Topic: Soil, Earth's crust, Weathering, Pedogenic processes

JRF/ SRF Coaching Classes & Examination Series

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Soil

Concept

Word soil derived from **LATIN** word " **Solum**" = Ground or floor

Land- 2D entity representing geographical area and landscape,

Soil- 3D body with length, breadth and depth and is hidden below the land surface.

They form a continuation over the land surface and differ in properties from place to place. Its upper boundary is air or water and lower boundary is the rock lithosphere.

Approaches of Soil Study

Pedology- The study of genesis, survey, classification and geological distribution of soils

Edaphology- Study of soil from the stand point of higher plants.

Definitions

- **Whitney** (1892): Soil is a nutrient bin which supplies all the nutrients required for plant growth
- **Hilgard** (1892): Soil is more or less a loose and friable material in which plants, by means of their roots, find a foothold for nourishment as well as for other conditions of growth”
- **Dokuchaiev** (1900): Russian scientist - Father of soil science - Soil is a natural body composed of mineral and organic constituents, having a definite genesis and a distinct nature of its own.
- **Joffe** (1936): “Soil is a natural body of mineral and organic constituents differentiated into horizons - usually unconsolidated - of variable depth which differs among themselves as well as from the underlying parent material in morphology, physical makeup, chemical properties and composition and biological characteristics”.

- **Jenny** (1941): Soil is a naturally occurring body that has been formed due to combined influence of climate and living organisms acting on parent material as conditioned by relief over a period of time.
- **Ruffin and Simonson** (1968): Soil is a mixture of Earth's uppermost mantle of weathered rock and organic matter
- **Buckman and Brady** (1969): Soil is a dynamic natural body on the surface of the earth in which plants grow, composed of mineral and organic materials and living forms

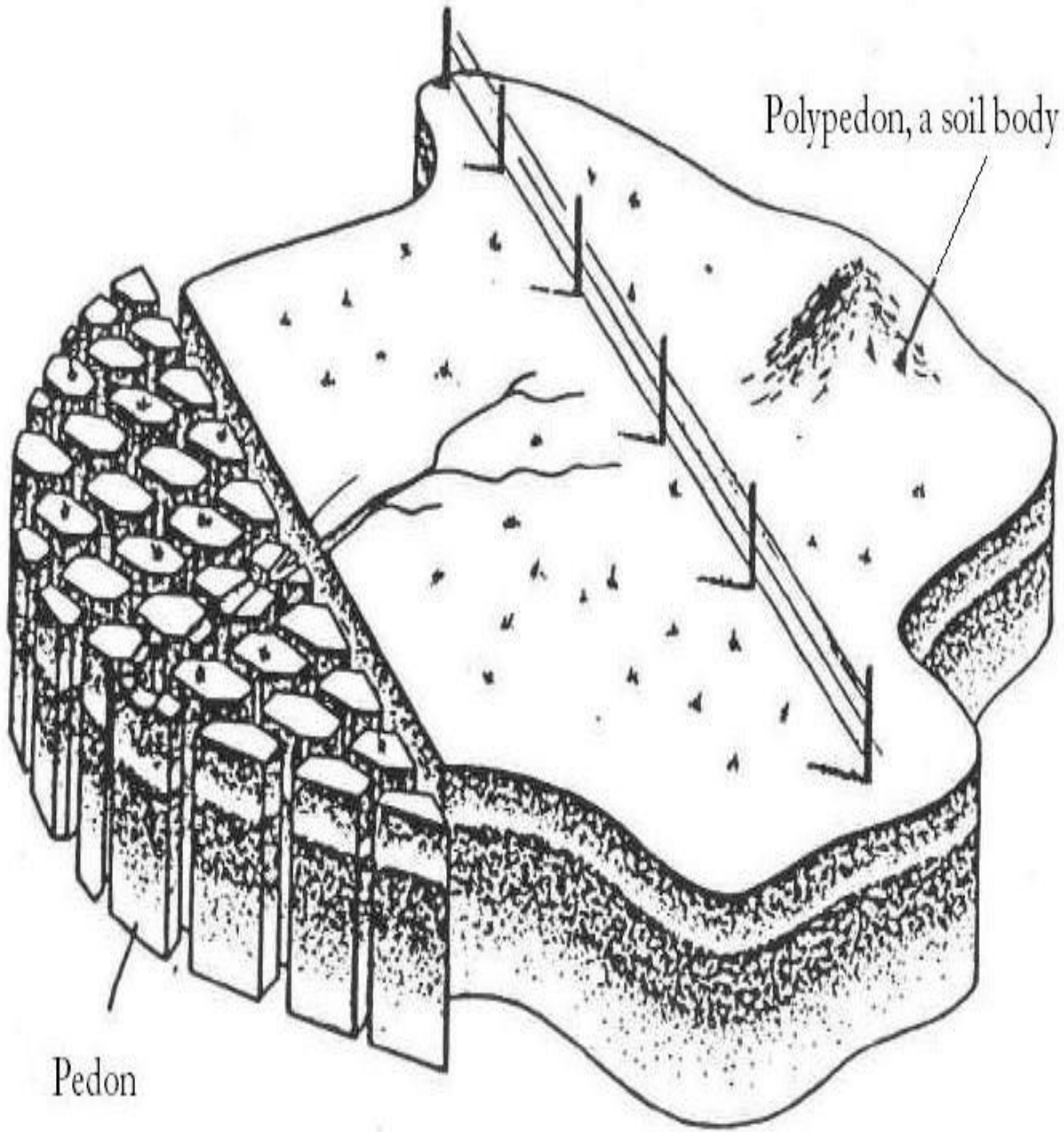
Pedon and Polypedon

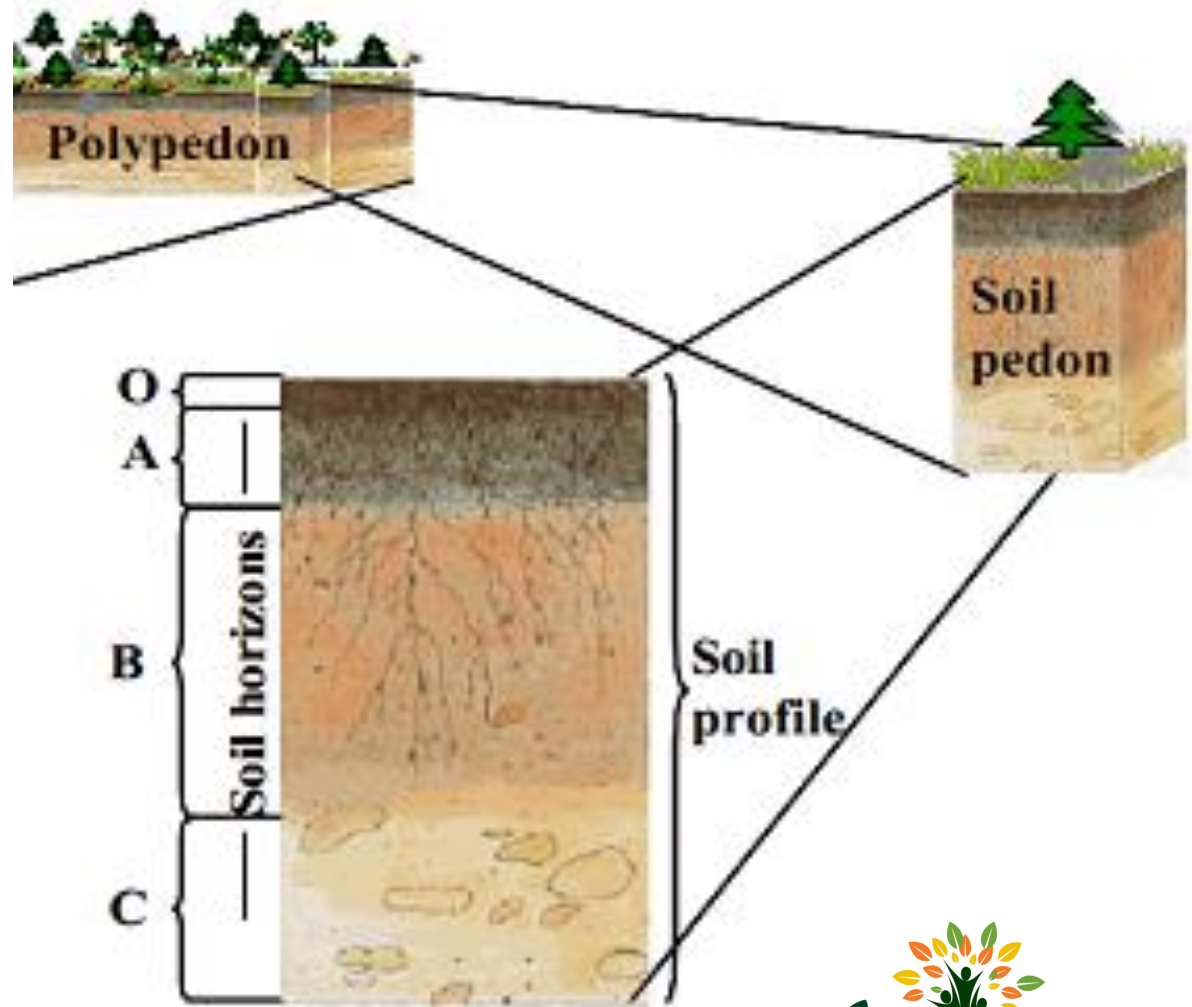
Pedon- Smallest volume that can be called "a soil" is pedon. At the same time, it must be large enough volume of soil to be observable, and to exhibit a full set of horizons.

- Area- 1-10 m^2 Shape- Roughly hexagonal
- It is 3D and Unit for soil sampling.
- Set of pedons must fit within the range of one series and occur in a continuous group to form a polypedon

Polypedon- Similar pedons bounded on all sides by pedons of unlike characters. Minimum area more than 1 sq.km and an unspecified maximum area.

