COAL GENESIS AND CHARACTERISATION

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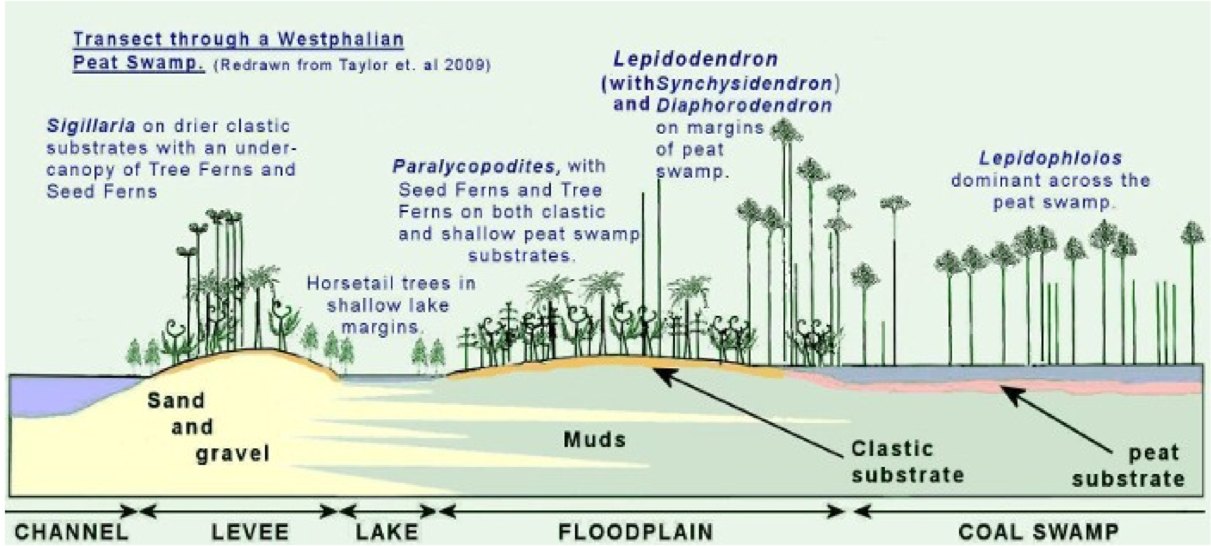
- ***Coal*** **is a Fossil Fuel.**
- **Organic sedimentary rock which forms from the decay of plant materials such as moss, ferns and parts of trees (dried out peat bogs) in a swampy environment.**
- **Most favorable conditions : 360 million to 290 million years ago, during the Carboniferous age.**
- **In swampy environment - low in O2→ Anaerobic bacteria start decomposing the OM→ decomposition stops when the plants have been converted to peat**



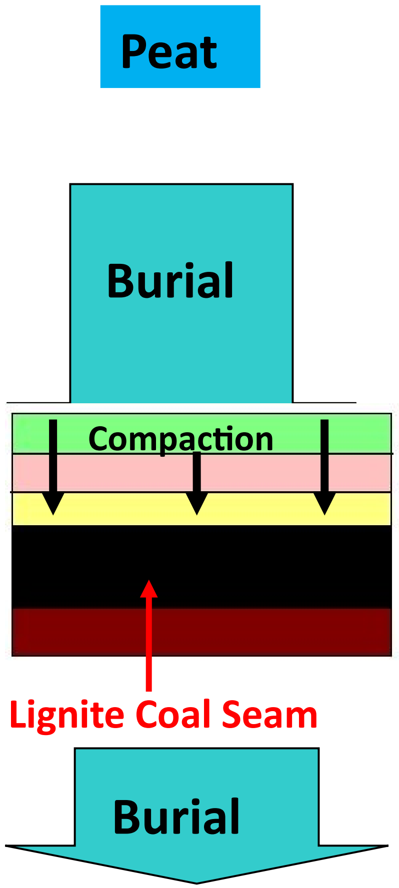
Source
http://www.geologyatsheffield.co.uk/sagt/palaeoecology/

Formation and evolution of Peat.

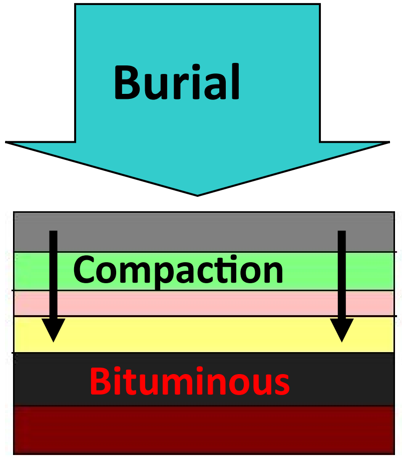
Swamps are areas where organic matter from plants accumulate. As the plants die and get buried they compact to become peat. With time and more compaction, almost all of the water is lost and three different grades of coal result.

Compaction of the peat due to burial drives off volatile components like methane and water, eventually producing *lignite* .

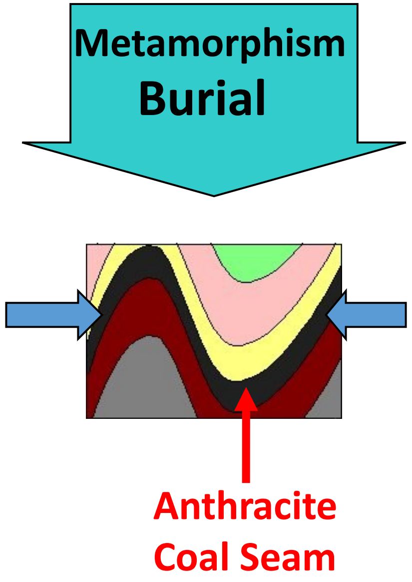
Soft brown coal which consist of about 40% carbon and do not burn efficiently.



- Further compaction and heating results in a more carbon- rich coal called ***bituminous*** coal.
- Consist of about 85% carbon and burns readily but produces a lot of smoke.

