

ASAC 1101 (2-1-0)

FUNDAMENTALS OF SOIL SCIENCE

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MODULES

- I. OVERVIEW
- II. SOIL PHYSICAL PROPERTIES
- III. SOIL PHYSICOCHEMICAL PROPERTIES
- IV. SOIL ORGANIC MATTER AND SOIL BIOLOGY
- V. SOIL CLASSIFICATION AND SOIL POLLUTION



01. Soil – Pedological and Edaphological concepts

Soil science is the study of soil as a natural resource on the surface of the earth including soil formation, classification and mapping; physical, chemical, biological, and fertility properties of soils; and these properties in relation to the use and management of soils.

Sometimes terms which refer to branches of soil science, such as pedology (formation, chemistry, morphology and classification of soil) and edaphology (influence of soil on organisms, especially plants), are used as if synonymous with soil science. The diversity of names associated with this discipline is related to the various associations concerned. Indeed, engineers, agronomists, chemists, geologists, physical geographers, ecologists, biologists, microbiologists, sylviculturists, sanitarians, archaeologists, and specialists in regional planning, all contribute to further knowledge of soils and the advancement of the soil sciences.

Soil scientists have raised concerns about how to preserve soil and arable land in a world with a growing population, possible future water crisis, increasing per capita food consumption, and land degradation.

Soil occupies the pedosphere, one of Earth's spheres that the geosciences use to organize the Earth conceptually. This is the conceptual perspective of pedology and edaphology, the two main branches of soil science. Pedology is the study of soil in its natural setting. Edaphology is the study of soil in relation to soil-dependent uses. Both branches apply a combination of soil physics, soil chemistry, and soil biology. Due to the numerous interactions between the biosphere, atmosphere and hydrosphere that are hosted within the pedosphere, more integrated, less soil-centric concepts are also valuable. Many concepts essential to understanding soil come from individuals not identifiable strictly as soil scientists. This highlights the interdisciplinary nature of soil concepts.

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 Science has six well defined and developed disciplines

Soil fertility : Nutrient supplying properties of soil

Soil chemistry	:	Chemical constituents, chemical properties and the chemical reactions
Soil physics	:	Involves the study of physical properties
Soil microbiology	:	Deals with micro organisms, its population, classification, its role in transformations
Soil conservation	:	Dealing with protection of soil against physical loss by erosion or against chemical deterioration i.e excessive loss of nutrients either natural or artificial means.
Soil Pedology	:	Dealing with the genesis, survey and classification

Views on Soil (Science)

The term SOIL was derived from the Latin Word "SOLUM" Means FLOOR

- For a Layman soil is dirt or debris
- For an Agriculturist soil is a habitat for plant growth (to grow crops)
- For a Mining Engineer soil is a debris covering the Rocks
- For a Civil Engineer soil is a material on which road bed or house bed is formed
- For a Home Owner soil is a mellow or loamy or hard material

Definitions

Generally soil refers to the loose surface of the earth as identified from the original rocks and minerals from which it is derived through weathering process.

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

Soil Science Society of America (1970)

(i) Soil is the unconsolidated mineral matter on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of parent material, climate (including moisture and temperature effects), macro and microorganisms and topography, all affecting over a period of time and producing a product, that is "SOIL" that differs from the material from which it is derived in many, physical, chemical, biological and morphological properties and characteristics.

(ii) The unconsolidated mineral material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.

Dr. W.E.H. Blum

Soils not only serve for agriculture and forestry, but also for filtering, buffering and transformation activities between the atmosphere and the ground water, protecting the food chain and drinking water against pollution and biodiversity

As soil provides nutrients, water, air and anchorage and supports life on Earth, it can be called as Soul Of Infinite Life (SOIL)

List of International Soil Scientists

1. Van Helmont (1577 – 1644)
2. Theoder De Saussure
3. John Woodward
4. Boussingault (1802 – 1882)
5. J.V. Liebig (1803 – 1873)
6. J.B.Laws & J.H. Gilbert (1855)
7. J.T.Way (1856)
8. R.Warrington (1876)
9. E.W. Hilgard (1860)
10. V.V. Dokuchaiev (1846-1903)
11. K.D.Glinga (1914)
12. C.F.Marbut (1927)
13. Hens Jenny (1941)

Indian Scientists

1. J.W.Leather (1906)
2. Madam Scholasky (1932)

3. Wadia et al. (1935)
4. Viswanath & Ukil (1943)

Soil as a three dimensional body

Soil is a three dimensional body having length, breadth and depth. 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.