- Real soil bodies that we classify into series and higher categories





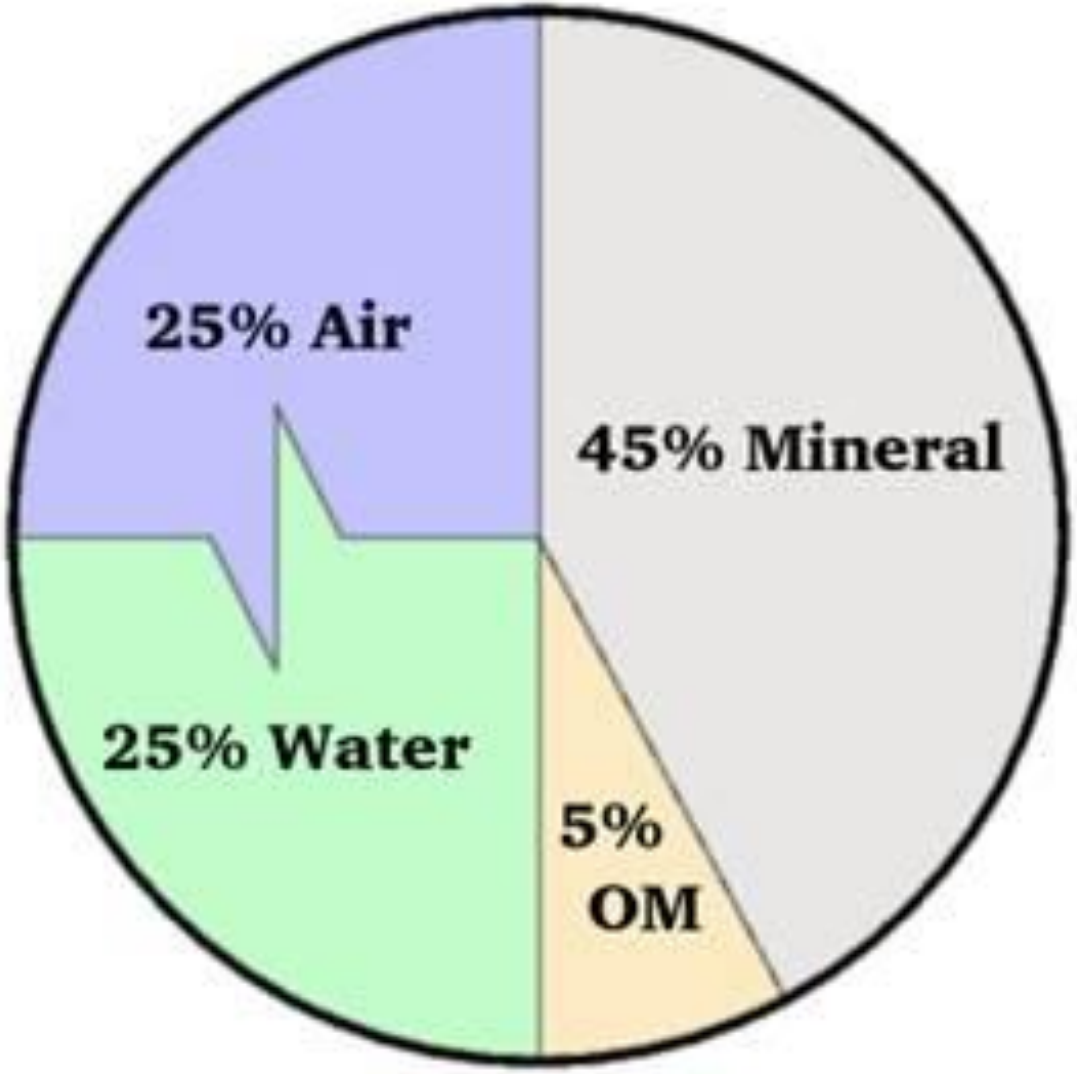
Soil versus Regolith

Regolith- Loose unconsolidated inorganic material of weathered rock on the earth's surface.

- It is the result of disintegration and decomposition of the exposed bed rock
- Parent material of soil. On this material the soil forming factors and processes interplay to form true soil.
- Weathered products of rocks and rock minerals are called as Parent materials
- Upper and biochemically weathered part of regolith- soil

Composition of soil

- Mineral matter - 45%
- Organic matter - 5%
- Soil water -25%
- Soil air - 25%



Surface soil	**Subsurface soil**
Immediate uppermost loose layer- Furrow slice	Compact soil below furrow slice
0-15 cm depth	Cannot be cultivated by tillage – hard pan formation
Fertile	Less fertile

Soil Profile

Vertical section through a soil- showing all its horizons.

Horizon- Layer approximately parallel to the surface of soil

Soil profile- up to a depth of 1.5-2 m in deep soils.

In shallow soils vertical cut is made up to bedrock or up to water table in case of waterlogged soils

Soil horizons are of two types

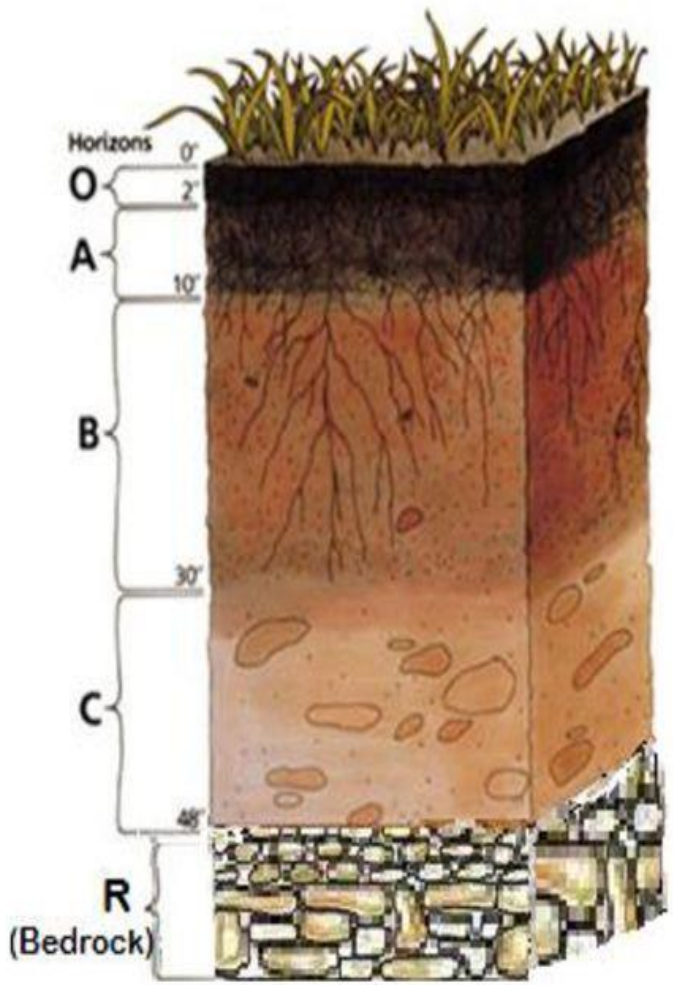
1) Genetic horizons
2) Diagnostic horizons

Genetic horizons

- Master horizons
- Transitional horizons
- Subordinate distinction within master horizons

Master Horizons

- O = The layer of organic matter on the surface of a mineral soil (not very common in SD)
- A = Topsoil. The mineral soil horizon on the surface with organic matter and low clay
- E = The horizon of maximum leaching. Not in all soils, but if present, is located just below the "A" horizon; whitish color
- B = Subsoil. Horizon most often located below A horizon. The zone of maximum clay accumulation; salt accumulation
- C = Weathered rock. Lies below the "A" and/or "B" horizons and has NOT been acted upon by the soil forming processes
- R = The hard, consolidated rock beneath the soil



- Top most Mineral horizon- A
- Horizon of eluviation- E
- Zone of accumulation- B
- Horizon represents the parent material- C

AgriGates
Exploring frontiers in agriculture

- **L horizon-** Include both organic and mineral limnic materials that are deposited in water by precipitation or through the action of algae and diatoms. Found only in histosols
- **M-layer-** Root limiting subsoil layers. Geotextile liners, asphalt, concrete rubber and plastic
- **W –layer-** It is water layer within or beneath the soil.

Transitional horizons- The horizon which is dominated by properties of one master horizon but having subordinate properties of another.

Eg: AB, EB, BE

First symbol indicates horizon with the greater volume than another

Subordinate distinctions within master horizons

Table 2.2
LOWERCASE LETTER SYMBOLS TO DESIGNATE SUBORDINATE DISTINCTIONS WITHIN MASTER HORIZONS

Letter	Distinction	Letter	Distinction
a	Organic matter, highly decomposed	n	Accumulation of sodium
b	Buried soil horizon	o	Accumulation of Fe and Al oxides
c	Concretions or nodules	p	Plowing or other disturbance
d	Dense unconsolidated materials	q	Accumulation of silica
e	Organic matter, intermediate decomposition	r	Weathered or soft bedrock
f	Frozen soil	s	Illuvial organic matter and Fe and Al oxides
ff	Dry permafrost	ss	Slickensides (shiny clay wedges)
g	Strong gleying (mottling)	t	Accumulation of silicate clays
h	Illuvial accumulation of organic matter	u	Presence of human-manufactured materials (artifacts)
i	Organic matter, slightly decomposed	v	Plinthite (high iron, red material)
j	Jarosite (yellow sulfate mineral)	w	Distinctive color or structure without clay accumulation
jj	Cryoturbation (frost churning)	x	Fragipan (high bulk density, brittle)
k	Accumulation of carbonates	y	Accumulation of gypsum
m	Cementation or induration	z	Accumulation of soluble salts

Earth’s Sphere

There are 3 spheres corresponding to three states of matter (solid, liquid, and gas) which constitute the earth.

- Solid sphere - Lithosphere
- Liquid sphere- Hydrosphere- the complete covering of water forming seas and oceans
- Gaseous sphere- Atmosphere- the gaseous envelop over the Earth’s surface

ATMOSPHERE

- The envelop of air that covers both the lithosphere and hydrosphere.
- It contains water molecules and dust, which may act as nuclei for the condensation of water vapour to form clouds or fog.
- It composed of :
  - **Nitrogen : 78.084 % (Main component)**
  - **Oxygen : 20.946%**
  - **Argon : 0.934%**
  - **Carbon dioxide : 0.04%**
- In addition inert gases such as neon, helium, krypton, and xenon are present.
- The water vapours present in the air vary in amounts at different places and times
- The air becomes less dense with height

HYDROSPHERE

- Water covers almost **three -fourth** of the Earth's surface.
- Most of it lies within the ocean basins; it also appears on the surface of land in the form of rivers, ponds, lakes, and as ground water

The quality of different water varies.

