COAL
&
PETROLEUM

Contents

Chapter 1 : COAL

1.1 Introduction :

Coal is a combustible compact black or dark-brown carbonaceous sedimentary rock formed from compaction of layers of partially decomposed vegetation and occurs in stratified sedimentary deposits.

Coal is formed by biological, physical, and chemical processes, governed by temperature and pressure, over millions of years on plant remains, deposited in ancient shallow swamps. The degree of alteration (metamorphism), caused by these processes, during the temporal history of development determines their position or rank in the coalification series which commences at peat and extended through lignite to bituminous coal and finally anthracite. The relative amount of moisture, volatile matter and fixed carbon content vary from one to the other end of the coalification series. The moisture and volatile matter decrease with the enhancement of rank while carbon content increases i.e., carbon content is lowest in peat and highest in anthracite.

1.2 Origin of coal :

There are two theories behind the origin of coal i.e. in-situ theory & Drift theory.

The in-situ theory : According to this theory, it is assumed that the coal is formed at the same place where the forests grew indicating autonomous coal.

At first, the vegetable matter is accumulated in the forest. Now the vegetable matter is submerged underwater as the land starts to sink. With time the sinking rate of land increased which results in burial of the vegetable matter covered by large quantities of sand and mud. So there is no time for decomposition and destruction of matters. This stage is followed by uplifting in which land emerged out of the water and the coal forests came into existence again. This is a repetitive cycle and in this manner, coal is found alternating with layers of mud and sand.

Evidence in favor of in-situ theory :

i.In swamps, a huge amount of plant materials found today.

ii. Tree trunks, stem of fossil trees are found associated with coal bands.

iii. The coal bands are pure relatively that indicate the coal has not suffered any transportation history.

iv. There is a uniformity in thickness and homogeneity in the composition of coal which suggests the coal is in-situ.

Drift theory :

Drift theory suggests that all coal seams are not of in-situ origin, rather these are transported by water or stream from their origin and deposited at other places. After deposition coal seams are

formed by rapid and oscillatory earth movements and seams are found alternative with sediments.

All Indian coal seams are of drift origin. Evidence in favor of Drift theory :

1. Coal composition is not uniform and shale bands are found associated sometimes.
2. Fossil tree trunks are found.
3. The bands are not uniform in thickness.

1.3 Coalification stages :

The formation of coal from plant debris takes millions of years. This phenomenon is called coalification which is divided into two stages as follows:

1.3.1.Bio-chemical stage :

This is the first stage of coal formation, also known as the bio-chemical stage as peat is formed from plant materials in the absence of oxygen. Peat is formed by bacteria that release oxygen and hydrogen. The impurities and moisture are removed with increased temperature and pressure which leads to carbon concentration. In this stage, the coal seam is found with 75-90% water plus abundant plant debris. Therefore peat is not considered coal.

1.3.2.Physico-chemical stage :

The biochemical stage is followed by a Physico-chemical or geochemical stage in which coal grades from peat to anthracite with enrichment of carbon content and removal of CO_2, CH_4, and H_2O. The processes involved in this stage are dehydroxylation and decarboxylation. The types that are formed in geochemical stages are lignite or brown coal, bituminous, and anthracite coal. Anthracite can change into graphite with extreme metamorphism.

1.4 Peat formation & types:

The peat is formed by micro-organisms activity resulting in decay of plant debris such as lignin, cellulose, resins, etc. As the peat is a porous, fibrous humic substance, hence the formation of peat is known as humification.

The conditions for peat formation are

i. The water table must remain at or near the ground surface and
ii. The water table must rise slowly and steadily with land subsidence.

Peat land :

Peat forming land is known as Mire. Mire is of three types :

i. Ombrogeneous : this is also known as ombrotelmite, forest bog, raised bog or high moor.
ii. Topogenous , topotelmite, eutropic,low moor or swamp.
iii. Transitional , intermediate or mesotropic.

1.5 Types of coals :

Coal is broadly divided into two main groups depending upon the origin, the humic coals and the sapropelic coals.

1.5.1.Humic Coal :

The coals which are formed from macroscopic plant debris is called humic coals. Humic coal is divided into four lithological types i.e. Vitrain, clarain, durain and fusain.

1.5.1.1.Vitrain : This occurs as a thin bands which is black, glassy and vitreous material. As this band is brittle so they break into angular fragments. Vitrinite is composed of microlithotype vitrite mainly.

1.5.1.2.Clarain : This band occurs as fine laminations and lustre lies in between vitrain and durain bands. The microlithotypes associated with clarain band are vitrite, clarite, durite, fusite and trimacerite.