Composition of soil on volume basis (Soil components)

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

Soil can be compared to various systems of animals

Digestive system	: Organic matter decomposition
Respiratory system	: Air circulation & exchange of gases
Circulatory system (blood)	: Water movement within the soil
Excretory system	: Leaching out of excess salts
Brain	: Soil clay
Colour	: Soil colour
Height	: Soil depth

Approaches of Soil Study

Two Concepts: One treats soil as a natural body, weathered and synthesized product in nature (Pedology) while other treats soil as a medium for plant growth (Edaphology).

Pedological Approach: The origin of the soil, its classification and its description are examined in Pedology. (From Greek word *pedon*, means soil or earth). Pedology is the study of soil as a natural body and does not focus on the soil's immediate practical use. A pedologist studies, examines and classifies soil as they occur in their natural environment.

Edaphological Approach: Edaphology (from Greek word *edaphos*, means soil or ground) is the study of soil from the stand point of higher plants. Edaphologists consider the various properties of soil in relation to plant production. They are practical and have the production of food and fibre as their ultimate goal. They must determine the reasons for variation in the productivity of soils and find means for improvement.

Soil

- As early as 5000BC, the Vedas and Upanishad as well as other Indian literature mentioned soil as synonymous with land – the Mother – supporting and nourishing all life on earth.
- For a laymen it is the dirt and dust on the surface of the earth.
- To the farmer, soil is that portion of the earth's surface which he can plough and grow crops to provide him with food and fiber for his own needs and that of animals, to the poor man.
- For a mining engineer soil is debris covering the rocks
- For engineers soil is any unconsolidated material removed in excavations and used for filling or provide foundation structure

Definitions:

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Simonson (1957): The soil is three dimensional body having length, breadth and depth which form a continuum over the land surface and differ gradually from place to place.

Soil Science Society of America (1970):

(i) The unconsolidated mineral material on the immediate surface of the earth that serves as a natural medium for the growth of plants

(ii) Soil is the unconsolidated mineral matter on the surface of the earth that has been subjected to and influenced by genetic and environmental factors viz. parent material, climate, macro and microorganisms and topography, all affecting over a period of time and producing a product, that is “SOIL” that differs from the material from which it is derived in physical, chemical, biological and morphological properties and characteristics.

Land and Soil:

- Land and soil are often confused by students as synonymous. Land is broadly defined as total natural environment of the areas of the earth not covered by water. In addition to soil, its attributes include all the living organisms, the air and water bodies with in or on it and rocks below.
- Soil forms a part of an ecosystem which is the base functional unit of ecology including both biotic and abiotic environment mutually influencing each other to maintain dynamics of life on earth.
- The biotic component comprises all the living organisms whereas the abiotic component consists of the solid mineral matter on earth, the water in the oceans, lakes, river etc., the gaseous mixture in the air and radiant solar energy.
- Soil as natural body: The scientist considers the soil to be a natural body having both depth and surface (L X B) area. In fact, the soil is product of nature resulting from both destructive and synthetic forces. The weathering of rocks and minerals and decomposition of the organic matter are the examples of destructive processes. Whereas, formation of various minerals, clays and development of different horizons are synthetic processes. Thus, a scientist considers the soil as a habitat for the plants. He recognizes the contribution of plants in the development of soil and also its importance in crop production. The term soil is derived from Latin word "Solum" which means the floor.

Major component of soil:

- Soil is composed of partly weathered, unweathered, transformed products of rocks, rock minerals and organic matter.
- The mineral soil consists of four major components/phases: mineral material and organic matter (solid), water (liquid) and air (gases). In an ideal surface soils these components are observed in amounts (by volume, Fig.2) as follows,

Solid Phase (Mineral matter): The solid phase is broadly composed of inorganic and organic constituents. The inorganic constituents which forms bulk of solid phase of soil includes silicates, carbonates, soluble salts and free oxides of Fe, Al and Si in addition to some amorphous silicates. Only a small fraction of the solid phase is of organic origin. The sources of organic constitutes are plant and animals. Of total volume, about half is solid space, 45 per cent mineral matter and 5 % organic matter.