- ***Sea water*** contains the highest amount of soluble salts (EC **60,000** dS/m), most of which is ***NaCl***
- ***River water*** contains only a fraction of such salts. (EC **591 dS/m**, or even less)

LITHOSPHERE

- It is the solid surface
- Continents, ocean basins, plains, plateaus, mountains, valleys sand dunes, lava flows and the interior of the earth which consists of rocks and minerals.
- It is covered by gaseous and watery envelope

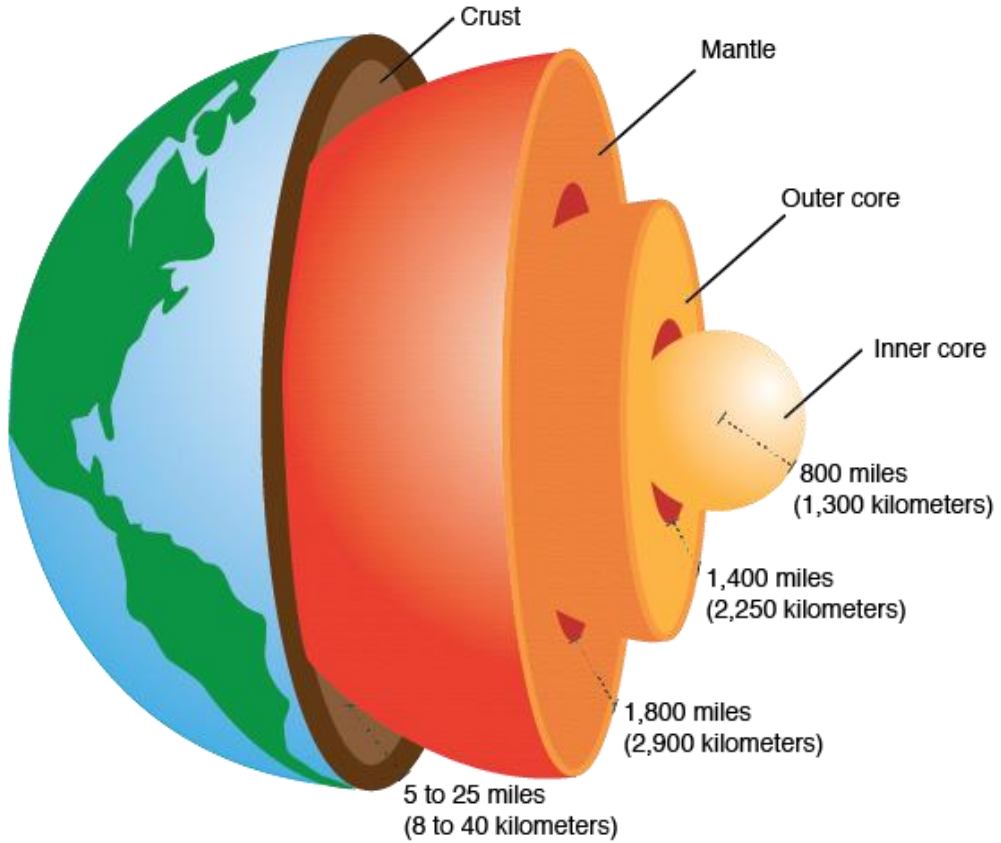
Atmosphere- 0.03% weight to the Earth

Hydrosphere- 6.91 %

Lithosphere- 93.06%

INTERIOR OF THE EARTH

	Thickness	Density
Crust	5-56 km (5-11 km- Oceans 35-56 km- continents)	2.6-3 g cm^{-3}
Mantle	2900 km	3-4.5 g cm^{-3}
Core	3500 km (Outer- 2250 km Inner- 1300 km)	9-12 g cm^{-3}



The density of the Earth - **5.5 g/cm^3**

Density of common rocks: **2.6 – 2.7 g/cm^3**

Density of heaviest rock : **4 g/cm^3**

- **Mantle-** Rock composed of Si, O_2, Al, Mg and Fe
  Temp– 870 ° C (upper) and 4400 ° C (lower)
- **Outer core-** Melted Fe and Ni (2200 °C)
- **Inner Core-** Centre of Earth - Solid Fe and Ni (5000 °C)

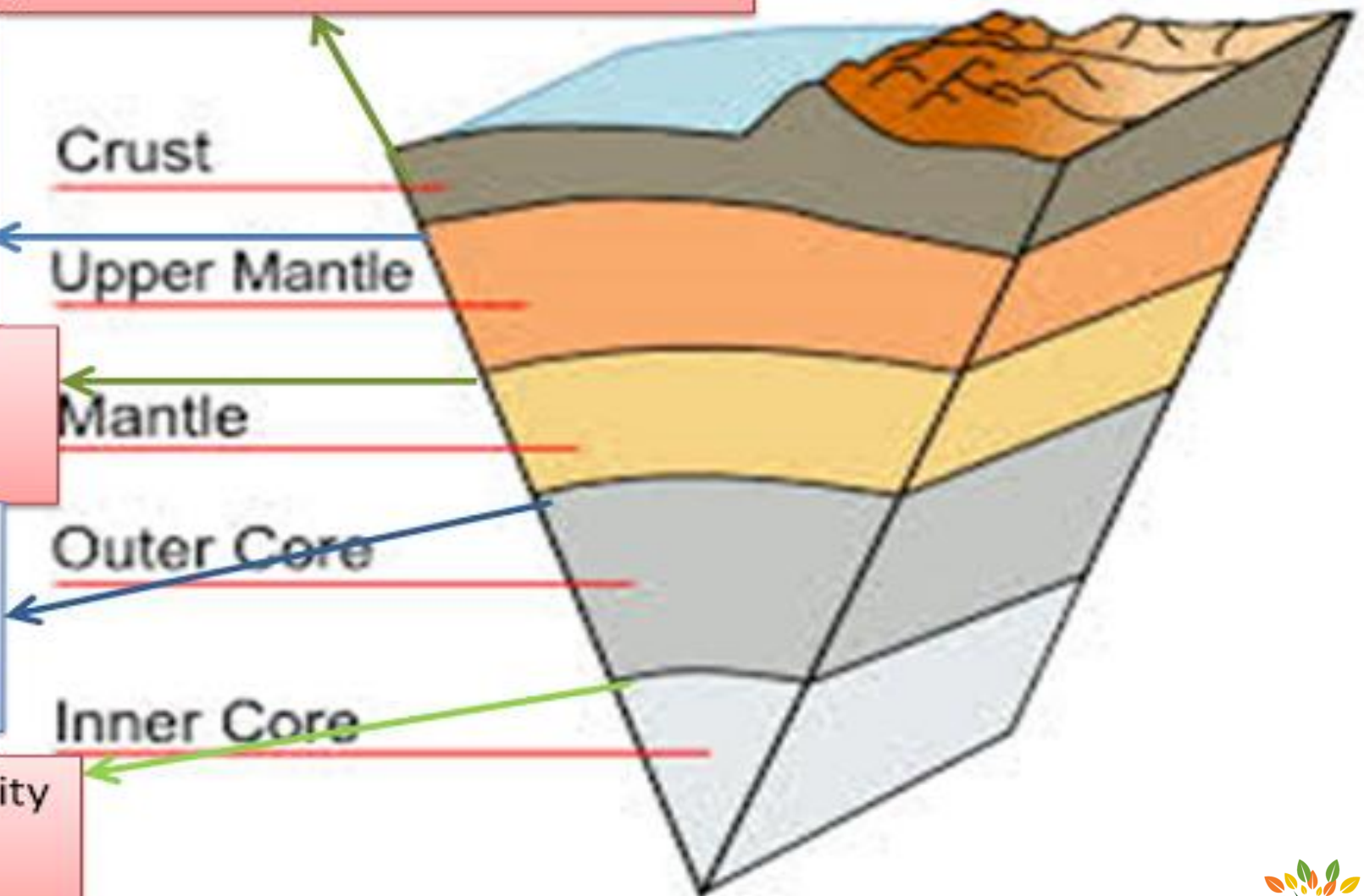
Conorod discontinuity – between upper & lower crust

Mohorovicc discontinuity – between lower crust & upper mantle

Repiti discontinuity – between upper & lower Mantle

Guttenberg discontinuity – between lower Mantle & outer Core

Lehmann discontinuity – between outer & inner core



Composition of Earth's Crust

- Hard and naturally- formed substance of the earth- Rock
- Out of 106 elements known, 8 are sufficiently abundant to constitute 98.6% of earth's crust upto 16km

The elements are geochemically distributed into 5 main groups on their bonding characters:--

- Lithophiles - Which **ionize readily** or form stable oxyanions.
- Chalcophiles - Which tend to form **covalent bonds** with sulphide.
- Siderophiles - Which readily form **metallic bonds**.
- Atmosphiles - Which tend to **remain in atmospheric gases**.
- Biophiles - Which tend to be **associated with living organisms**.

- Dominant element in the Earth's crust- Oxygen
- Second most abundant element- Si
- Dominant metallic element-- Al
- Dominant exchangeable cation- Ca

Name of the Element	Percentage
O_2	**46.6**
Si^{4+}	**27.72**
Al^{3+}	**8.13**
Fe^{2+}	5.00
Ca^{2+}	3.63
Na^{+}	2.83
K^{+}	2.59
Mg^{2+}	2.09
Others	1.41

Non- metals-74.32%

Metals—25.68%

ROCKS AND MINERALS

Rocks

Rocks are a naturally occurring **hard mass of mineral matter** formed after the solidification of molten magma comprising of two or more rock forming minerals *e.g.* granite, basalt, and gneiss.

But some may be monomineralic *e.g.* olivine, and dunite.

- ***Petrology*** is the branch of science which study about the rocks.
- ***Petrography*** -which gives information about description of rocks
- ***Petrogenesis*** which deals with origin of the rocks
- **Minerology-** Study of minerals

Rocks in the Earth Crust

Up to 5 km of the Earth's crust

Igneous rocks-18%

- Granite -15%
- Basalt-3%

Sedimentary rocks- 74%

- Shale- 52%
- Sandstone- 15%
- Limestone & Dolomite- 7%
- Others- 8%

Whole Earth' crust

Igneous rock– 95 %

Sedimentary rock- 5 %

- shale 4%,
- sandstone- 0.75%
- limestone- 0.25%)

Formation and Classification of Rocks

Igneous rocks:

- Non-laminar, massive structure, formed by cooling and crystalization of molten materials (magma) on or beneath the earth surface.
- 95% of earth's crust

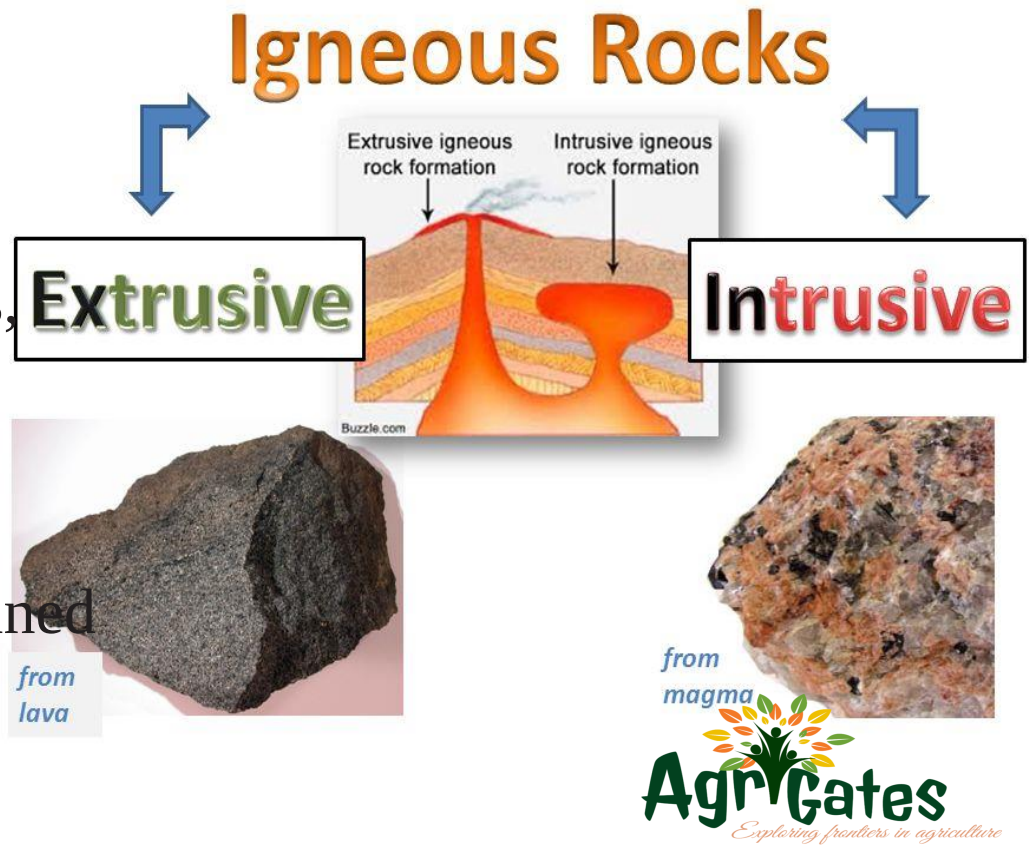
a. Based on origin

➢ ***Extrusive/ Volcanic-*** At the surface, fine size crystals, Formed a glassy structure