1.5.1.3.Durain : It is grey to black in color with dull lustre. The microlithotypes are durite and trimacerite.

1.5.1.4.Fusain : Fusain occurs as lenses and it is soft and friable in nature. Fusain disintegrates into fibrous powder.

1.5.2 Sapropelic coal :

Sapropelic coals are formed from microscopic plant debris and it is homogeneous in appearance and shows conchoidal fractures. It is divided into two types- cannel coal and boghead coal.

1.5.2.1.Cannel coal :

Cannel coal is composed of miospores and organic mud. This coal shows conchoidal fracture and black and dull in appearance.

1.5.2.2.Boghead coal :

This is formed from algal materials but not necessarily found in algal colonies. Boghead coal may grade into true oil shales.

1.6 Ranks & Grades of coal :

Ranks refer to the maturity of coal and grades define the purity of coal.

Rank is based on the carbon content. As the coalification stage proceeds, carbon contents increase with a decrease in moisture content and volatile matter. The decrease in the volatile matter is proportional to a depth from the surface. This phenomenon is known as '**Hilt's law**'.

The coal is broadly divided into four types based on its rank – Peat, lignite, bituminous, and anthracite.

Peat: Peat is formed at the first stage of coal and yellowish-brown in color. It is used as fertilizer as it contains a large amount of nitrogen and also used in the manufacture of briquets. The calorific value is very low for peat so it is not so economic.

Lignite: it is also known as brown coal because of its characteristic brown color.

Lignite is a good fuel because of its calorific value and very prone to combustion. It is exclusively used for power generation, besides lignite is used for manufacture of producer gas and coke.

Bituminous coal : Most of the Indian coal bituminous in nature, which is a dense with well -defined bright and dull bands. Bituminous coal is black in color and mainly used for steam-electric power generation. On the basis of fuel ratio, this coal is divided into two types such as high volatile and low volatile bituminous coal. In high volatile, the fuel ratio is less than 2 while for low volatile coal the ratio becomes greater than 2.

Anthracite : this is the highest rank of coal which is iron black in color. Anthracite is used for residential and commercial space heating.

The other properties of different ranks are described in table below.

1.6.1 Properties of different ranks

Coal ranks	Carbon content (%)	Moisture content (%)	Volatile matter (%)	Calorific value (KJ/kg)
Peat	60	>75	>53	16800
Lignite	60-71	35	53-49	23000
Sub-bituminous	71-77	25-10	49-42	29300
Bituminous	77-87	8	42-29	36250
Anthracite	77-87	<8	29-8	>36250

1.6.2 Grade of coal

Grading of Indian coal is based on calorific value and ranges from A to G.

Grade	Calorific value(kCal/kg)
A	>6200
B	5600 – 6200
C	4940- 5600
D	4200- 4940
E	3360 -4200
F	2400- 3360
G	1300-2400

D, E and F grades are found in India.

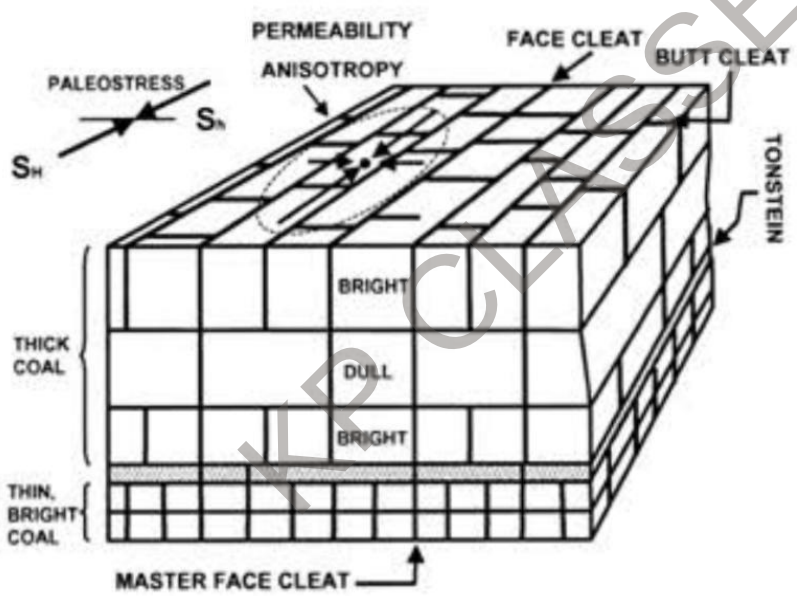
1.7. Cleat formation, types & importance in coal exploration :

The fractures developed within coal seam are known as cleats or joints. Due to presence of these cleats, bituminous rocks break into cubes while peat or lignite coals break irregularly.