Liquid phase (Soil water): Forty to fifty per cent of the bulk volume of the soil body is occupied by soil pores, which may be completely and partially filled with water. The soil acts as a reservoir for supplying water to plants for their growth. The soil water keeps salts in solution which act as plant nutrients. Thus, liquid phase is an aqueous solution of salts.

Gaseous Phase (Soil air): The air filled pores constitutes the gaseous phase of the soil system. The volume of the gaseous phase is thus dependent on that of liquid phase. The nitrogen and

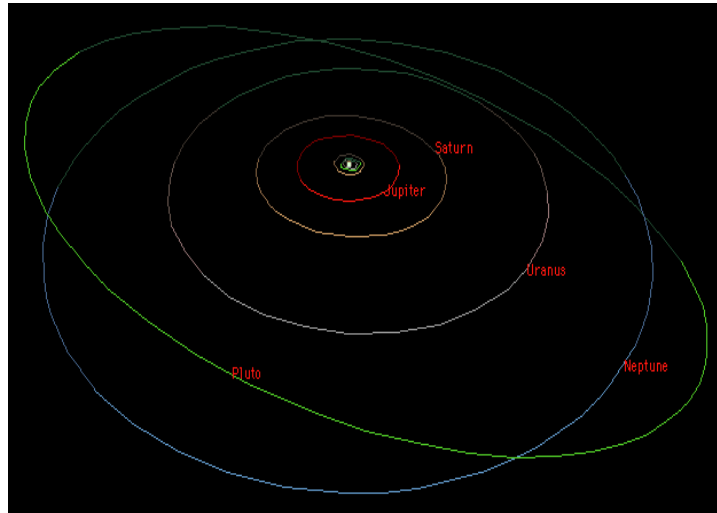
oxygen contents of soil air are almost same as that of atmospheric air but concentration of carbon dioxide is much higher.

The four major components of a typical soil exist mainly in an intimately mixed condition. The proportion of these components may vary from time to time and from place to place. The volume composition of sub-soil is different from the surface soil. Compared to top soils they are lower in organic matter content, lower in total pore space and contain a higher percentage of small pores. This means they have a higher percentage of mineral and water and considerable lower content of organic matter and air.

Origin of the earth – Earth's crust – Composition

Origin of earth

Earth is one of the 9 planets (8 excluding Pluto) orbiting the SUN in the Solar System. The Universe is composed of several Galaxies. Our solar system is part of Milky way galaxy which is disk shaped with about 1, 00,000 million stars of varying sizes. Our solar system consists of 9 planets and 31 satellites, a belt of asteroids.



Theories about origin of Earth

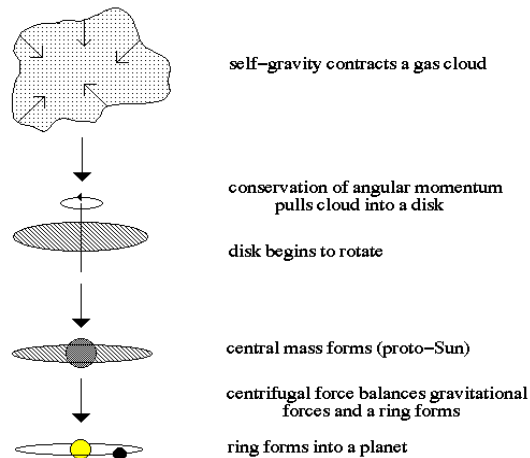
Nebular hypothesis (Kant and Laplace, 1755)

This hypothesis suggests that the solar system formed through the condensation of a nebula which once encircled the Sun. The outer planets formed first, followed by Mars, the Earth, Venus, and Mercury. This hypothesis suggests a sequential origin from outermost planet to innermost. As per this hypothesis, Mars evolved earlier than the Earth. This hypothesis is widely accepted to explain origin of different planets.

