

The Origin of Coal

M.Sc. Geology (Sem IV)

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E-Content

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Accumulated, compacted and altered plants form a sedimentary rock called coal.

Coal is a brown to black naturally occurring combustible organic rock that originated by accumulation and subsequent physical and chemical alteration of plant material over long period of time.

Vegetal (from plants) Origin of Coal

We know that **Coal is Organic** in nature although it also has certain amounts of **Inorganic material** in the form of impurities (**Mineral Matter or Ash**).

Also, it has been accepted since 1825 that Coal has a vegetal origin i.e. Coal originated from plant material mainly.

COAL = Plant Matter + Animal Matter + Mineral Matter

Mother Substance of Coal

Plant or Vegetal Matter mainly consists of the following primary constituents, all of which have different properties & decomposition rates :--

Cellulose	-- Decomposed very fast
Lignin	-- Acidic & Resistant
Waxes & Resins	-- Resistant (converted to Bitumen)

Protein & Mineral Salts – Provide Energy

Earlier, scientists were of the belief that because Plant matter was predominantly made up of Cellulose, which was present in double the amount of Lignin, **Cellulose should be the Mother substance of coals.**

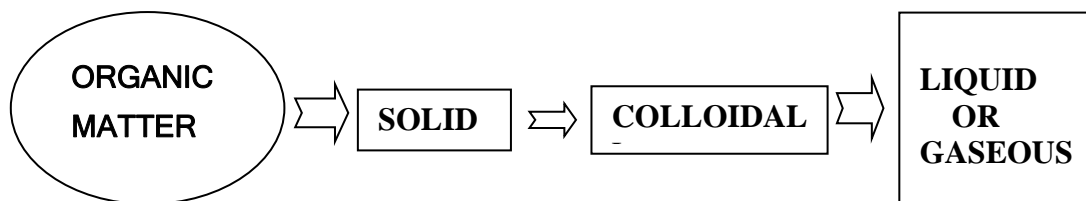
Later on, when it was discovered through more scientific studies, that under bacterial degradation in Peat swamps, Cellulose decomposed very fast to Carbon dioxide, Methane & Aliphatic acids. Thus, it was proposed that Lignin was the Mother substance of Coals (**Lignin Theory**).

Evolution of Humic Matter

Waxes & Resins : are the constituents in plant matter which are most resistant to decay and decomposition and are thus fossilized with no change during coal formation process.

Rest of the constituents of Plant Matter like Lignin, Cellulose & Proteins are converted into 2 parts mainly :--

- **Humic Substance** (Jelly-like mass), which sometimes contain embedded / preserved Spores & Cuticles also
- **Inert Carbonaceous matter**



That is, in coal formation, remnants of Organic Matter in Coal Swamps which are initially in Solid state are gradually converted into Colloidal material and finally a Liquid or Gaseous state.

Order of Decomposition of Plant Constituents

To understand the entire process of formation of Coal in nature it is vital to realise that as the decomposition of plant material progresses => **there is a gradual selective and preferential removal of Hydrogen first and foremost, followed by selective removal of Nitrogen then in quantities over Carbon** i.e. Carbon is most stable compared to Hydrogen and Nitrogen and so in the entire decomposition process the end result is the **enrichment in organic CARBON**.

Organic HYDROGEN >>Organic NITROGEN >> Organic CARBON

In conclusion Biochemical Decomposition of Vegetal Matter ultimately leads to **Carbon enrichment**

Mode of deposition of coal :-

- Coal is formed largely from **terrestrial plant material** growing on dry land and not in swamps or bogs.
- The **original plant debris** was transported by water and deposited under water in lakes or in the sea.
- The **sediments, inorganic and organic**, settled down in regular succession.
- The process of **sedimentation of the organic and inorganic materials** continues till these deposits are **covered by mineral matters, sand, etc.** and results in **coal seams**.
- The **coal properties vary widely** due to the **varied types of vegetation deposited**.

Plant debris accumulated in Fluvial conditions & buried under sediments --The plant debris accumulated in various wet environments & fluvial conditions in which trees, ferns and the like are deposited, and buried by sand, silt and mud.

- As a result of temperature and pressure effects, **metamorphosis of the woody material** occurs to produce the various types of coal.
- The **initial transformation** of vegetable materials probably includes various types of **degradation and decay** due to some **fungal and bacterial action**. Slow atmospheric oxidation may also take place.

The accumulating spongy, water-saturated, plant-derived organic material, known as **peat**, is called the **precursor of coal**. This is **primary transformation (Peatification)**.

The **secondary transformation** which is rather a slower process of **aging of Peat deposits** under substantially **anaerobic condition**, higher pressures and elevated temperature. (**Coalification**). This progressive transformation of peat to higher coals is called **Coalification process**.

- Increasingly deeper burial under hundreds to thousands of feet of younger sediment is required to advance coalification to the **bituminous and anthracite** stages.
- The pressure exerted by the weight of the overlying sediments and the heat that increases with depth, as well as the length of exposure to them, determines the **degree of coalification**, as well as the **Rank of coal**.