Eg: Basalt, Rhyolite, Trachyte

➢ ***Intrusive/ Plutonic-*** Beneath the surface- Coarse grained

Eg: Gabbro. Granite, syenite diorite

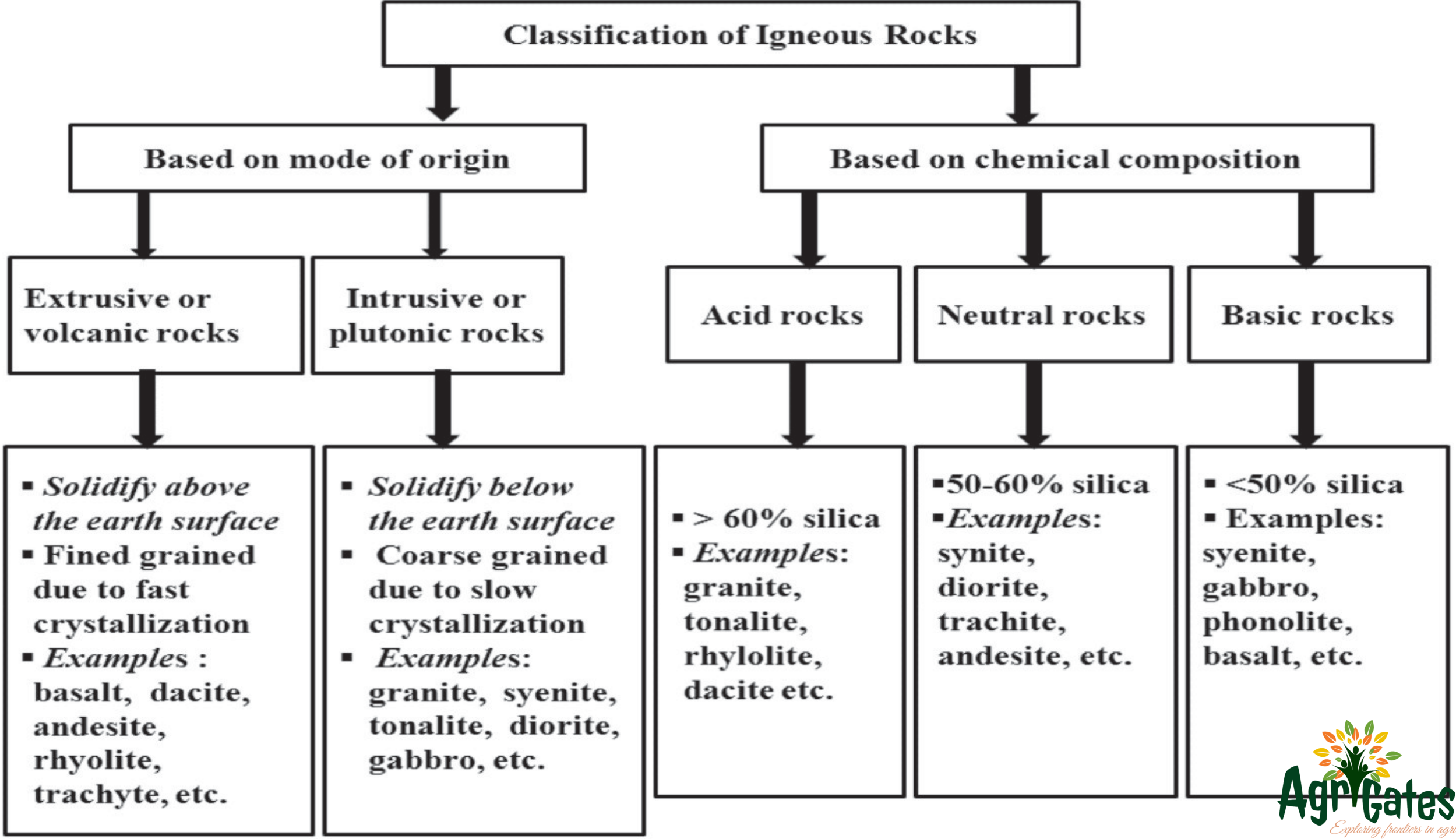


b. Based on chemical composition

- 3 main classes- based on relative amount of acid and basic components- acid, neutral, basic
- Acidic component- silicic acid or silica
- Basic components- soda, potash, Al, lime, magnesia, and iron oxides

➢ ***Acid/ Oversaturated-*** **>60% silica** – Eg: garanite

➢ ***Basic/ Under saturated-*** **<50% silica** – Eg: basalt


Classification of Igneous Rocks
Based on mode of origin
Based on chemical composition
Extrusive or volcanic rocks
Intrusive or plutonic rocks
Acid rocks
Neutral rocks
Basic rocks
▪ Solidify above the earth surface
▪ Fined grained due to fast crystallization
▪ Examples : basalt, dacite, andesite, rhyolite, trachyte, etc.
▪ Solidify below the earth surface
▪ Coarse grained due to slow crystallization
▪ Examples: granite, syenite, tonalite, diorite, gabbro, etc.
▪ > 60% silica
▪ Examples: granite, tonalite, rhylolite, dacite etc.
▪50-60% silica
▪Examples: synite, diorite, trachite, andesite, etc.
▪ <50% silica
▪ Examples: syenite, gabbro, phonolite, basalt, etc.

Important Igneous Rocks

- ***Basalt***: Most *abundant extrusive rock* formed from molten magma. Fine grained, dark coloured rocks, containing *50% feldspar and 50% ferromagnesian* minerals *(pyroxens and olivine*), basic in nature
- ***Gabbro***: Similar properties as ***basalt*** but coarse-grained.
- ***Granite***: Coarse textured, light colour, acidic in nature, contain *60-70% feldspar* (40- 45% orthoclase, 20-25% plagioclase), *20-30% quartz* and *3-10% ferromagnesian minerals.*
- ***Rhyolite***: Similar to ***granite*** but fine-grained.
- ***Pumice***: *Very light weight* rock, *specific gravity lower than water*, thus it *floats on water*. Texturally, it is like a *sponge*.

Sedimentary Rocks

Formed from sediments showing different stages of formation

- ***Weathering***: Physical, chemical and biological weathering of primary rocks give rise to quartz, secondary minerals and soluble substances (Ca, Mg, Fe, and salts.)
- ***Transportation***: Transportation of weathered material by water, wind, glaciers and runoff .
- ***Deposition or sedimentation***: Transported sediments settled to form *graded bedding***.** The coarse particles settle first followed by finer particles down the stream.
- ***Diagenesis*: *Transformation of unconsolidated sediments to hard rock*** with compaction and cementation processes.

Classification of Sedimentary Rocks

Fragmental, detrital or mechanically formed

- Formed by the deposition and cementation of fragments of pre-existing rocks.
- Varied in texture or structure
- Examples

Conglomerate : rounded fragment, coarse grained, quartz dominant

Breccia : angular fragment

Sandstone : found between coarse grained conglomerate and fine grained shale

Arkose : quartz and feldspar dominant sandstone

Shale : fine grained, composed of clay and silt

Chemically formed

Inorganically formed

By evaporation

Examples:

Halite : rock salt- more soluble (mineral of NaCl)

Gypsum (anhydride) : less soluble

By precipitation or flocculation

Examples:

Limestone, Dolomite

Organically formed or biochemically formed

- Formed due to accumulation and partial decomposition of organic remains under anaerobic condition.
- Examples:

Peat, lignite, anthracite (hard coal), coal, bituminous, semi-bituminous etc.

Important Sedimentary Rocks

- ***Shale:*** Fine grained detrital rock made up of clay and silt sized particles.
- ***Conglomerate:*** It is detrital rock made up of more or less rounded fragments. The rock is termed as ***breccia***, if the fragments are angular rather than rounded.
- ***Lime stone:*** It contains mainly calcite mineral, which is *formed by precipitation.*
- ***Sand stone:*** Mainly composed of quartz mineral. It is called ***arkose***, if quartz and feldspar are predominantly present. Its texture is intermediate between fine grained shale and coarse grained conglomerate.

Metamorphic Rocks

- Developed from the transformation of existing rocks (igneous and sedimentary rocks) by the process of metamorphism, which means "***change in form***".
- The chemical or physical changes in their original form are brought by the ***heat and pressure***
- **Thermal metamorphism-** Heat is the dominant factor
  - Also known as **contact or additive metamorphism**.
  - Addition of magmatic material to the metamorphosed rock
- **Dynamo thermal metamorphism-** Pressure and Heat forms one of the most powerful metamorphic force
  - Leading to more or less complete recrystallization of minerals with new structure
  - Associated with mountain building processes

Thermal metamorphism

Dynamo thermal metamorphism

- The structure and mineral composition of metamorphic rocks depend upon the composition of the original rock and the kind of metamorphism.
- The ***banded or laminated*** character is the most peculiar feature of the metamorphic rocks

Pre-existing rocks and their equivalent metamorphic rocks

Pre- existing rock	Metamorphic rock
Conglomerate/granite/syenite/gabbro	Gneiss
Shale	Slate
Basalt	Schist
Sandstone	Quartzite
Limestone/Dolomite	Marble
Coal	Graphite
Iron ores	Haematite- schist

Important Metamorphic Rocks

- ***Gneiss***: Crystalline rock, bended appearance. Feldspar, quartz, mica, biotite and muscovite are dominant minerals.
- ***Schist***: ***Finely foliated*** or laminated rock. Mica and chlorite are dominant minerals.
- ***Marble: Non-foliated***, crystalline rock. Calcite and dolomite are dominant minerals.
- ***Slate: Very fine foliated rock***, splits into thin smooth sheets. Mica, quartz and chlorite are dominant minerals.