During the past, the entire solar systems existed as a hot gaseous mass called nebula rotating in space. With time, the gaseous mass (nebula) cooled and contracted. Due to contraction, there developed a bulge at the equatorial region. This bulge subsequently separated into several rings. The ring coalesces in the form of a globe and continues to revolve around the nebula. In similar manner, ten rings were formed of which nine of them gave rise to nine planets.

One broke down into smaller fragments to form the group of planetoids, while the remnant of the pre-existing nebula formed the central incandescent mass of the solar system and is known as the **Sun**. The planets were originally gaseous but were subsequently cooled down into liquid and ultimately to the solid state.

Nebular Hypothesis



Planetesimal hypothesis (Chamberlain and Moulton, 1905)

Planets were formed as a result of mutual interaction between the sun and another star of suitable size. This is the theory of **biparental** origin of the solar system. This theory postulates that due to the near approach of a larger star, tidal distortions were raised upon the surface of the sun and these in conjunction with the eruptive force prevalent in the sun (known as the solar prominence) brought about a description of the mass of the sun and a number of gaseous bulbs were shot forth, in space, to great distances.

These gaseous solar materials thus ejected in space were subjected to immediate chilling, resulting in the formation of a number of minute solid particles known as **planetisimals**

These planetisimals continued to rotate round the sun in highly elliptical orbits. The orbits must have happened to intersect one another and at points of intersection, they must have collided whereby the small planetisimals continued to coalesce gradually giving rise to the planets. During collision and coalescence of the planetisimals, large quantities of heat must have been generated and were dissipated in space before the next collision could occur and accordingly the planets must have been solid all the time during the growth. This theory accepts that the collision must have taken place in quick succession and accumulation of heat might have caused a melting of the masses of the planets.

Gaseous tidal hypothesis (Jeans and Jeffreys, 1925)

This also accepts the idea of biparental origin like that of planetesimal hypothesis but refuses to consider the disruptive forces in the sun (i.e. the solar prominence) had anything to do with the formation of the planets.

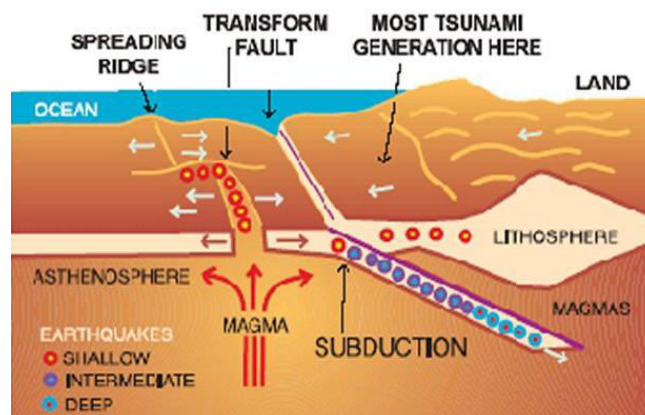
According to Jeans and Jeffreys, during the ancient past, an extremely large star, while moving in space chanced to approach the sun. Due to progressive and nearer approach of the star, a tidal pull was raised on the surface of the sun and this increased in size with the

nearer approach of the passing star. At the stage, where the passing star began to recede, the tidal pull on the surface of the sun, thus formed, was detached from the body of the sun in the shape of a spindle bulging near the centre and tapering at both ends. This very large mass of gas, thus ejected in space, was naturally extremely unstable and was immediately broken down into a number of small fragments. In all, ten such pieces were formed, nine giving rise to the planets and one, which was broken down into pieces, to the group of planetoid. These fragments formed into globular masses revolving round the sun along definite orbits and cooled down gradually from the gaseous to the liquid and ultimately to the solid state.

This hypothesis is the most popular one due to do simplicity and capability of explaining the co-planar placement of the planets and the features relating to the distribution of mass and density in them and the density stratification that exists within the earth.

Tectonic plate theory

Tectonic plates are layers of rock inside the earth. This crust and upper mantle form lithosphere. Under the lithosphere lies a fluid rock layer called asthenosphere. The rocks in Tectonic plates are able to float upon the asthenosphere. There are seven large and several small plates. The largest plates include the pacific, North American, Eurasian, Antarctic and African plates.