Factors that determine the composition of coal :--

- **Mode of accumulation and burial** of the plant debris forming the deposits.
- **Age** of the deposits and the **geographical distribution**.
- **Structure** of the coal forming plants, particularly details of structure that affect **chemical composition** or resistance to decay.
- **Chemical composition** of the coal forming debris and its resistance to decay.

- **Nature and intensity** of the peat decaying agencies.
- Subsequent **geological history** of the residual products of decay of the plant debris forming the deposits.

Theories of Coal Formation

The natural agencies causing the observed chemical and physical changes include the action of bacteria and fungi, oxidation, reduction, hydrolysis and condensation - the effect of heat and pressure in the presence of water.

There are two theories proposed for the mode of accumulation of the plant materials to transform into coal.

1) **In-situ theory**- 2) **Drift theory**-

In-situ (Autochthonous) Theory of Coal Formation

The popular theory is that the plants which compose the coal were accumulated in large freshwater swamps or peat bogs during many thousands of years. This theory which supposes growth-in-place of vegetable material is called the ***autochthonous theory***.

According to this theory, the coal seams are observed where once **forest grew**. As the land was **sinking slowly**, the accumulated vegetation matters went **under water slowly** and did not decompose and get destroyed.

In the course of time, the **rate of sinking of land was increased** and coal forest was submerged under water. Again, **land along with the coal forest emerged out of water** after sufficient time and this **cycle went on again and again**, which is responsible of formation of coal strata and seams.

Evidences :

- Relative purity & constancy in thickness and composition of coal seams (i.e no major transport)

- Presence of erect & rooted fossil tree trunks with roots in the Underclays
- Underclays below coals are generally poor in alkalies, lime etc.
- Wide lateral extent of coal belts

Accumulations of vegetable matter and associated mineral matter, generally clays and sands, are balanced by the subsidence, or motion of the Earth's surface, in the area on which these materials are accumulating. Hence, coal formed like this has **bands of coal and inorganic sedimentary rocks arranged in a sequence.**

Drift Theory (Allochthonous) of Coal formation

This theory suggests that coal strata accumulated from plants which had been rapidly transported and deposited under flood conditions. Because this theory assumes transportation of vegetable debris it is called the ***allochthonous theory***.

According to this theory, the plant material was transported with the flowing water from one place to another, and finally got deposited in a place of swamps, lakes, seas & estuaries having suitable condition like supply of sediments. **The coal seams of India are of drift origin.**

Evidence :

- High Ash-content of coals
- Scarcity of plant fossils in roof of coal seams
- Digitation / Splitting of coal seams
- Lateral transition of coal to carbonaceous shales
- Peat / Brown coals are presently forming in river deltas (eg. Ganga, Mississippi etc.)
- Fish remains in coals suggest open waters (coastal / marine)

STAGES OF COAL FORMATION

(1) BIOCHEMICAL (PEATIFICATION) STAGE –

- Involves changes brought about in the transformation of plant debris through decay & decomposition of chemical constituents (Lignin, Cellulose, Proteins etc.)
- Changes are due to action of **Bacteria** & other Micro-organisms in bogs and swamps
- Favorable factors => **Oxygen supply, Temperature & Alkaline environment.**
- Products of decay are => **Humic Matter / Humus**
- Result => Porous, friable, fibrous mass called **Peat**.

Since the process of most severe Biochemical alteration occurs in the top layer (**0.5 meters depth**) of Peat surface (**Peatigenic Layer**) where **Aerobic Bacteria & Fungi** lead to Microbial & Chemical changes resulting in Peat formation it is called **Peatification Stage**.

Factors for Halt of Bacterial action or Peatification:

- **Burial of Peat** under layers of sediments
- **Replacement of Aerobic bacteria by Anaerobic bacteria** below Peatigenic Layer i.e. at depths of < 10 meters
- **Release of Acid Compounds** from Bacterial action

(2) COALIFICATION STAGE –

Coalification : development from Peat through the stages of Lignite (Brown coal), Sub-bituminous and Bituminous coals to Anthracite & Meta-Anthracite.

It is a Unidirectional process with a series of changes which result in the gradual increase in Carbon content and Calorific value in coals.

2 Types of changes in Coalification :

1. **Physico-chemical** => due to a gradual increase in Overburden Pressure with Depth.
 - a) Increase in Optical Anisotropy (*parallel to bedding planes*)
 - b) Increase in Porosity (*estimated by Moisture content of coals*).
2. **Chemical or Optical Properties** =>
 - a) **Change in Chemical Parameters** like Carbon, Hydrogen, Oxygen, Volatile Matter etc.
 - b) **Change in Optical Properties** like Reflectivity of Vitrinite

Lignite Stage : Porosity decrease leads to Decrease in Moisture and increase in Calorific Value is because of gradual rise in Carbon content.

Bituminous Stage :

- I. Rapid decrease in Vol.Matter (*by removal of Aliphatic groups*)
- II. Increase in Vitrinite Reflectivity (*by rise of Aromatic groups*)
- III. Carbon content alters only slightly with increasing Depth

Anthracite Stage :

- I. Rapid decrease in Hydrogen content
- II. Rapid decrease in atomic H/C ratio
- III. Strong increase in Reflectivity of Vitrinite