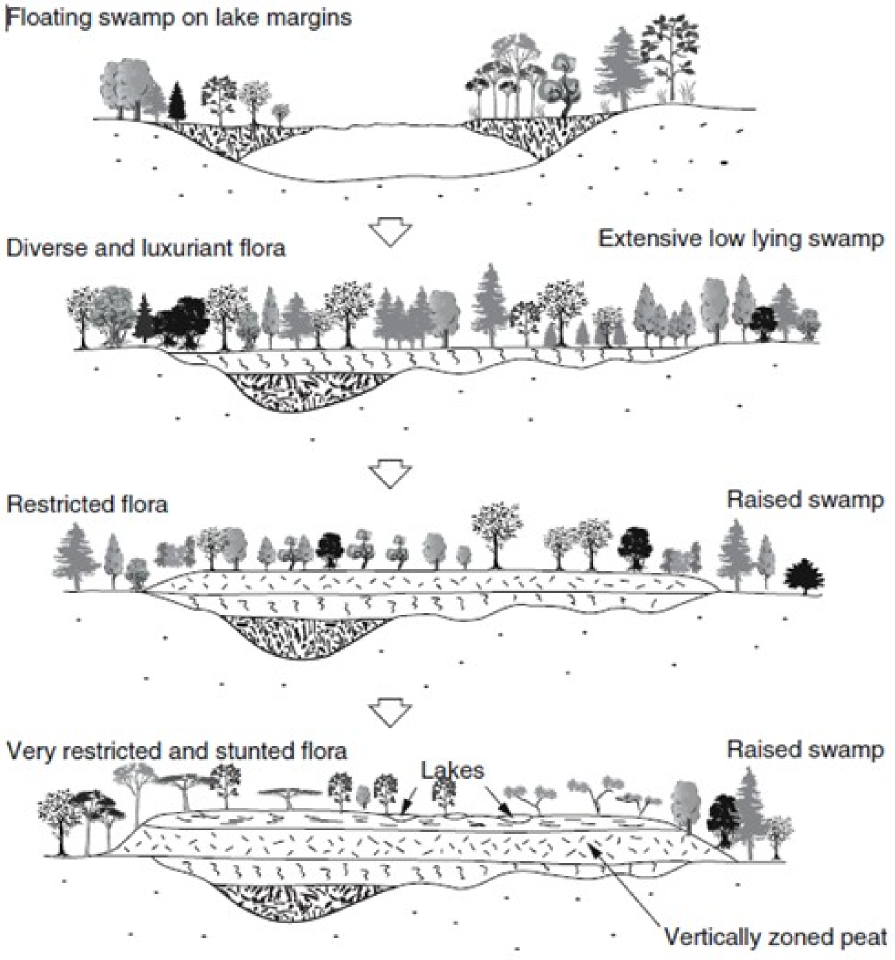


- If the rock becomes metamorphosed, a high grade coal called ***anthracite*** is produced.
- Hard dark coal which consist of 90% to 95% carbon and burns very clean.
- Anthracite coal produces the most energy when burned.



Peat formation can be initiated by:

- Terrestrialization: replacement of a body of water by a mire
- Paludification: replacement of dry land by a mire, due to a rising groundwater table



From McCabe (1984)

Composition of Coals

Constituents of coal can be divided into two groups:

(i) the **organic fraction/maceral**, which can be further subdivided into microscopically identifiable macerals; and

(ii) the **inorganic fraction/mineral matter**, which is commonly identified as ash subsequent to combustion.

The organic fraction can be further subdivided on the basis of its rank or maturity.

MACERAL GROUPS

Three maceral groups: vitrinite, liptinite, and inertinite

Vitrinite: Most abundant maceral of coal

- main contributor to the shiny black strands so familiar in coals.
- Formed from lignin, cellulose, woody parts
- Capable of producing hydrocarbon gas but only small amounts of oil

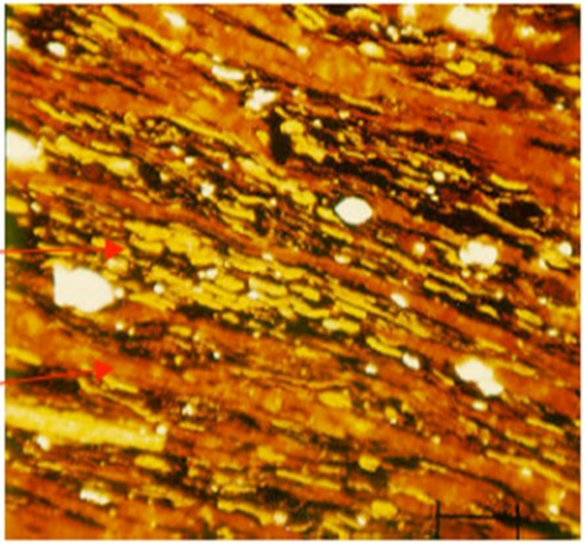
Liptinite : originates from spores, pollen, resins, algae, fats, bacterial proteins, and waxes

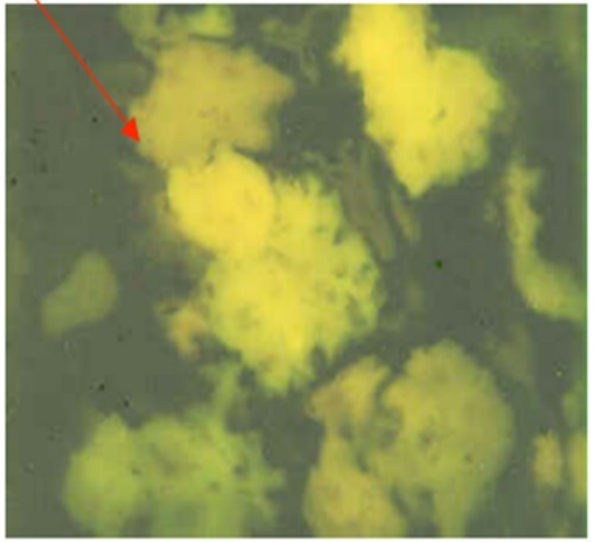
- Many of the volatiles, including methane, emitted by the coal comes from the liptinite. These macerals have the potential of producing hydrocarbon gases and oil.

Inertinite: oxidized or charcoaled cell walls or trunks of plants, resulting in high carbon and aromatic content but less hydrogen.

- Has relatively more carbon than the other macerals.
- Only small amounts of volatiles are generated by the inertinites. No potential of these macerals to produce hydrocarbons.