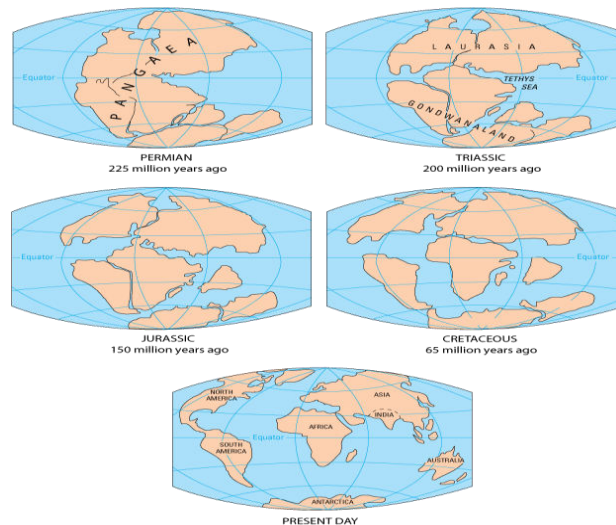


Continental drift theory

The huge land masses of the earth are in constant movement. The continents and the oceans rest upon rock plates. They move relative to each other at rates of few centimeters a year. Until 200 million years ago, the continents were connected into one single land mass called Pangaea. This Pangaea splits and pieces drifted apart creating 2 new continents 160 million years ago. The land mass that was to become India separated and

moved north ward (140 million years ago) and hit another landmass leading to the eruption of the Himalayas. Australia separated from Antarctica (100 million years ago). The two super continents then pulled apart east and west opening the Atlantic oceans.

The continents are still moving even today. The continental drift makes the Pacific Ocean smaller, the Atlantic Ocean larger and the Himalayan Mountains taller. The Atlantic oceans become wider, Mediterranean Sea collapses and Australia reaches equator in 60 million years.



Age of the earth

So far scientists have not found a way to determine the exact age of the Earth directly from Earth rocks because Earth's oldest rocks have been recycled and destroyed. Nevertheless, scientists have been able to determine the probable age of the Solar System and to calculate an age for the Earth by assuming that the Earth and the rest of the solid bodies in the Solar System formed at the same time and are, therefore, of the same age.

The ages of Earth and Moon rocks and of meteorites are measured by the decay of long-lived radioactive isotopes of elements that occur naturally in rocks and minerals and that decay with half lives of 700 million to more than 100 billion years to stable isotopes of other elements. These dating techniques, which are firmly grounded in physics and are known collectively as radiometric dating, are used to measure the last time that the rock being dated was either melted or disturbed sufficiently to **rehomogenize** its radioactive elements.

These ancient rocks have been dated by a number of radiometric dating methods and the consistency of the results give scientists confidence that the ages are correct to within a few percent. An interesting feature of these ancient rocks is that they are not from

any sort of 'primordial crust' but are lava flows and sediments deposited in shallow water, an indication that Earth history began well before these rocks were deposited.

In Western Australia, single zircon crystals found in younger sedimentary rocks have radiometric ages of as much as 4.3 billion years, making these tiny crystals the oldest materials to be found on Earth so far. The source rocks for these zircon crystals have not yet been found. The ages measured for Earth's oldest rocks and oldest crystals show that the Earth is at least 4.3 billion years in age but do not reveal the exact age of Earth's formation.

The best age for the Earth (4.54 Ga) is based on old mineral grains (zircon) with U-Pb ages of 4.4 Ga have recently been reported from sedimentary rocks in west-central Australia. The oldest dated moon rocks, however, have ages between 4.4 and 4.5 billion years and provide a minimum age for the formation of our nearest planetary neighbour. The age of 4.54 billion years found for the Solar System and Earth is consistent with current calculations of 11 to 13 billion years for the age of the Milky Way Galaxy (based on the stage of evolution of globular cluster stars) and the age of 10 to 15 billion years for the age of the Universe.