SOIL FORMING MINERALS

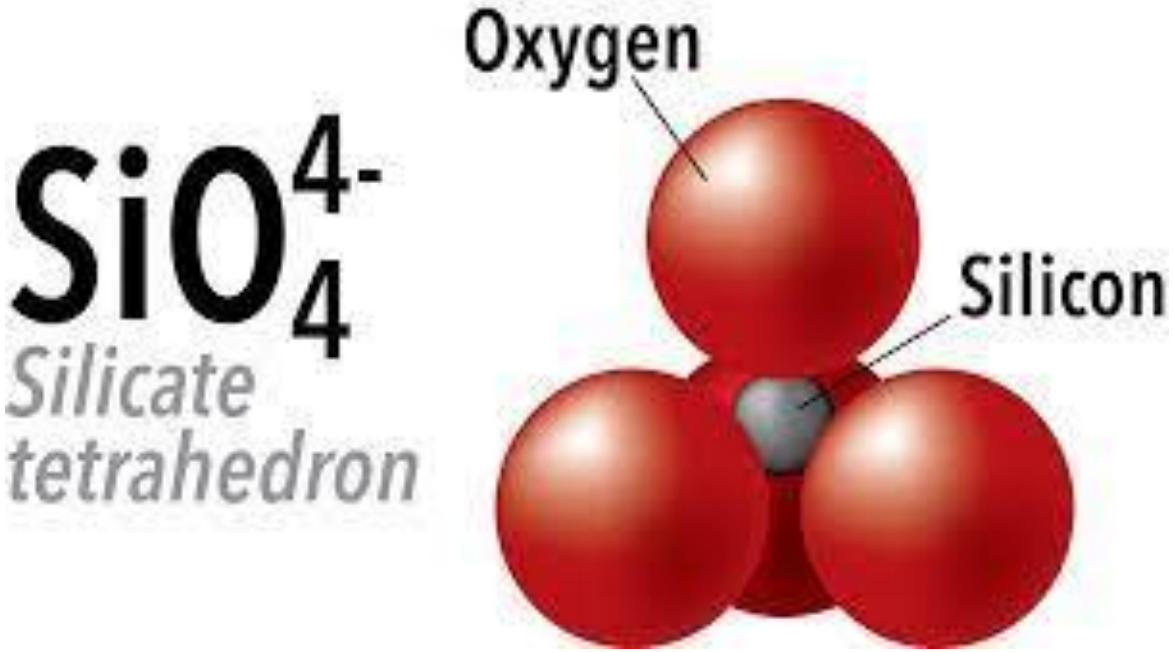
Minerals

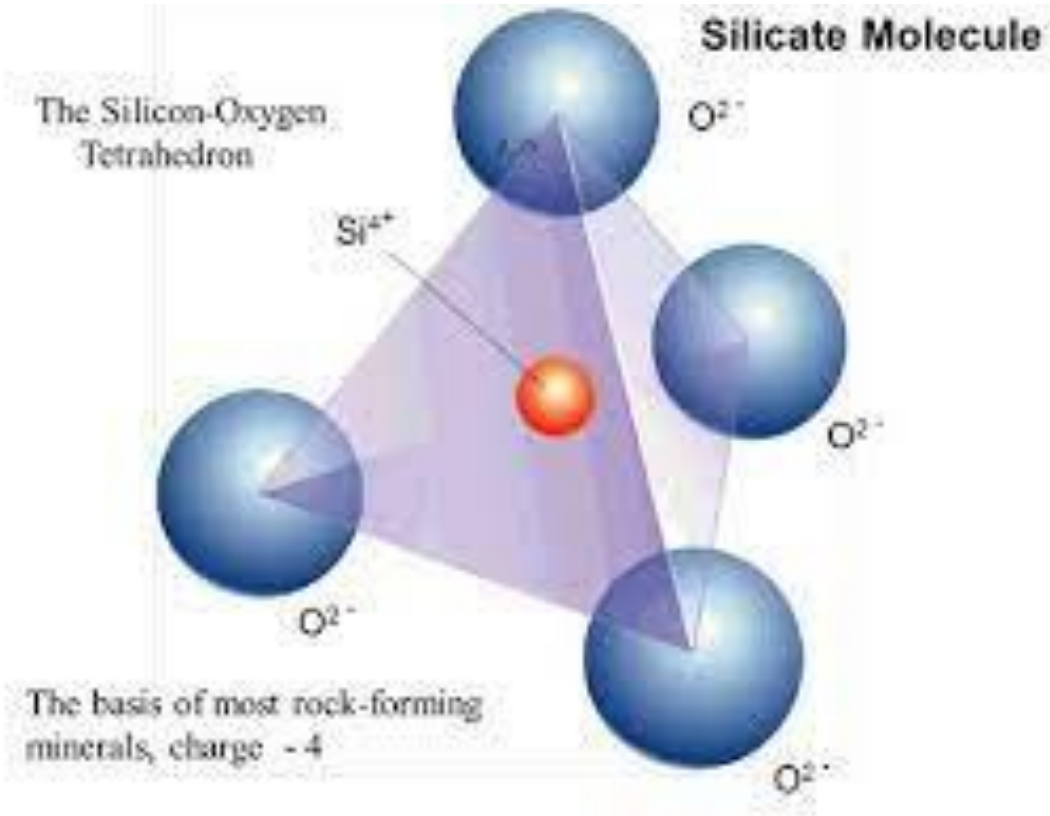
A mineral is a naturally occurring homogeneous inorganic solid, composed of atoms having orderly and regular arrangement with definite chemical composition and characteristic geometric form.

Formation of Mineral

- When molten magma solidifies, the different elements present therein freely arrange themselves in accordance with the attractive forces and geometric form.
- Geometrically it is possible to arrange only 4 oxygen atoms (with a radius of 1.32 Aº) around a central silicon cation (with a radius of 0.42 Aº) so that all are touching each other.
- This is the arrangement of tetrahedron.
- The ***silicate tetrahedron*** is the fundamental building block of all the silicate minerals of the Earth's crust.

- Charge carried by silicon ion is 4^+ and oxygen is 2^-
- In order to attain neutrality- one silicon (4^+) ion would combine with two oxygen ions ($2 \times 2^-$) to form SiO_2
- Geometrically stable SiO_4^{4-}





Classification of silicate minerals

Based on the tetrahedral linkage (sharing of oxygen) primary minerals are classified as follows

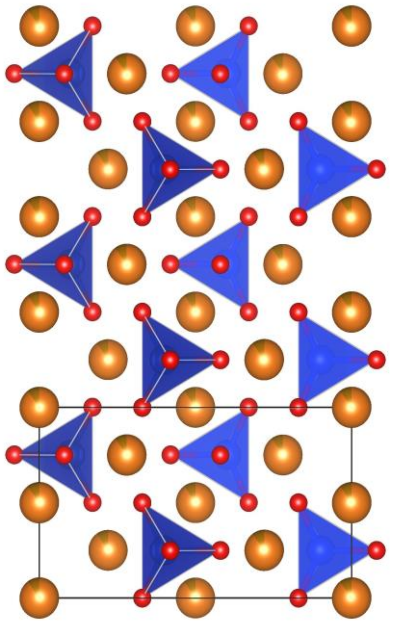
1. **Nesosilicates (or) Orthosilicates** (*Island silicates*) - ***No oxygen sharing*** and these are made up of ***individual silicon tetrahedral*** (SiO_4^{4-}), alternating with positively-charged metal ions.

Ex: Olivine $(Fe\ Mg)_2$, SiO_4

Fayalite Fe_2SiO_4

Forsterite $Mg_2\ SiO_4$

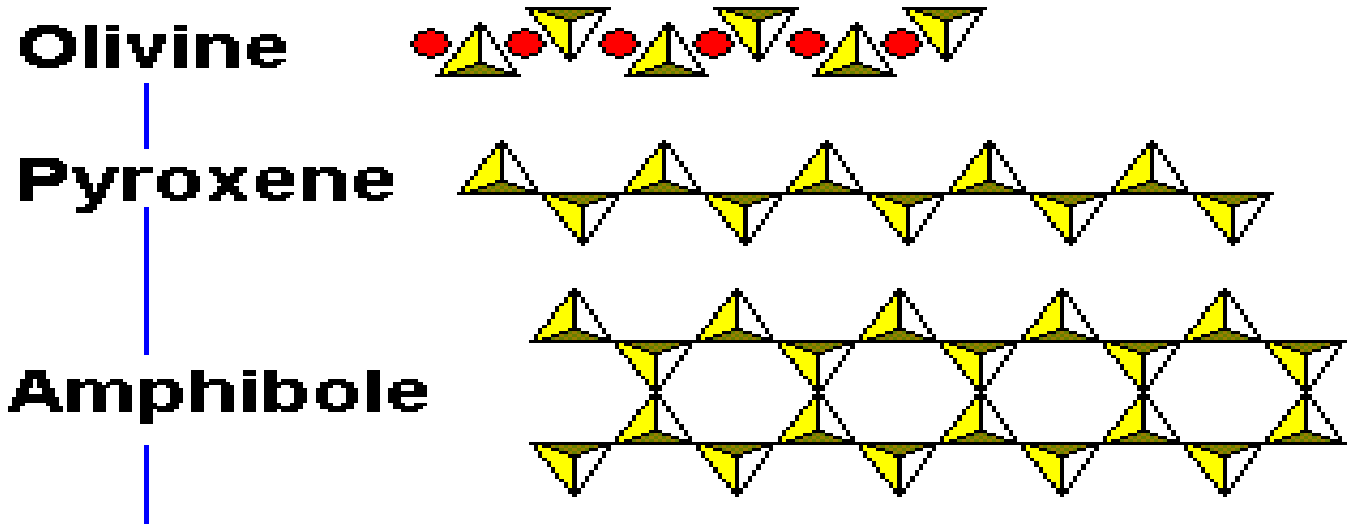
Zircon, Sphene, Topaz and Garnet



2. **Sorosilicates - *One oxygen sharing*** occur Ex: **Epidote**

3. Inosilicates (Chain silicates) – They divided into two types

- **Pyroxenes** (Single chain silicates) - ***Two oxygen ions*** are shared
  - Ex: Enstatite, *Augite*, Hypersthene, Diopside, Hedenbergite, Wollastonite and Rhodonite.
- **Amphiboles** (Double chain silicates) - ***Alternately two and three oxygen*** ions are shared
  - Ex: *Hornblende*, Tremolite, Actinolite, Cummingtonite and Grunerite



4. **Phyllosilicates** (*Sheet silicates*) **- 3 oxygen ions** are shared, *2-dimensional* sheet structure and having *Honey comb* structure.