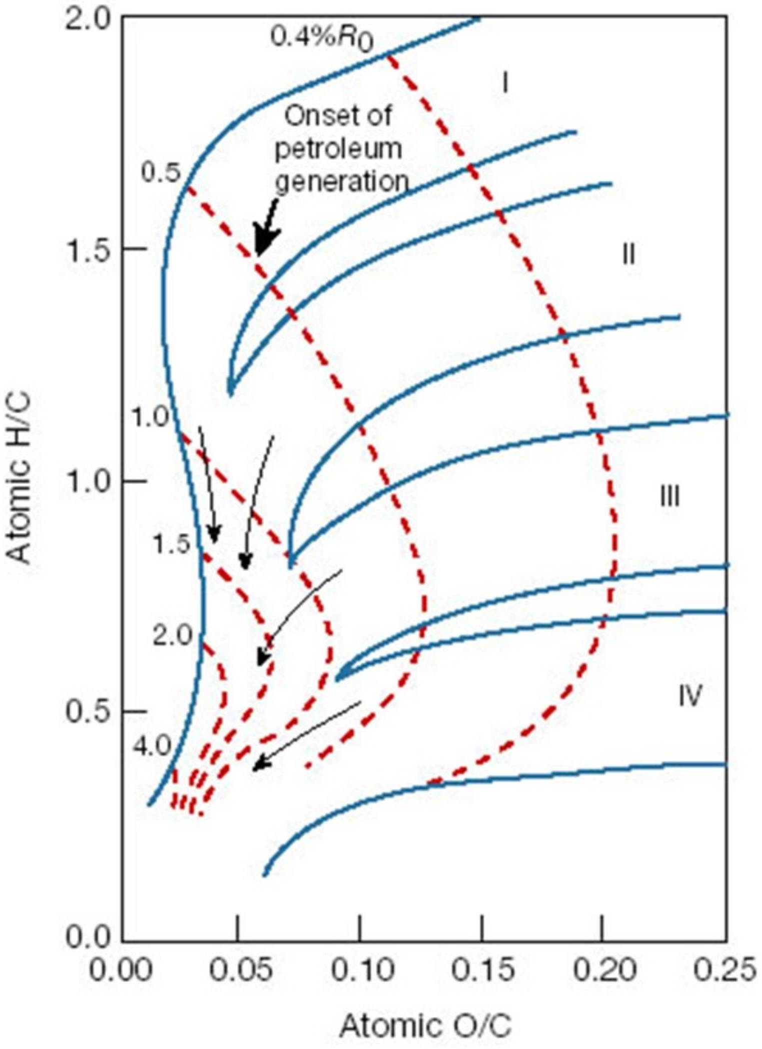
Maceral Type	Origin
Resinite	Plant resins
Sporinite	Spores, pollens
Bituminite	Degraded algae
Alginite	Algae
Vitrinite	Woody tissues
Fusinite	Carbonized woody tissues
Sclerotinite	Fungal hyphae





Study of macerals is necessary because different starting materials will give different C/H ratios in the coal product, which is important in coal use

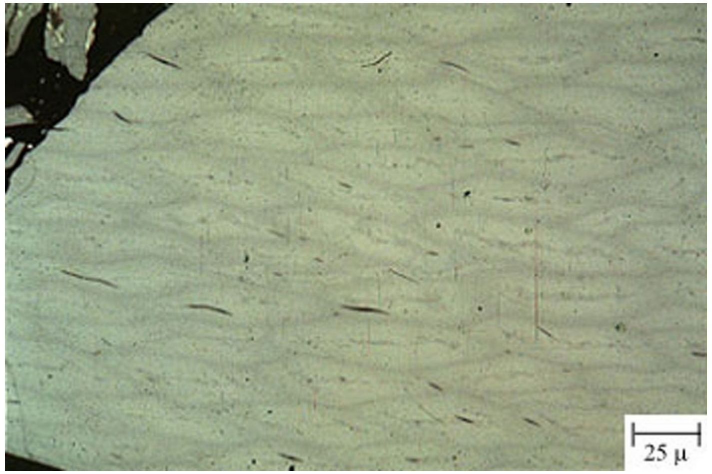
http://www.its.caltech.edu/~chem2/Slides_Lecture2.pdf



Van Krevelen diagram showing the chemical evolution of immature kerogen of varying composition (type I, II, III and IV) at increasing levels of thermal maturity
Source: Organic–inorganic interactions in petroleum-producing sedimentary basins , Jeffrey S. Seewald

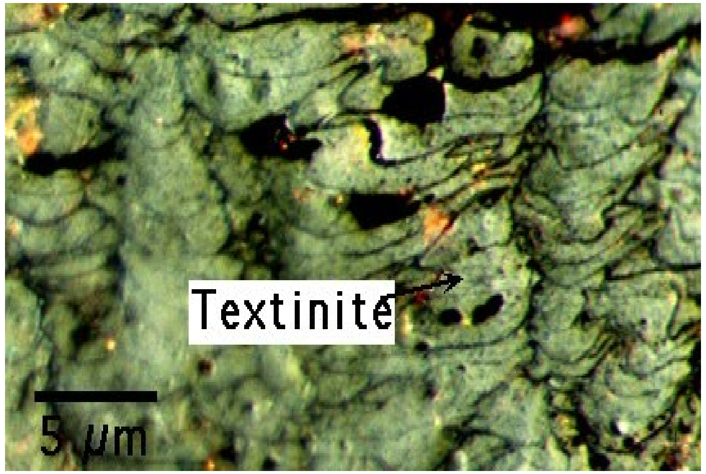
Vitrinite

Telocollonite



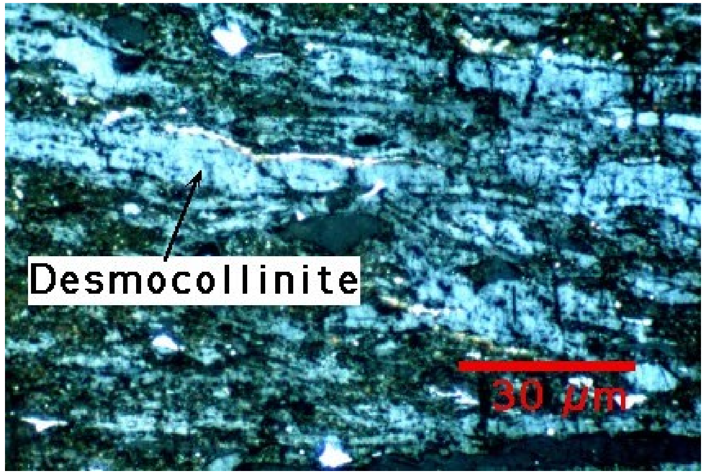
- Woody tissue of stems, branches, leaves and roots. Primary cell walls. Homogenous and banded.