Geological Time Scale of Earth – Development of Life

Era	Period	Age (m.Yr)	Organism
Archean	Archean	> 3500	Lifeless
Precambrian	Precambrian	-do-	Soft bodied plant & animals
Palaeozoic	Cambrian	500	Algae and shell bearing molluscus
	Ordovician	400	Molluscus & sea weeds
	Silurian	360	Land plants & breathing land animals
	Devonian	320	True fishes and ampibians
	Carboniferous	280	Coal forming materials , non flowering plants
	Permian	246	Reptiles
Mesozoic	Triassic	235	Marine life & reptiles
	Jurassic	185	Dinosours
	Cretaceous	139	Many plants & fishes
Cenozoic	Tertiary Eocene	20	Mammals

	Myocene	29	Mammals
	Pliocene	10	Mammals
	Quaternary		
	Pleistocene	01	Mammals
	Recent time		Mammals

Radius, distance from sun and revolution period

S.No	Planet	Radius (km)	Distance from sun(m.k)	Revolution period (day)
1	Mercury	2439	57.9	88
2	Venus	6052	108.2	245
3	Earth	6378	149.4	365.25
4	Mars	3397	227.9	687
5	Jupiter	71398	778.3	4333
6	Saturn	60000	1427	10743
7	Uranus	23620	2870	30700
8	Neptune	24300	4496.5	60280
9	Pluto	1150	5970	90130

Present condition of the earth

Our earth is supposed to have been formed in similar manner. It must have been hot and plastic when it was first formed. At present the outside of the earth is quite cool and solid but the interior is very hot and in a fluid condition. The outer cool layer, which we know as the earth's crust rests upon a denser molten substratum in which various gases are dissolved at high pressure

Interior of Earth

The Earth Ball consists of 3 concentric rings namely Crust, Mantle and Core.

Crust: 5 to 56 km on the surface of Earth. Density of rocks is 2.6 to 3.0 g cc⁻¹. **Distance:** 5 to 11 km in oceans and 35 to 56 km in the continents. The crust has been divided into two sub-zones called Sial and Sima. The Sial is a heterogeneous mixture of rocks. The Sima is a homogenous plastic or semi-plastic concentric layer that behaves like a solid. The Sial floats on the Sima, which in turn floats on the lower concentric layer called the Mantle.

Sial contains about 65-75 % silica. Aluminium is the next important element in the Sial, represented by the most common rocks like granite, and rhyolite. Silica decreases to about 50-60 percent in the Sima where aluminium has largely been replaced by magnesium

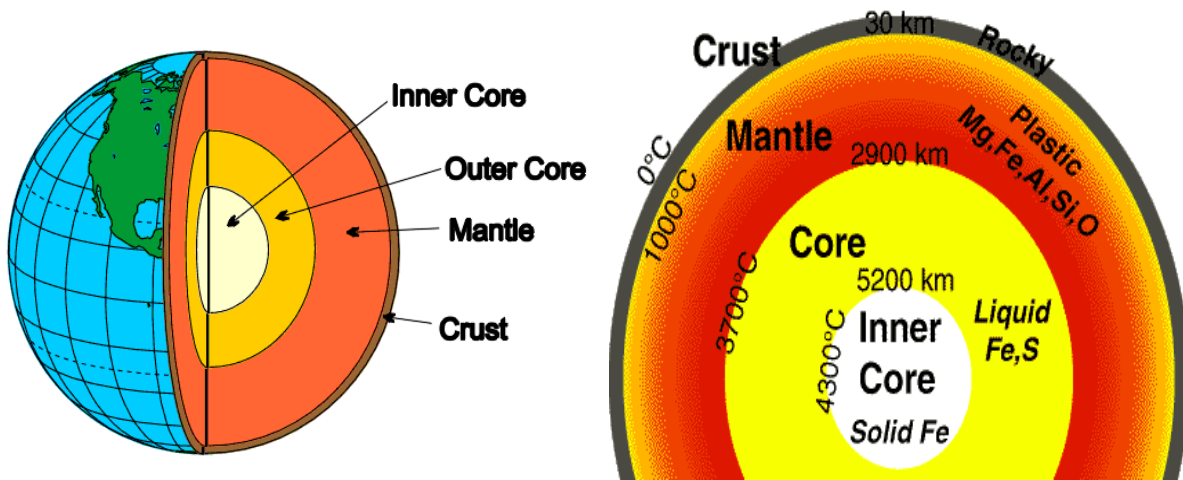
with minor quantities of iron. Sima is represented by the most common rocks like basalt and gabbro at the upper level and by olivine rich rocks at the lower level.