Ex: Micas (Muscovite (White Mica), Biotite (Black Mica), Phlogopite) Chlorites, Clay minerals- Talc, Pyrophyllite, Kaolinite, Smectite, Vermiculite, Serpentines, Antigorite and Chrysotile

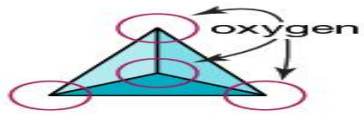
5. **Tectosilicates**– **4 oxygen ions** are shared, *3-d structure* can be formed and also called *framework silicates or Network silicates*

Ex: Feldspars (Orthoclase, Albite and Anorthite)

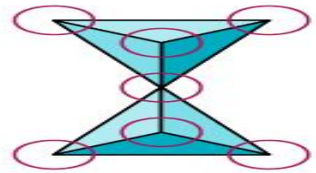
SiO_2 group (Quartz Tridymite and Cristobalite)

Structural linkage schemes among silicates

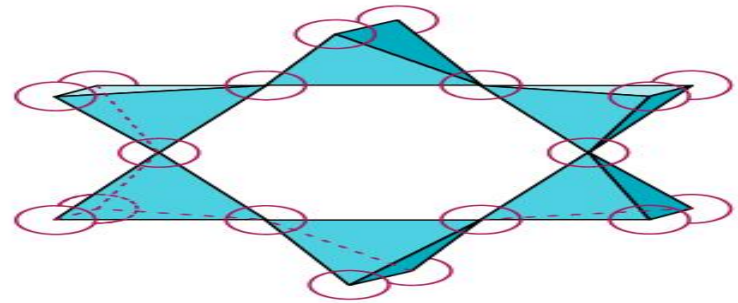
Nesosilicates
Unit composition: $(SiO_4)^{4-}$
Example: olivine,
$(Mg, Fe)_2SiO_4$



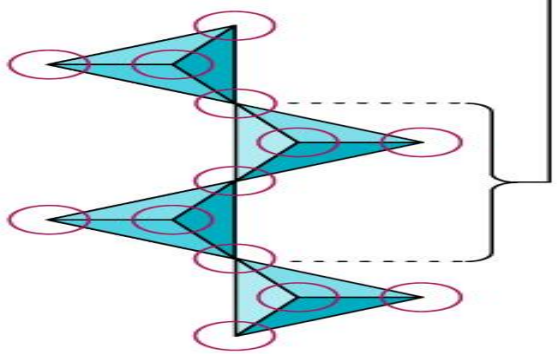
Sorosilicates
Unit composition: $(Si_2O_7)^{6-}$
Example: hemimorphite,
$Zn_4Si_2O_7(OH)_2 \cdot H_2O$

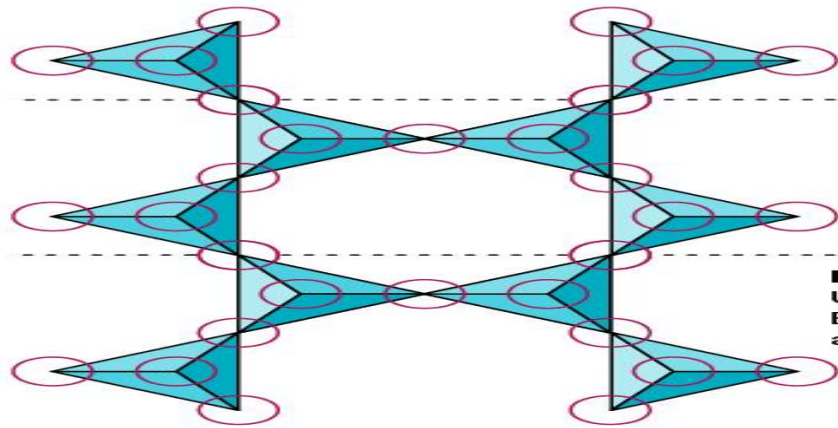


Cyclosilicates
Unit composition: $(Si_6O_{18})^{12-}$
Example: beryl,
$Be_3Al_2Si_6O_{18}$

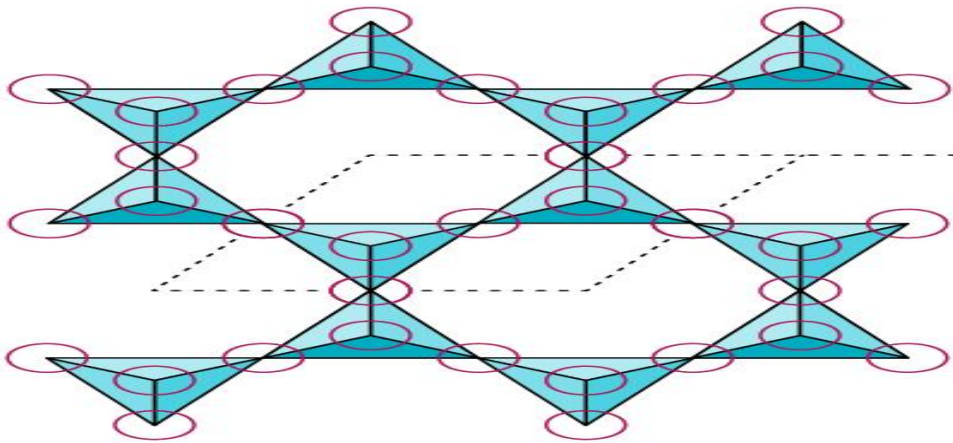


Inosilicates (single chain)
Unit composition: $(Si_2O_6)^{4-}$
Example: pyroxene—e.g.,
enstatite, $MgSiO_3$



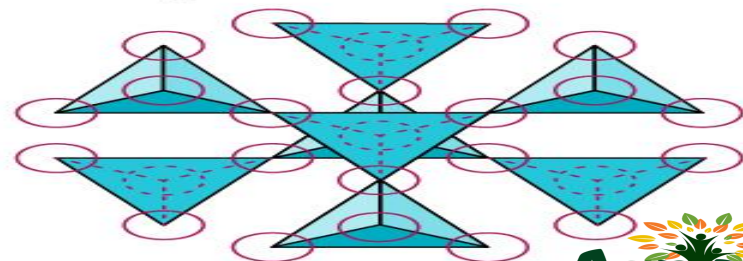


Inosilicates (double chain)
Unit composition: $(Si_4O_{11})^{6-}$
Example: amphibole—e.g.,
anthophyllite, $Mg_7Si_8O_{22}(OH)_2$



Phyllosilicates
Unit composition: $(Si_2O_5)^{2-}$
Example: mica—e.g.,
phlogopite, $KMg_3(AlSi_3O_{10})(OH)_2$

Tectosilicates
Unit composition: $(SiO_4)^{4-}$
Example: high cristobalite,
SiO_2



Silicate classes and Formula

Silicate class	Formula
Nesosilicate and Orthosilicate	$(SiO_4)^{-4}$
Sorosilicate	$(Si_2O_7)^{-6}$
Cyclosilicate	$(Si_6O_{18})^{-12}$
Single chain silicate	$(SiO_3)^{-2}$
Double chain silicates	$(Si_4O_{11})^{-6}$
Phyllosilicate	$(Si_2O_5)^{-2}$
Tectosilicates	(SiO_2)

Feldspar

- Most common mineral (61 % of earth's crust)
- Feldspars are aluminosilicates (X Al_2,Si_3 O_8), X- Na, K, Ca
- Present in sand and silt fractions of soil.
- Divided into two groups viz., *Orthoclase and Plagioclase*
- Orthoclase feldspars are mainly potassium feldspars- $KAlSi_3O_8$
- Plagioclase feldspars are either-

  Sodium Feldspar eg: Albite- Na $AlSi_3O_8$

  Calcium-feldspar eg: Anorthite- $CaAl_2Si_3O_8$

Quartz (SiO_2)

- High degree of purity and strongly resistant to weathering
- Present in almost all soils, of which sand and coarse silt fractions contain the largest

Pyroxenes and Amphiboles

Long chain of silica tetrahedra, also referred to as *inosilicates*

Pyroxenes
Single chain
Found in basic rocks
Weather easily
Eg. *Augite*

Amphiboles
Double chain
Found in acidic rocks
Weather slowly
Eg. *Hornblende*

Mica

- **Potash mica**: white, clear and transparent, known as *muscovite* mica
- **Magnesium mica**: Black , It is called *biotite* mica
- White mica is more resistant than black

Classification of Minerals

1. Mode of origin as

Primary Mineral

- **Formed by crystallization of molten magma** — **Silicate minerals**
- Inherited from igneous and metamorphic rocks — *Quartz, feldspar, pyroxenes, amphiboles, hornblende, olivine, mica*
- Formed at elevated temperature
- Chemically remain unchanged.
- Percentage in soil depends on its sand and silt content

- Oxygen and silicon together or with one or more cations are combined to form silicate minerals which are more than 90% in the earth crust.

Secondary minerals

Formed by weathering of primary minerals or inherited by soils from some sedimentary rocks

- Most common is clay minerals
- Other secondary minerals found in soils of arid and semi-arid (dry) regions are **gypsum, calcite, apatite** etc.

Silicates

(clay Minerals)

Kaolins, Smectites. Vermiculite, Mica Chlorite

Non-silicates

Hematite (Fe_2O_3)

Goethite ($FeO(OH)_n$ H_2O)

Gibbsite $\{Al(OH)_3\}$

Calcite ($CaCO_3$)

Dolomite $\{Ca.Mg(CO_3)_2\}$

Gypsum ($CaSO_4.2H_2O$)

Apatite $\{Ca_3(PO_4)_2\}$

2. Quantity as

Accessory Minerals

Occur only in **small quantities** in rocks but not essential **(2-5%)**

Form a group of heavy minerals due to their high specific gravity

Non-silicate

Zircon	$Zr(SiO4)$
Zeolite	Ca, Na,and K silicates
Pyrite	FeS_2
Magnetite	Fe_3O_4
Illemenite	$FeTiO_3$
Barytes	$BaSO_4$
Serpentine	$Mg6(Si4O10)\ (OH)8$

Essential mineral

Forms major part of the rock (**95-98%)**

Characteristic component of rock

Calcite and Silicate minerals

3. Specific gravity as

Light minerals	Having S.G below 2.85	Quartz 2.6 Feldspar 2.65 Muscovite 2.5—2.75
Heavy minerals	Having S. G above 2.85	Haematite 5.3 Pyrite 5.0 Limonite 3.8 Augite 3.1-3.6 Amphiboles 2.9—3.8 Olivine 3.5

4. Chemical composition

Native elements	Graphite Sulphur, gold, copper
Oxides and hydroxides	Quartz, Haematite
Sulphates	Gypsum and Pyrite
Carbonate	Calcite
Halides	Rock salt
Silicates	Orthoclase, Mica, and Olivine

Mafic and Felsic minerals

- **Mafic minerals-** Contain iron and magnesium in their structure –

  Ferromagnesian minerals- dark in colour

  Eg: Olivine, Pyroxenes, amphiboles, and biotite

- **Felsic minerals-** Devoid of iron and magnesium- ***Non ferromagnesian minerals-*** light in colour

  Eg: Feldspar, Quartz, clay minerals, muscovite mice

Identification of Minerals

1. Colour

Name of mineral	Colour
Quartz	Colourless
Feldspar, calcite, Dolomite, Gypsum, Muscovite	White to pale
Iron Pyrite **(Fools Gold)**	Yellow/Golden
Serpentine, Hornblende	Greenish
Garnet	Reddish- Brown
Biotite, Augite, Haematite, Graphite	Black
Orthoclase	Pink or flesh colour
Olivine	Olive-green
Goethite	Pink or grey
Limonite **(Bog Iron)**	Yellow to brown
Gibbsite (Hydrargillite)	Naturally white

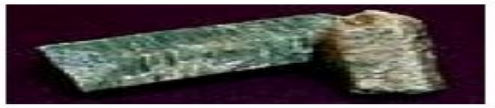
2. **Striations -** The parallel thread like lines or narrow bands running cross the surface of a mineral are called striations.

- These are clearly observed on crystals of *quartz, feldspars and pyrite*.

3. **Hardness -** *The resistance of a mineral to scratching* is known as hardness.