1.7.1 Types :

There are different types of cleats based on formation stage as follows :

i. Primary cleat or first-order cleat: developed on the face of the coal seam.
ii. Secondary cleat or second-order cleat: developed perpendicular to face cleat. It is also called butt cleat.
iii. Tertiary cleat or third-order cleat
iv. Master cleat or super cleat: extends from bottom to top of the coal seam, cuts different lithology.
v. Micro cleat or fourth-order cleat: when the cleat is distinguished on a microscopic scale.



1.7.2 Importance of cleats in coal exploration :

The cleat intensity is maximum in bituminous coal and minimum in lignite and anthracite coal. When coalification takes place, there must be a release of volatile matter to increase the carbon content. At the initial stage, there are lots of pore spaces but with increasing pressure and temperature, these pores get blocked. Hence, to release the volatile, cleats or fractures are developed in the bituminous stage. Again, in the anthracite formation stage, cleat intensity becomes less.

The cleats have importance in coal exploration such as :

i. The direction of pillar and gallery of underground mining is determined by cleats.
ii. Cleats give permeability of coal seams.
iii. For extraction of Coal Bed Methane (CBM), bituminous coal is preferred as it has maximum cleat intensity.

1.8.Microscopic properties of coal (Macerals)

1.8.1 Definition :

The smallest organic homogeneous microscopic unit of coal is known as maceral. Based on physical and optical properties, macerals are divided into three types i.e. vitrinite or huminite, liptinite and inertinite. Again these types are sub-divided into different groups .

1.8.2 Division & sub-division of macerals :

Vitrinite/ Huminite : This originates from woody materials such as lignin and cellulose of cell walls of a plant. Humification and gelification are the two main processes associated with vitrinite formation. The term Huminite is used for medium rank coal. The reflectance of vitrinite is crucial for identifying the ranks of coal. Color and reflectance of vitrinite change with increasing rank. In low rank coal, vitrinite is dark grey in color but with increasing rank it becomes light grey to white. The reflectance also defines the stage of coal or oil formation. The reflectance of 0.5% defines the generation of petroleum like substance, 0.8-0.9% reflectance indicates the maximum oil generation while 1.3% reflectance is indicative of end of oil generation.

Liptinite : Liptinite is from hydrogen rich plant materials such as spores, resins, cuticles etc. Liptinite is important because it defines the coalification jump based on its sporinite reflectance.

Inertinite : The term refers to the substances that are more inert in nature or non-reactive. This orginates from oxidized plant materials. Based on reflectance and textural patterns, inertinite is again subdivided into different types tabulated in below.

Group	Sub-group	Macerals
Vitrinite/Huminite	Telovitrinite	Tellinite
		Collotelinite
	Detrovitrinite	Vitrodetrinite
		Collodetrinite
	Gelovitrinite	Corpogelinite
		Gelinite
Litinite/Exinite		Alginite
		Sporinite
		Cutinite
		Resinite
		Lepidodetrinite
Inertinite		Fusinite

	Macerals with plant cell structure	Semifusinite
		Funginite
	Macerals lacking plant cell structure	Secretinite
		Macrinite
		Micrinite
	Fragmented inertinite	Inertodetrinite

1.9. Microlithotypes :

1.9.1 Definition :

Association of macerals are known as microlithotypes.

1.9.2 Classification of microlithotypes:

Classification of microlithotypes is based on group of macerals. If only one type of maceral is present, for example, vitrinite or liptinite, then it is known as Monomaceral. On the other hand, combination of two or three group of macerals is called bimaceral and tricmaceral respectively.

Microlithotypes	Principal group of constituent macerals	Type of microlithotype
Vitrite	Vitrinite	Monomaceral
Liptite	Liptinite	
Inertite	Inertinite	
Clarite	Vitrinite + Liptinite	Bimaceral
Durite	Inertinite + Liptinite	
Vitrinertite	Inertinite + Vitrinite	
Duroclarite	Vitrinite + Liptinite + Inertinite	Trimaceral
Clarodurite	Inertinite + Liptinite + Vitrinite	

1.10 Combustion properties of coals :

1.10.1 Calorific value : Calorific value is defined as the amount of heat generated by combustion of unit mass of coal. This is expressed in Gross calorific value and Net calorific value.

Gross calorific value (GCV) : This is higher heating value. GCV is the amount of heat produced during laboratory testing at constant volume.

Net Calorific value (NCV) : NCV is the maximum achievable calorific value during combustion of coal. So this is lower heating value. NCV is measured at constant pressure.