Mantle

A massive solid to semi solid layer below the crust; 2900 km in thickness; comprises mixed metals and silicate and basic rocks with density of 3.0 to 4.5 g cc^{-1} .

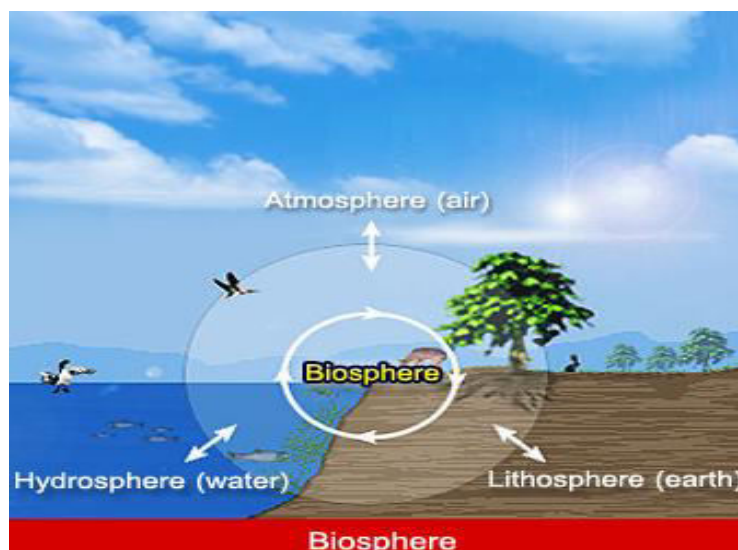
Core

Innermost portion of Earth, 3500 km in thickness, contains molten metals like Nickel, iron; average density: 9.0 to 12.0 g cc^{-1} .



Exterior of Earth

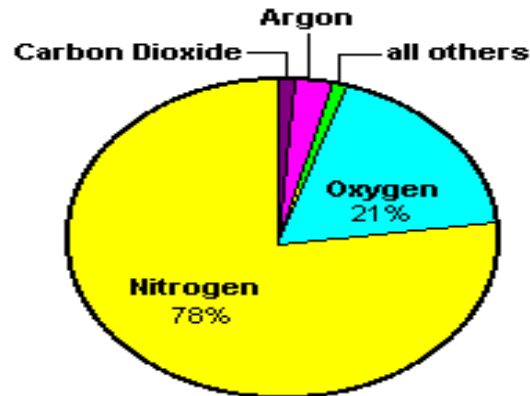
Solid lithosphere, Liquid hydrosphere and gaseous atmosphere. The atmosphere is of 320 km above the lithosphere / hydrosphere. (70% of Earth's surface is covered by water (**Hydrosphere**)).



Composition of atmospheric air

	By volume (%)	By weight (%)
N ₂	78.08	76.5
O ₂	20.9	23.1
CO ₂	0.033	0.04
Other gases	0.93	1.36

(H, NH₃, H₂S, SO₂, O₃, He, Argon, Neon, Krypton, Xenon)



Proportional Volume of Gases Composing Dry Air

Hydrosphere

It is the layer of water surrounding the lithosphere. It is present in the form of seas and oceans. It covers 70% of the earth leaving only about 30% above sea level. The surface of the waters of the various seas is in one level in contrast with the surface of the land. This surface is known as the sea level.

The seawater has a higher specific gravity than terrestrial water due to the salts it contains in solution. The average density is 1.026, but it varies slightly from place to place. Sea water contains 3.5% salts (minerals) It is least dense at the places where river enters the sea and very heavy at places where evaporation is high.

