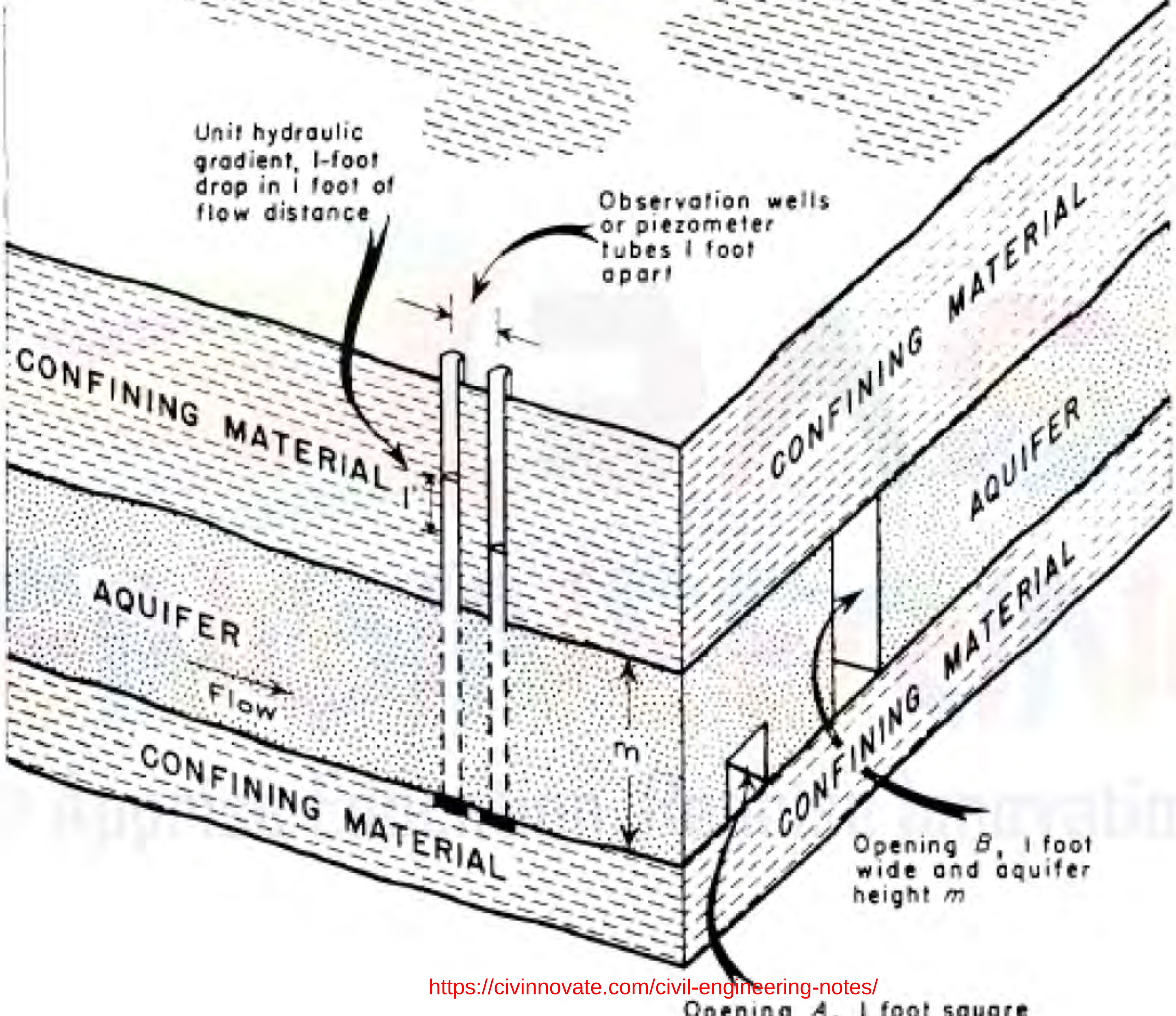
- Permeability is the capacity of the rock to transmit fluids through it.



Connected pores give a rock permeability.

- **Hydraulic conductivity** is the rate of flow under a unit hydraulic gradient through a **unit cross-sectional area of aquifer** (opening A)

- **Transmissivity** is the rate of flow under a unit hydraulic gradient through a **unit width of aquifer of thickness m** (opening B)


Unit hydraulic gradient, 1-foot drop in 1 foot of flow distance
Observation wells or piezometer tubes 1 foot apart
CONFINING MATERIAL
AQUIFER
Flow
CONFINING MATERIAL
m
CONFINING MATERIAL
AQUIFER
CONFINING MATERIAL
Opening B, 1 foot wide and aquifer height m
Opening A, 1 foot square

Sedimentary Rocks	
Rock Type	**Hydraulic Conductivity (m/sec)**
Karst and reef limestone	1×10^{-6} to 2×10^{-2}
Limestone, dolomite	1×10^{-9} to 6×10^{-6}
Sandstone	3×10^{-10} to 6×10^{-6}
Siltstone	1×10^{-11} to 1.4×10^{-8}
Salt	1×10^{-12} to 1×10^{-10}
Anhydrite	4×10^{-13} to 2×10^{-8}
Shale	1×10^{-13} to 2×10^{-9}

Crystalline Rocks	
Material	**Hydraulic Conductivity (m/sec)**
Permeable basalt	4×10^{-7} to 2×10^{-2}
Fractured igneous and metamorphic rock	8×10^{-9} to 3×10^{-4}
Weathered granite	3.3×10^{-6} to 5.2×10^{-5}
Weathered gabbro	5.5×10^{-7} to 3.8×10^{-6}
Basalt	2×10^{-11} to 4.2×10^{-7}
Unfractured igneous and metamorphic rock	3×10^{-14} to 2×10^{-10}