- The hardness is expressed in **Mho's scale** and identified by numerals *(1-10).*
- *Talc is the softest* and *Diamond is the hardest mineral* known

Hardness Mho's Scale

Mineral	Mohs Hardness	Image
Talc	1	
Gypsum	2	
Calcite	3	
Fluorite	4	
Apatite	5	
Feldspar	6	
Quartz	7	
Topaz	8	
Corundum	9	
Diamond	10	

4. **Lusture-** *General appearance of a mineral in reflected light*

- Characteristics of each mineral

5. **Transparency -** It is the *degree of penetration of light through a mineral*

Eg: Transparent - Mica

Translucent - Quartz

Opaque minerals - Pyrite and Magnetite

6. **Specific Gravity-**It is the ratio between the weight of a mineral or a substance to the weight of an equal volume of water.

- Based on specific gravity minerals at substance divided into heavy minerals and light minerals.

7. **Tenacity -** *The resistance that a mineral offers to breaking, crushing or bindings* known as tenacity.

8. **Cleavage -** *The tendency of a mineral to split in certain directions along smooth plane surfaces* is called cleavage.

Ex: Mica and Gypsum

9. **Fracture -** Property of mineral *to break along an irregular surface*

Ex: Glass and Quartz

10. **Pleochroism -** Some minerals *change colour when crystal is rotated on the stage of the polarizing microscope.*

Ex: Albite, Hornblende and Tourmaline

Some important points

- Zoning is commonly exhibited by minerals which are grouped together Isomorphous

  Eg: Albite, Anorthite series of Plagioclase

- *Orthoclase feldspars* are liable to *partial alteration*

- ***Magnetite*** shows a ***black appearance*** and Ilmenite shows ***silvery*** appearance in reflected light

- Apatite, Muscovite and Augite liable to property of ***angle of extinction***.

- **Siderite** ($FeCO_3$) mineral- mineral in ***waterlogged soils***

Weathering of Rocks and Minerals

Weathering refers to ***physical disintegration and chemical decomposition*** of rocks and minerals resulting in the formation of parent material.

It is basically a combination of transformation and synthesis *or* the process of disintegration and decomposition of rocks and minerals which are brought by physical, chemical and biological weathering, leading to formation of parent material.

Classification of weathering process

Physical weathering :

A mechanical process causing disintegration of consolidated massive rocks into smaller pieces under favourable climatic conditions through various agents viz. *temperature*, *water*, *ice* and *wind*

a) Temperature

- *A* differential expansion and contraction of minerals occurs owing to diurnal temperature changes resulting in peeling off the surface layers from the rocks (breakdown into small fragments).
- This phenomenon is called as ***exfoliation or onion- type weathering***.
- Eg: Basalt and granite
- Cold temperature causes freezing of entrapped water inside the rock which expands 9% in volume and exerts a pressure of about 1465 tonnes/m^2 (t m^{-2}) resulting in the break-down of rocks.

b)Water

- Most pronounced and widespread weathering agent.
- Action of flowing water - collision of rocks-- formation of smaller fragments -transported and deposited at the far-off places.
- Sediment-loaded water has tremendous capacity to cut the rocks and hard surfaces-- *gorges*, *ravines* and *valleys* are formed.

c)Ice

- Moving ice or glaciers cause great deal of cutting and crushing of the bedrocks.
- On moving, glaciers exert a tremendous pressure
- The loose material moves forward and gets deposited- This deposit is called *Moraine*.
- Eg: The huge boulders seen in Kangra valley of Himachal Pradesh

d) Wind

- An important agent of *transportation of suspended particles*
- Also exerts an abrasion effect - more pronounced in the aridic climates.
- Poorly grained or single – grained deposits are more prone to the wind erosion.
- Eg: The rounded rock (Mushroom rock) remnants in the Aravalis

  Prominent in Thar desert of Rajasthan.

Chemical Weathering:

- *Decomposition process* - takes place primarily at the junction of lithosphere and atmosphere called ***weathering front***.
- It leads to alteration or disappearance of some minerals and *formation of new minerals*.
- This process is generally dominant in tropical than in arid climate and governed by various agents.
- The rate of chemical weathering increases with increasing amounts of dissolved CO_2 and other minerals in water.
- The presence of organic and inorganic acids accelerates the chemical weathering.
- The chemical weathering has great role in conversion of primary minerals (*feldspars*, *mica*, *amphiboles etc*.) into secondary minerals (*kaolinite*, *montmorillonite*, *vermiculite etc*.).
- Most important process in soil formation

a) Solution

- Water is a universal solvent and its solubility action is enhanced with dissolved CO_2, organic and inorganic acids or salts in it.
- Decomposition of rocks depends on composition of rocks and solubility action of water.
- Eg: halite (NaCl) is readily soluble, quartz is sparingly soluble

- $H_2O + CO_2 \longrightarrow H_2CO_3$

b) Hydration

- Hydration means chemical *combination of water molecules with a mineral* to form a new mineral.
- Hydration reactions occur primarily on the surface and edges of mineral grains
- The adsorbed water provides a bridge or entry for the hydronium ions (H_3O^+) or hydrogen ions (H^+) to attack the structure.
- Commonly occur in secondary minerals like *aluminium oxide*, *iron oxides* and *gypsum*

- $CaSO_4 + ½\ H_2O \longrightarrow CaSO_4.0.5H_2O$ (Hemihydrate)
- $CaSO_4 + 2H_2O \longrightarrow CaSO_4.2\ H_2O$ (Gypsum)
- Olivine + $H_2O \longrightarrow$ Serpentine
- $2Fe_2O_3 + 3\ H_2O \longrightarrow 2Fe_2O_3.3\ H_2O$

c) Hydrolysis

- Hydrolysis is one of the *most important* processes of chemical weathering.
- Dissociation of water (H_2O) into hydrogen (H^+) and hydroxyl (OH^-) ions.
- It is a type of *double decomposition process*, in which CO_2, minerals and organic acids-rich water get easily dissociated into H^+ and OH^- ions which chemically combine with a mineral and form a new mineral.
- Hydrolysis reactions may be considered as the *fore- runner* in clay formation (secondary clay minerals).

$$H_2O \longrightarrow H^+ + OH^-$$

$$KAlSi_3O_8 + H_2O \longrightarrow HAlSi_3O_8 + KOH$$

(orthoclase) (Clay minerals)

d) Oxidation

- Oxidation is *combination of oxygen* dissolved in water or from atmospheric air with exposed rocks or minerals.
- It is an important chemical reaction occurring in the *well-aerated* rock and soil materials where oxygen supply is high and biological demand is low.
- Rocks containing pyroxenes, hornblende, biotite, glauconite and chlorite etc. are susceptible to oxidation- Contain Mn^{2+} and S^{2-}
  - $4FeO + O_2 \longrightarrow 2Fe_2O_3$
  - $4Fe_3O_4 + O_2 \longrightarrow 6Fe_2O_3$

(Magnetite) (Haematite)

e) Reduction

- The process of *removal or loss of oxygen* is called reduction.
- Occurs where a mineral is water-saturated, oxygen supply is very low and biological demand of oxygen (BOD) is very high,
- Conversion of the higher valent metals to the low valent states (e.g. Fe^{3+} into Fe^{2+}).
- Lepidocrocite is also formed in this condition which imparts orange and yellow mottles to soil matrix under reduced conditions.
  - $2Fe_2O_3 \longrightarrow 4FeO + O_2$
  - $6Fe_2O_3 \longrightarrow 4Fe_3O_4 + O_2$

f) Carbonation

- Carbonation is the combination of carbon dioxide with any base.
- When water reacts with CO_2 it gives carbonic acid (H_2CO_3), which is a very important agent of chemical weathering of rocks and minerals.
- The solubility of calcium bicarbonate ($CaHCO_3$) is considerably higher than that of calcite ($CaCO_3$).
  - $H_2O + CO_2 \longrightarrow H_2CO_3$
  - $CaCO_3 + H_2CO_3 \longrightarrow CaHCO_3$

    (insoluble) (soluble)

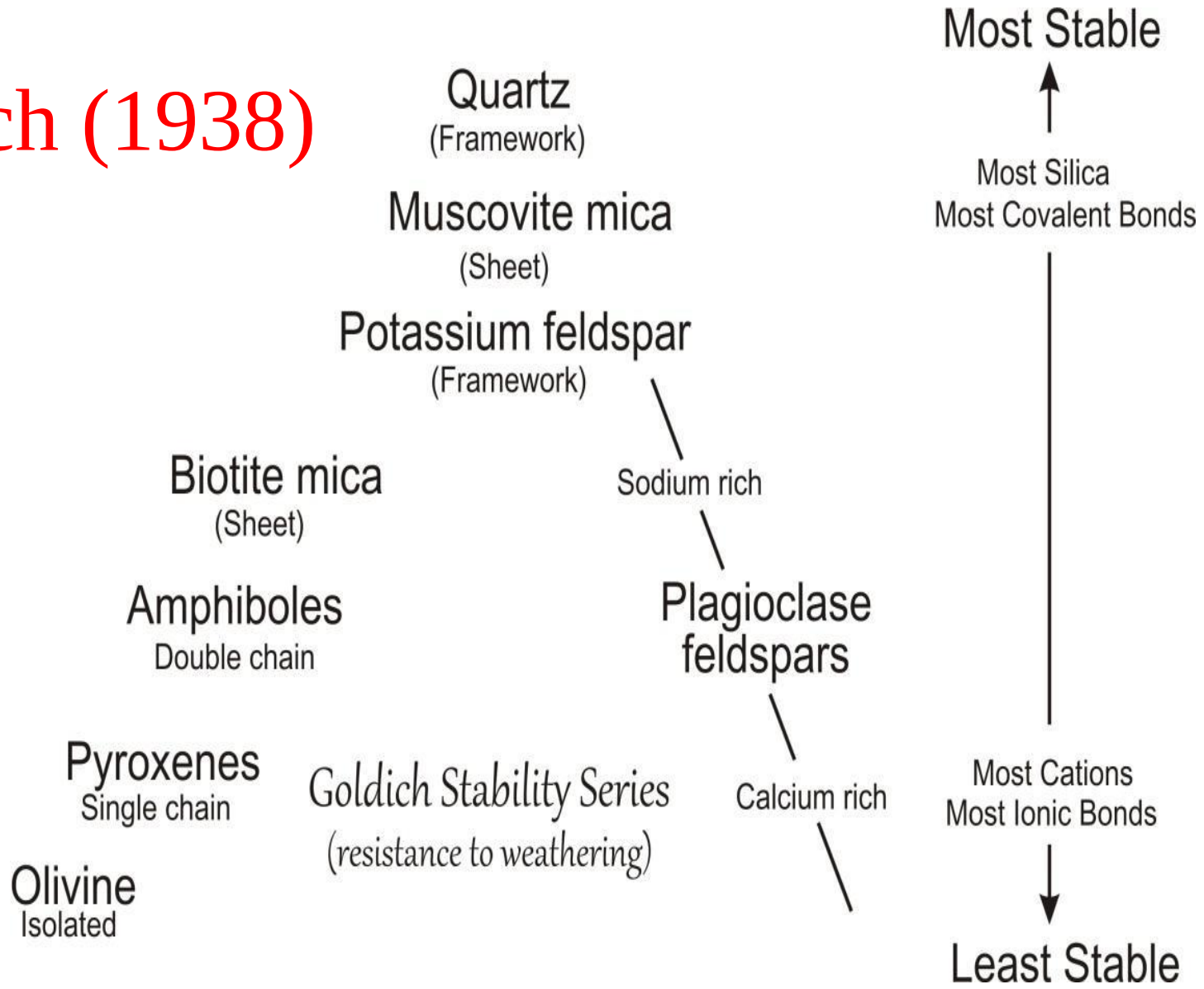
Important Points….