Textinite



- Woody tissue of stems, branches, leaves and roots. Primary cell structure still distinguishable

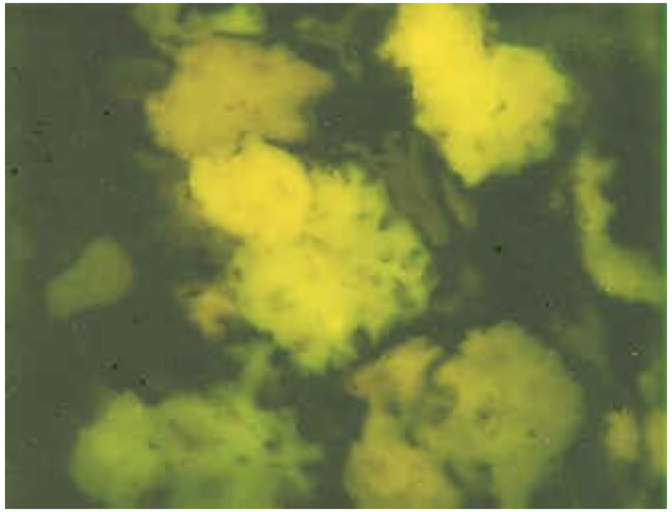
Desmocollinite



- Precipitated humic gels. Groundmass vitrinite. Slightly darker and slightly lower in reflectivity compared to telocollinite

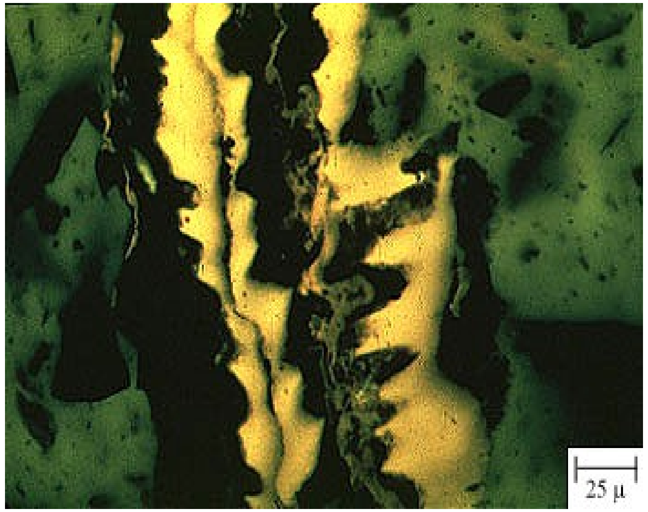
Liptinite

Alginite



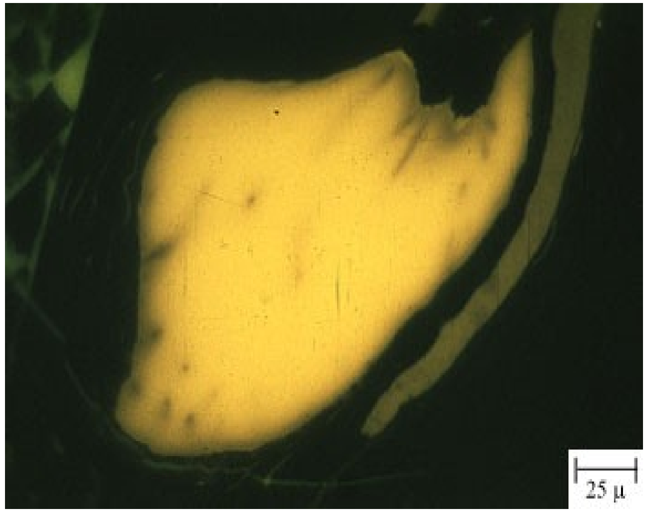
- Marine and freshwater algae. Sub-macerals include Telalginite (individual and colonial algae) and Lamalginite (thin, laminar algae)

Cutinite



- Waxy cuticles from plant leaves

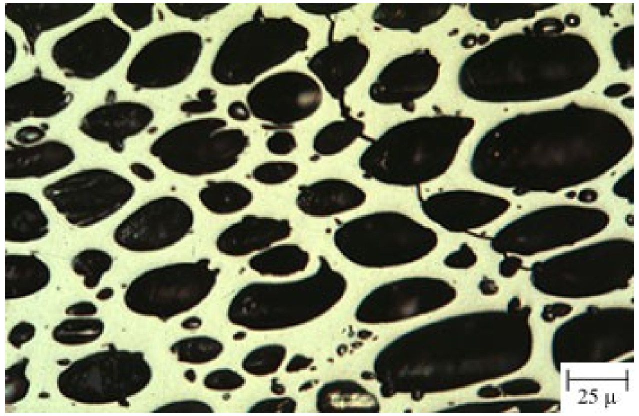
Resinite



- Resins, fats and oils from plant bark, stems and leaves

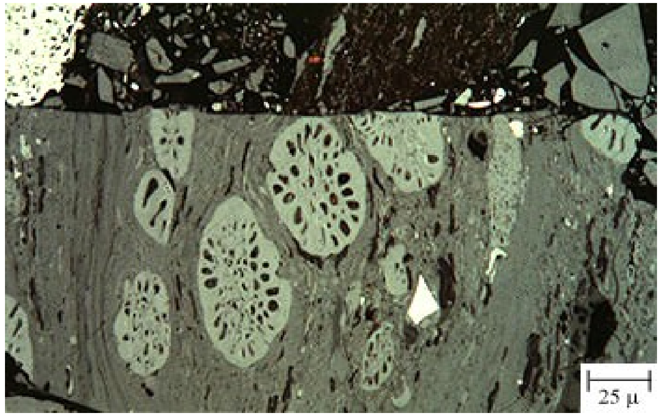
Inertinite

Fusinite



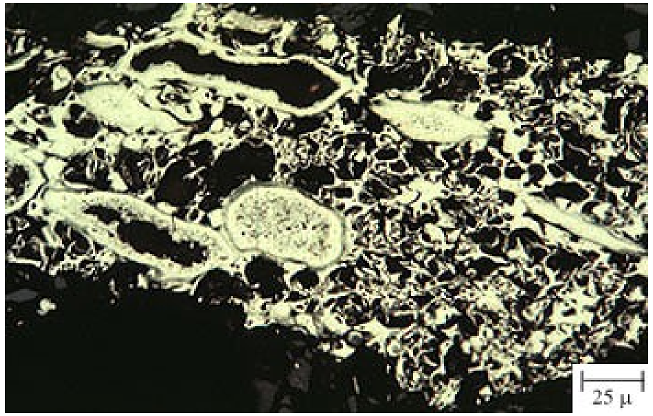
- Woody tissue aromatized during early coalification (charring, oxidation etc)

Sclerotinite



- Fungal mycelia (spores). Possible product of oxidation of liptinite macerals.

Semifusinite



- Woody tissue partly aromatized during early coalification

Coal Classification

- Two main ways for classifying coal - by rank and grade
- **Coal Rank :** The degree of 'metamorphism' or coalification undergone by a coal, as it matures from peat to anthracite
- **Low rank coals,** such as lignite and sub-bituminous coals, are typically softer, friable materials with a dull, earthy appearance; they have high moisture levels and low carbon content, and hence a low energy content.
- **Higher rank coals** are typically harder and stronger and often have a black vitreous lustre.