Lithosphere

It is the inner most body within the gaseous and watery envelopes. That portion of the lithosphere, which rises above the seawater, is visible to us and is known as land. The land is only about $\frac{1}{4}$ th of the total surface of the earth. Most of this land is situated in the northern hemisphere. The lithosphere consists of two portions, viz.,

1. The upper or outer cool solid surface.
2. The inner hot and molten mass.

It is the heaviest of the three spheres. Its mean density is 5.5 compared to that of water as one. The outer crust has a density of about 2.5 to 3.0, while the inside core, consists of much heavier materials.

The outer solid layer, called as the earth's crust is estimated to be about 10 to 20 miles thick. It consists of the various rocks together with a more or less thin mantle of soil enveloping them. It is on this crust that life, both animal and plant sustains. The inner mass, which forms the interior of the earth, is in molten condition. According to one belief, the whole of the inner core is a molten mass of materials, upto the centre. According to another view, the interior of the earth consists of a molten magma, about 50 to 100 miles thick, surrounding a gaseous centre. A gradation exists from the central gaseous nucleus, through the intermediate molten mass, to the outer solid crust.

The interior of the earth is intensely hot and is at the same time under enormous pressure. There is progressive increase in temperature with depth. Though, the increase is not uniform at all depths and all places, there is a rise of 1°F for every 64 feet on an average. Assuming the temperature to increase at this rate, at a depth of 25 to 50 miles, it should be sufficiently high to melt all substances known to us. This indicates that the interior of the earth is in molten condition.

Composition of the earth's crust

The Earth's crust is principally composed of mineral matter. This mineral matter is made up of various elements combined together to form compounds. Some elements exist as such without forming compounds. Almost all the elements known to us at present, except the inert gases, are present in the earth's crust. The elements do not exist in the earth's crust as such. Each element is in combination with one or more other elements to form definite chemical compounds known as **minerals**. Many of these minerals in turn combine together to form aggregates, which we know as **rocks**. Almost all the mineral matter is present in the form of rocks in the earth's crust. Rock is composed of elements, which in turn are made up of atoms. Out of 106 elements known, 8 are sufficiently abundant as to constitute about 99 percent by weight of the Earth's Crust (upto 16 Km). The elements are geochemically distributed into five main groups based on their bonding characters.

➤ **Lithophile elements**- which ionize readily or form stable oxyanions, viz. O, Si, Ti, Fe, Mn, Al, H, Li, Na, K, Rb, Cs, Be, Mg, Ca, Sr, Ba, B, Ga, Ge, Sn, Sc, Y, F, Cl, Br, I, C, HF, Th, P, V, Nb, Ta, Cr, W, U, Zr, (Mo), (Cu), (Zn), (Pb), (Tl), (As), (Sb), (Bi), (S), (Se), (Te), (Ni), (Co) and rare earths.

- **Chalcophile element** – which tend to form covalent bonds with sulphide, viz, S, Se, Te, (Fe), Ni, Co, Cu, Zn, Pb, Mo, Ag, Sb, (Sn), Cd, In, Tl, Pb, As, Bi, Re, (Mn), (Ga) and Ge).
- **Siderophile elements** – which readily form metallic bonds, viz, Fe, Ni, Co, Ru, Rh, Pd, Ir, Os and Au.
- **Atmosphere elements**- which tend to remain in atmospheric gases, viz. N, (O) He, Ne, Ar, Kr, Xe.
- **Biophile elements**- which tend to be associated with living organisms, viz. C, H, O, N, P, S, Cl, I, B, Ca, Mg, K, Na, Mn, Fe, Zn, Cu, Ag, Mo, Co, Ni, Au, Be, Cd, Se, Tl, Sn, Pb, As and V.

Composition of Earth crust (% by weight)

Non - metallic	Oxygen	O_2^-	46.60%	74.32% ($\frac{3}{4}^{\text{th}}$)
	Silica	Si^{4+}	27.72%	
Metallic	Aluminium	Al^{3+}	8.13%	$\frac{1}{4}^{\text{th}}$ of the total
	Iron	Fe^{2+}	5.00%	
	Calcium	Ca^{2+}	3.63%	
	Sodium	Na^+	2.83%	
	Potassium	K^+	2.59%	
	Magnesium	Mg^{2+}	2.09%	
	Others	-	1.41%	

Eight elements are abundant – 98.6%