- Most important chemical weathering process- *Hydrolysis*
- Most important chemical weathering process in primary minerals- *Hydrolysis*
- Results in complete disintegration and drastic modification of primary minerals- *Hydrolysis*
- Most important chemical weathering process in secondary minerals- *Hydration*
- Double decomposition process- *Hydrolysis*
- Forerunner of clay formation- *Hydrolysis*
- Vermiculite can be formed from muscovite by *Hydrolysis*
- Serpentine formed from olivine by *Hydration*
- Haematite from magnetite by *Oxidation*
- Bog iron from Haematite by *Hydration*

Biological Weathering

- Change brought by living agents - controlled by prevailing environment - responsible for both physical and chemical changes.
- The mosses and lichens growing on rocks secrete chemical exudates which act chemically on the minerals present in the rocks and tend to form new minerals.
- Burrowing animals, movement of animals and human activities facilitate the physical weathering.

Stability series- Goldich (1938)



Weathering index
- Jackson (1964)

Stage	Typical Minerals
EARLY WEATHERING STAGES	
1	Gypsum
2	Calcite
3	Olivine, pyroxene, hornblende
4	Biotite, glauconite
5	Albite, anorthite
INTERMEDIATE WEATHERING STAGES	
6	Quartz
7	Muscovite, illite
8	Vermiculite and mixed layer minerals
9	Montmorillonite
ADVANCED WEATHERING STAGES	
10	Kaolinite, halloysite
11	Gibbsite, boehmite
12	Haematite, goethite
13	Anatase, rutile, zircon

Stages of weathering

Name of stage	Stage of weathering
Initial	Un weathered parent material
Juvenile	Weathering just started but most of the original material can be seen
Virile	Less resistant minerals decompose easily and increase clay content
Senile	Only resistant minerals can be seen like quartz
Final	Formation of soil over

SOIL FORMING FACTORS

- Dokuchaev (1889) established that the soils develop as a result of the action of soil forming factors

  S= f (p, cl, o)

- Jenny (1941) – added two factors- relief and time

  S= f (cl, b, r, p, t)

S= f (cl, b, r, p, t)- **Jenny** (1941)

Joffe (1949)

- **Active**
  - cl- climate
  - b- biosphere
- **Passive**
  - r- Relief
  - p- Parent material
  - t- Time

Climate

- Most influential factor – Precipitation and Temperature
- *Rainfall- more significant climatic element*
  - *Arid climate- Saline soils*
  - *Cool humid climate- Podzols*
  - *Warm humid climate- Laterites*
- Temperature- Second most important
- Van't Hoff Law- With every 10 ^{0}C rise in temperature, speed of chemical reaction increases by a factor of two or three

Biosphere

- *Macro-organisms* such as rodents, moles, snails, earthworms, termites, milliped centipedes etc.- *burrowing habit*, cause mixing of soil material
- Retard the differentiation of soil horizons and as a consequence retard the process of soil development
- *Microorganisms* such as bacteria, fungi actinomycetes, protozoa and nematodes- decomposition of organic matter
- Rapid decomposition of mineral and organic matter leads to formation of soil

Relief or Topography

- Configuration of land surface describe in terms of elevation or slope
- Gently-sloping flat land is ideal for soil development
- Soil Catena-Milne (1935)
- A sequence of soil developed from similar parent material under similar climatic conditions but under varying conditions of relief.

Parent Material

- Jenny (1941) defined parent material as “the initial stage of soil system
- Loose unconsolidated mass of mineral matter formed upon the weathering of rocks which serves as the raw material for soil formation.
- *The initial stage of soil formation and soil properties are governed by the nature of parent material but with the time the influence of parent material on soil properties gradually diminishes.*
  - **Residual-** (formed in place/ insitu) Soils are developed at a place from the underlying rocks
  - **Transported-**

Parent material	Source
Colluvium	Gravity
Alluvium	Water
Aeolian	Wind- sand dunes
Loess	Wind- Silt or silt with fine sand and clay
Lacustrine	Lake water
Marine	Sea an ocean
Till/Morine	Glacial till (Ice)

Endodynamomorphic soils-under the influence of parent material

Eg: Calcimorphic and hydromorphic soils

Ectodynamomorphic- formed mainly due to climate

Eg: Podzol and Laterite soils

Time

- The period of time devoted by the nature from the stage of parent material to the stage of soil formation is considered as "**pedologic time"**
- *Warm humid climate*, *flat to gently sloping* topography, *sandy parent materials* are *favourable for soil formation*
- Cold and arid climate, clayey parent material, steep slope, flood plains and activities of burrowing animals retard the pace of soil profile development

Soil Forming Processes

The basic processes (According to Simonson)

1. ***Addition*** or ***gain*** of water, mineral and organic matter in the soil
2. ***Losses*** of the above materials from the soil
3. ***Transformation*** of mineral and organic materials with in the soil
4. ***Transfer*** or ***translocation*** of energy and matter (mineral or organic)

Fundamental Pedogenic Process

1. ***Humification-*** It is the process of transformation of raw organic matter into humus

- Raw organic materials - simple organic acids- Bacterial polymerization- dark brown colloidal substance resistant to microbial attack is called humus

2. ***Eluviation*** (Emigration) - Process of removal (wash out) of soil constituents

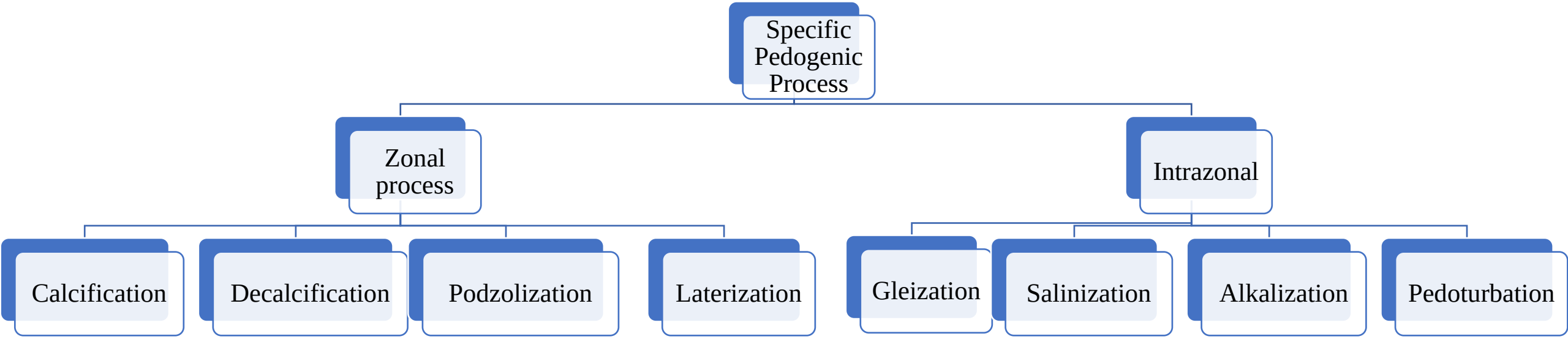
This process occurs in E-borizon or A_2 horizon of soil profile.

Order of mobility of inorganic soil constituents expressed relative to $Cl>SO_4>Ca>$ Na $>Mg>K>SiO_2 > Fe_2O_3>AI_2O_3$

3. ***Illuviation*** (Immigration)- Process of deposition of simpler soil constituents removed from upper layer to the lower layer

- This process occurs in B-horizon of soil profile

SPECIFIC PEDOGENIC PROCESS



Zonal Soil Forming Processes

The soil forming processes that are occurring under the prevailing conditions of climate and biosphere

Intrazonal Soil Forming Process:

These pedogenic processes are more influenced by certain local conditions such as relief or parent material than climate and vegetation.

Ex: Hydromorphic, halomorphic and Calcimorphic soils

Zonal Soil Forming Process

a) Calcification

- Process of precipitation and accumulation of calcium carbonate ($CaCO_3$) in some part of soil profile is called calcification
- occurs in arid and semi arid climates

b) *Decalcification*

- Process of removal of $caco_3$, or ca ions from the soil by leaching
- Process occurs in the humid climates

C) Podzolization

- Process of accumulation of silica and removal sesquioxides (Fe and Al oxides)
- "**Acid hydrolysis**" - pH. of soil remains below 5.0 due to the leaching of bases
- *Climate cold-humid*
- *Vegetation - coniferous (acidic nature and narrow leaf)*
- *Parent material- sandy (siliceous)*
- *Dominant organism - fungi*

d) Laterization

- Process of accumulation of sesquioxides and removal of silica.
- **Alkali hydrolysis**- pH remains alkaline to neutral.
- *Climate- Warm-humid*
- *Vegetation- Broad leaf tropical vegetation (basic nature)*
- *Parent material- Basic parent materials that contain high Fe (Ferromagnesian minerals)*
- *Dominant organism- Bacteria*

Intrazonal Soil Forming Process

a) Gleization

- Process results in the development of a gley horizon (g) in some part of profile due to poor drainage condition, impervious soil parent material, lack of aeration etc.
- Hydromorphic soils will be developed due to Gleization process.

b) Salinization

- The process of accumulation of salts such as SO_4^{2-} and Cl^- of Ca, and Mg in soil in the form of a salic horizon (z) leading to formation of saline soil
- In arid and semi arid climate
- White alkali soils/ Solonchalks

c) Alkalization

- Process of accumulation of sodium ions on exchange complex of the clay- alkali soils
- Black alkali soils- Sodic/Solonetz
- Contains mostly carbonate and bicarbonate of Na

Dealkalization/ Solodization- Removal of Na from exchange sites

d) Pedoturbation

Process of mixing of soil materials

- *Faunal Pedoturbation* - Mixing of soil by animals
- *Floral Pedoturbation* - Mixing of soil by plants
- *Argillo Pedoturbation* - Mixing of soil by churning process caused by swell shrinking of clays

- ***Clay migration" or Lessivage*** **-** Removal of clay, particularly of fine clay in suspension from the upper part of soil profile and its accumulation in lower part.
- ***Braunification or Rubification or Ferruginisation*** **-** Release of Fe from primary minerals and their dispersal as coatings on soil particles or as complexes with organic matter/clay or as discrete aggregates to impart a brown to red colour to the soil.
- ***Regur Formation*** **-** Formation of intensity dark colour complex of smectite clay and humus. Dominant process in black cotton soils

Thank You!

AgriGates

Exploring frontiers in agriculture

Lets Discuss Now..

Soil Science

The science dealing with soil as a natural resource on the surface of the earth, including Pedology (soil genesis, classification and mapping), physical, chemical, biological and fertility properties of soil and these properties in relation to their management for crop production.”

Soil is at the interface between the atmosphere and lithosphere. Its upper limit is air or water.