Coal Classification

Lignite : lowest rank of coal

- Browner and softer.
- High oxygen content (up to 30 percent), a relatively low fixed carbon content (20-35 percent), and a High moisture content (30-70 percent)

Sub-bituminous coals : dull black and waxy.

- Fixed carbon content between 35 to 45 percent and a moisture content of up to 10 percent.

Bituminous coals: dense black solids, containing bands with brilliant colors.

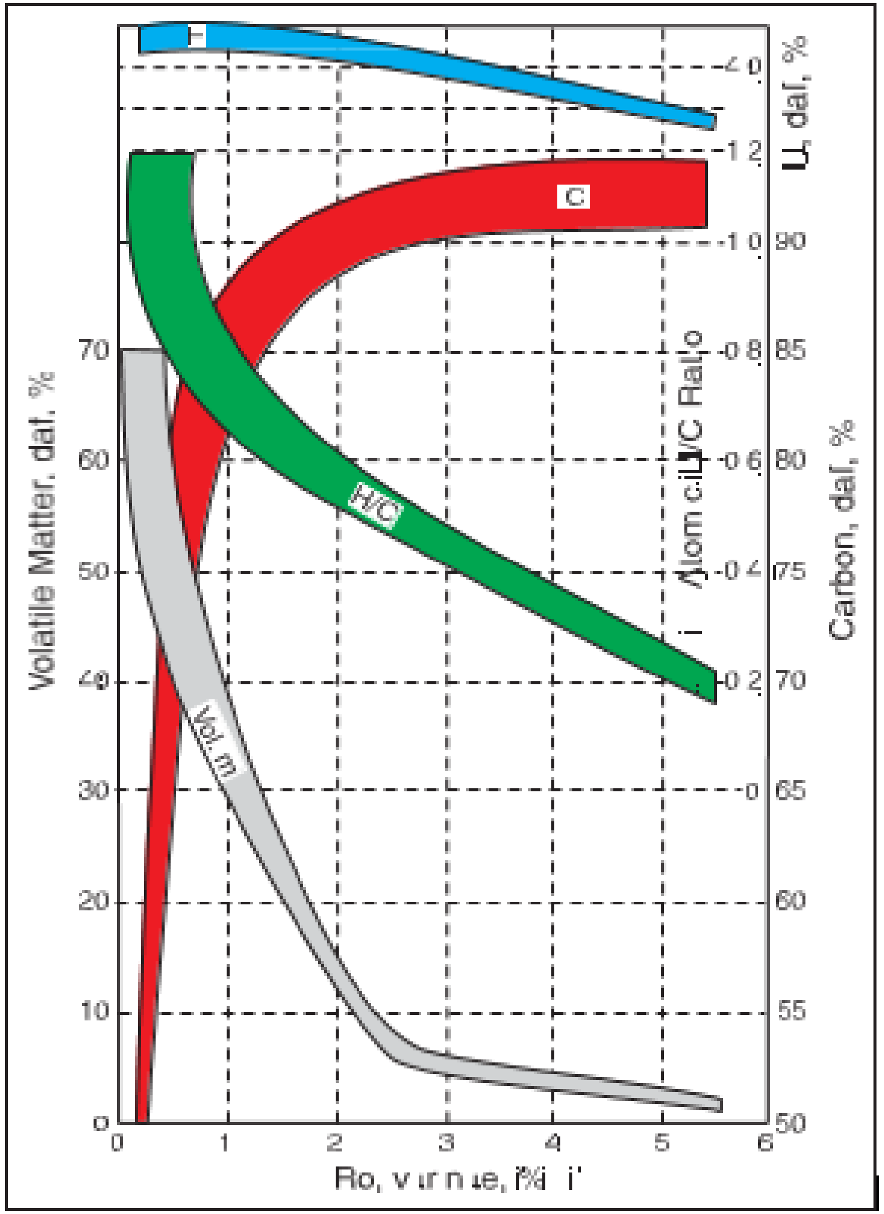
- Carbon content of these coals ranges from 45 to 80 percent and the water content from 1.5 to 7 percent.

Anthracite: dense, hard and shiny

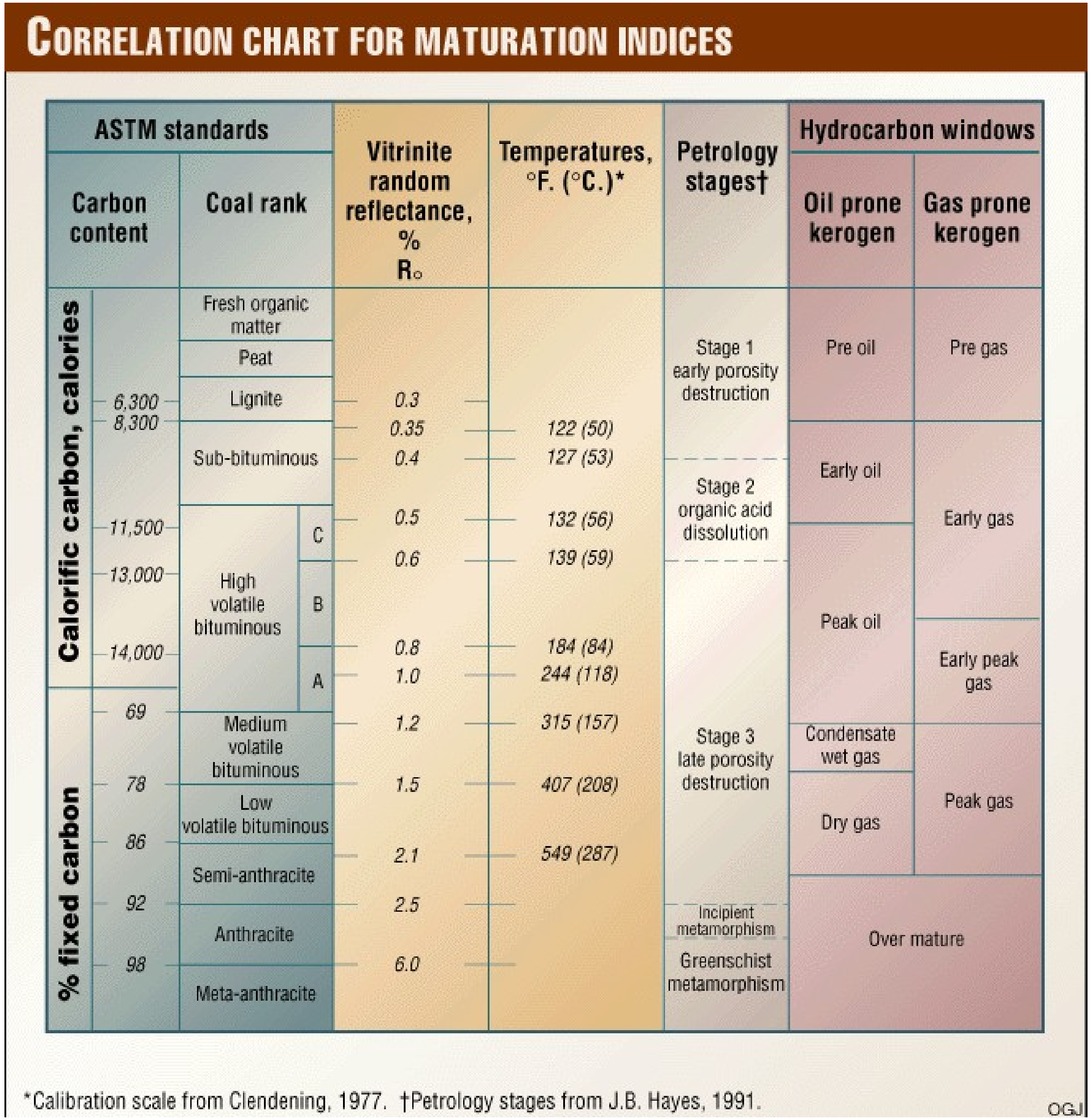
- Having more than 86% fixed carbon and less than 14% volatile matter on a dry, mineral-matter-free basis.
- Further divided into **semi-anthracite, anthracite, and meta-anthracite** groups based on increasing fixed carbon and decreasing volatile matter.
- High carbon and energy content coupled with being a relatively hard material and clean burning makes anthracite a desired product.

Vitrinite reflectance

- **Vitrinite: coal maceral→ determines coal rank**
- **Used for a long time to estimate coal *rank* (= maturity)**
- **Illumination of a vitrinite particle**
- **Determination of the percentage of light that is reflected**
- **The higher the maturity: the higher the reflectance value**
- **Ro = 0.6 to 1.2 commonly cited as the principal zone of oil and gas formation**



Changes in coal properties with increasing VRo



Source: http://www.ogj.com/articles/print/volume-97/issue-16l

Coal Classification: Grade

- Classification as per use: coking coal and non-coking coal
- Coking coal – use in steel making
- Non-coking : Mostly for burning to produce power.

Coking coal grades

GRADES: The gradation of coking coal is based on ash content

Grade	Ash Content
Steel Grade –I	Not exceeding 15%
Steel Grade –II	Exceeding 15% but not exceeding 18%
Washery Grade –I	Exceeding 18% but not exceeding 21%
Washery Grade –II	Exceeding 21% but not exceeding 24%
Washery Grade –III	Exceeding 24% but not exceeding 28%
Washery Grade –IV	Exceeding 28% but not exceeding 35%

Grades of Non- Coking Coal

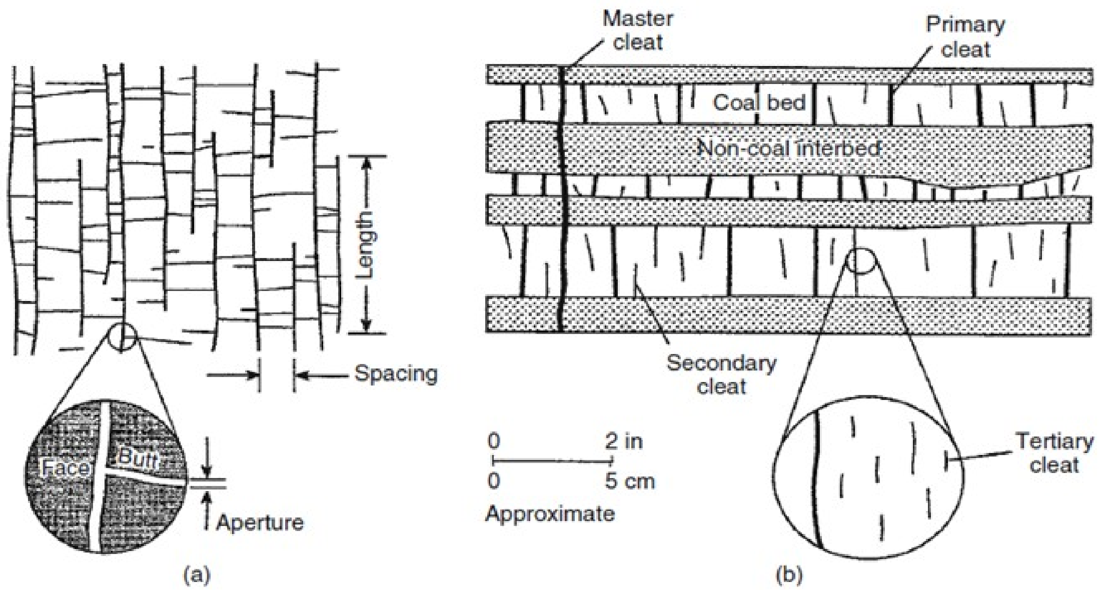
The gradation of non-coking coal is based on Useful Heat Value (UHV), and on ash plus moisture content.

Grade	Useful Heat Value (UHV) (Kcal/Kg) UHV= 8900-138(A+M)	Corresponding Ash% + Moisture % at (60% RH & 40^{O} C)	Gross Calorific Value GCV (Kcal/ Kg) (at 5% moisture level)
A	Exceeding 6200	Not exceeding 19.5	Exceeding 6454
B	Exceeding 5600 but not exceeding 6200	19.6 to 23.8	Exceeding 6049 but not exceeding 6454
C	Exceeding 4940 but not exceeding 5600	23.9 to 28.6	Exceeding 5597 but not exceeding. 6049
D	Exceeding 4200 but not exceeding 4940	28.7 to 34.0	Exceeding 5089 but not Exceeding 5597
E	Exceeding 3360 but not exceeding 4200	34.1 to 40.0	Exceeding 4324 but not exceeding 5089
F	Exceeding 2400 but not exceeding 3360	40.1 to 47.0	Exceeding 3865 but not exceeding. 4324
G	Exceeding 1300 but not exceeding 2400	47.1 to 55.0	Exceeding 3113 but not exceeding 3865

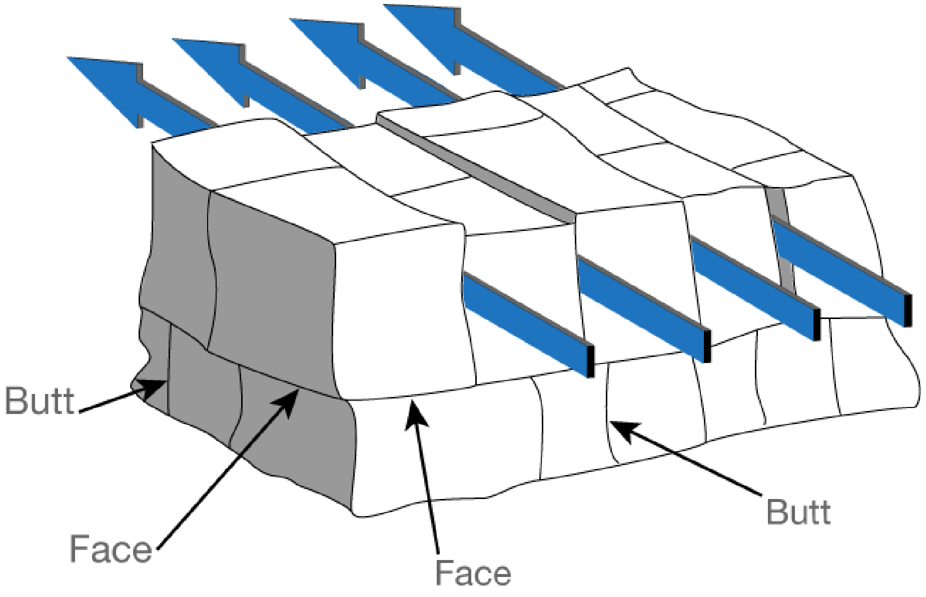
Cleats in coals

Cleats: form due to coal dehydration, local and regional stresses, and unloading of overburden.

- Control the directional permeability.
- Highly important for CBM exploitation through well placement and spacing.
- Two orthogonal sets of cleats develop in coals perpendicular to bedding.
- **Face cleats** are the dominant set →continuous and more laterally extensive; face cleats form parallel to maximum compressive stress.
- Cleat spacing is related to rank, bed thickness, maceral composition, and ash content. Coals with well-developed cleat sets are brittle reflecting fracture density.
- Cleats are more tightly spaced with increasing coal rank.



(a) Cleat-trace patterns in plan view. (b) Cleat hierarchies in cross-section view. (Laubach 1998).



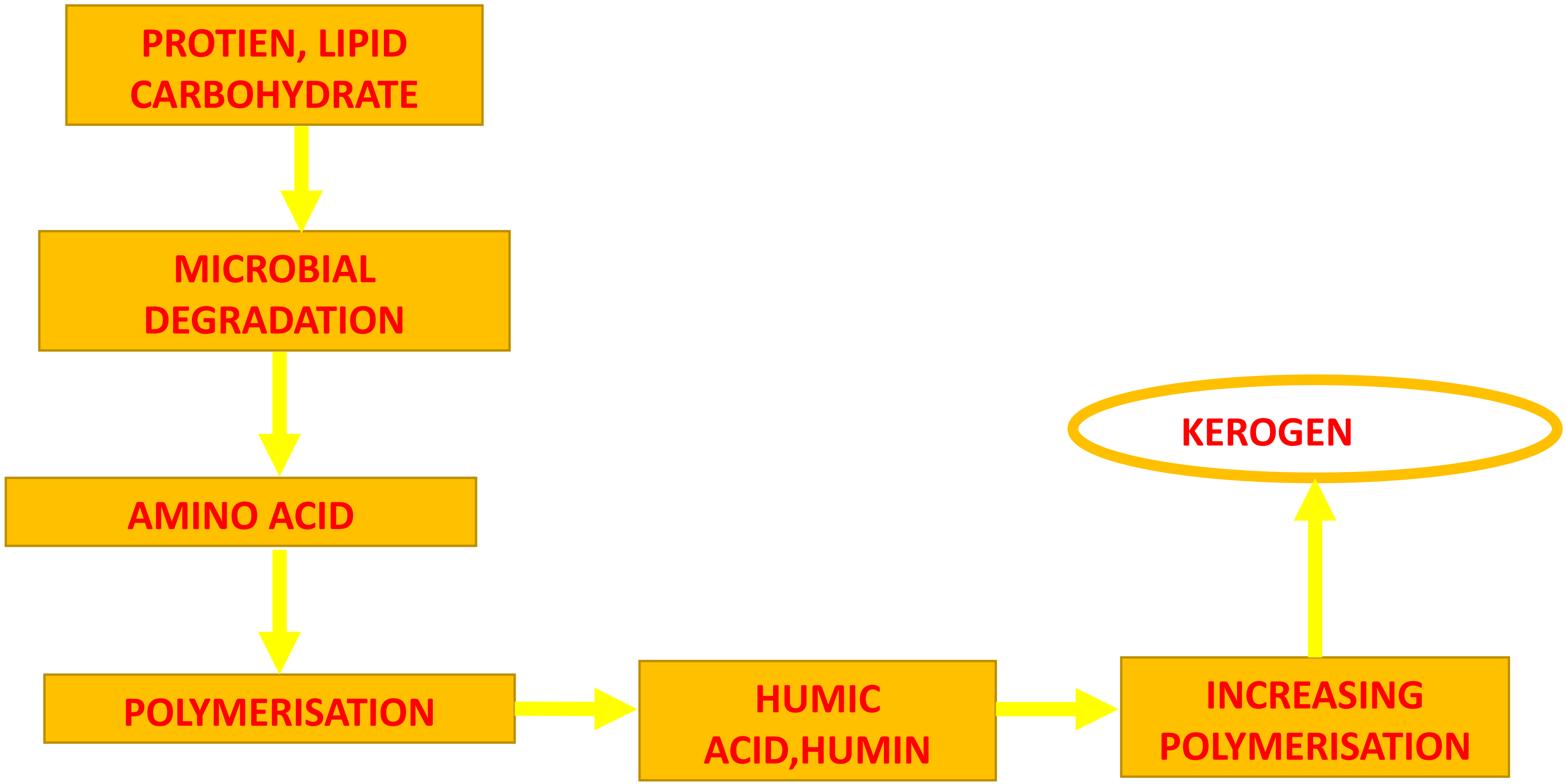
Face and butt cleats in coal. (scott 1994).

COAL AS A RESERVOIR FOR COAL BED METHANE

- Coal Bed Methane is naturally occurring methane obtained by both biogenic and thermogenic process.
- CBM contains small amounts of other hydrocarbon and non-hydrocarbon gases in coal seams as a result of chemical and physical processes.
- It is formed during the conversion of organic material to coal, and eventually trapped in pores and cleats in the coal seam.
- Organic matter is subjected to pressure and temperature, and further they are transformed into kerogen.
- These kerogens with continuing pressure and high temperature starts to break down to produce gas (this is thermogenic methane) leading to an increase in carbon content and decrease in hydrogen content.

GENERATION OF GAS

STEP 1. TRANSFORMATION OF ORGANIC MATTER TO KEROGEN



Step 2. Kerogen to gas

KEROGEN

↓

DIAGENESIS →

Shallow subsurface
Normal pressure and temperature
Released: CH_4, CO_2, H_2O

- Overall decrease in O
- Overall increase in H and C

↓

CATAGENESIS →

Deeper subsurface
Increased pressure and temperature
Released: oil & gas

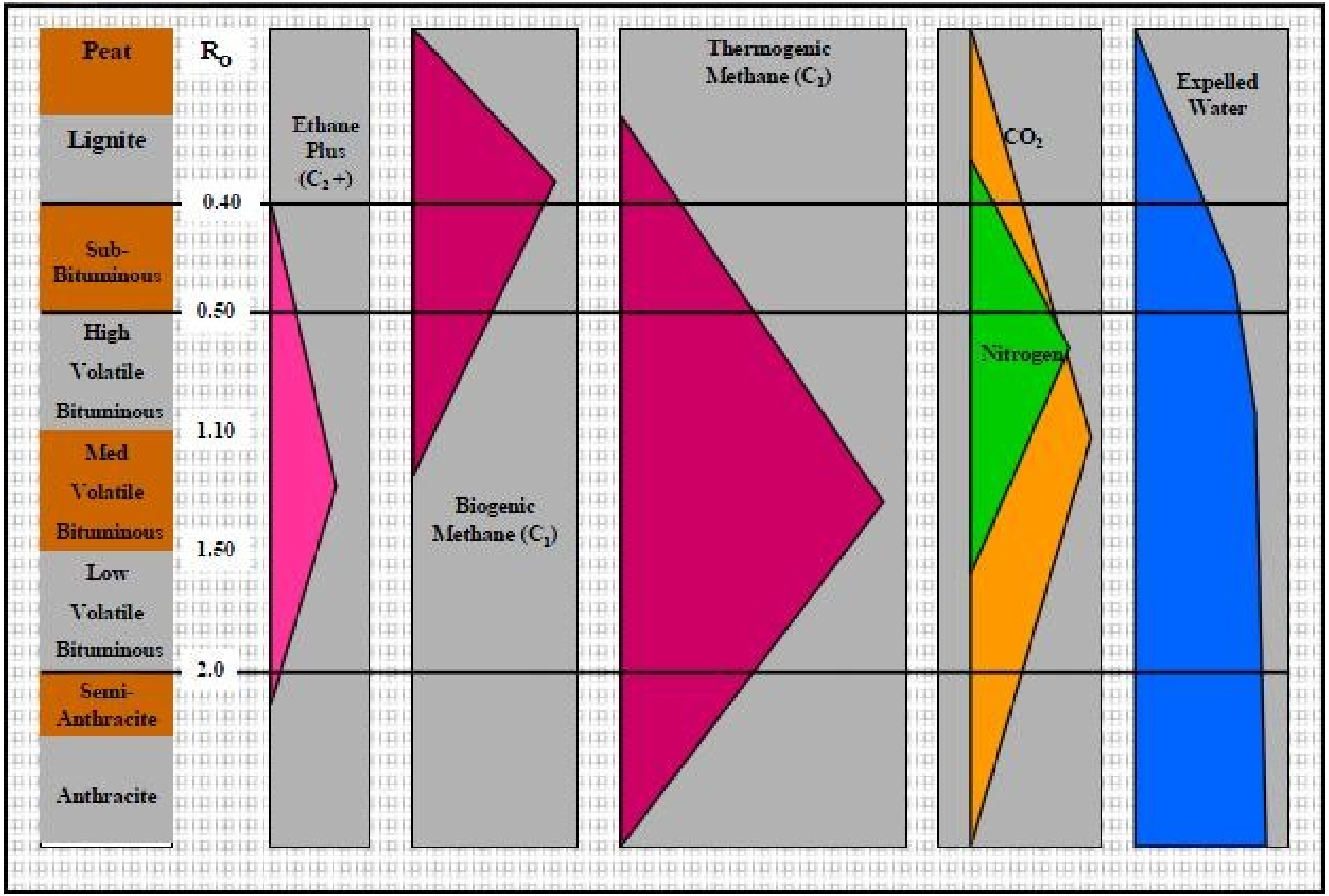
- Overall decrease in H and C

↓

METAGENESIS →

Metamorphism
High temperature and pressure
Only C remains: becomes graphite

(Source: Hunt, Petroleum Geochemistry and Geology,1995)

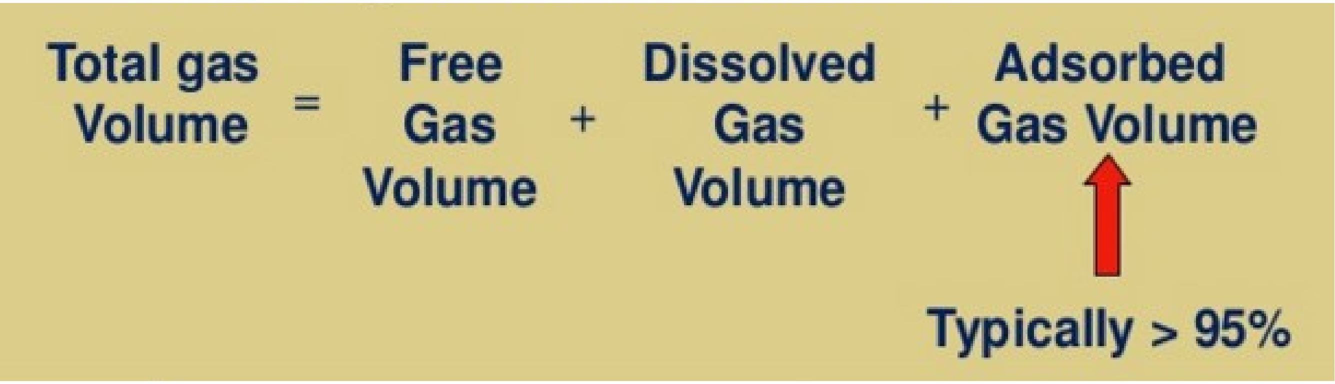


Coal maturation and gas generation chart.
Source: (ALL Consulting & Montana Board of Oil and Gas Conservation, 2003)

Storage

Coalbed methane is retained in coal in three ways:

- As a free gas within the pore space or fractures in the coal;
- As adsorbed molecules on the organic surface of the coal; and
- Dissolved in groundwater within the coal.



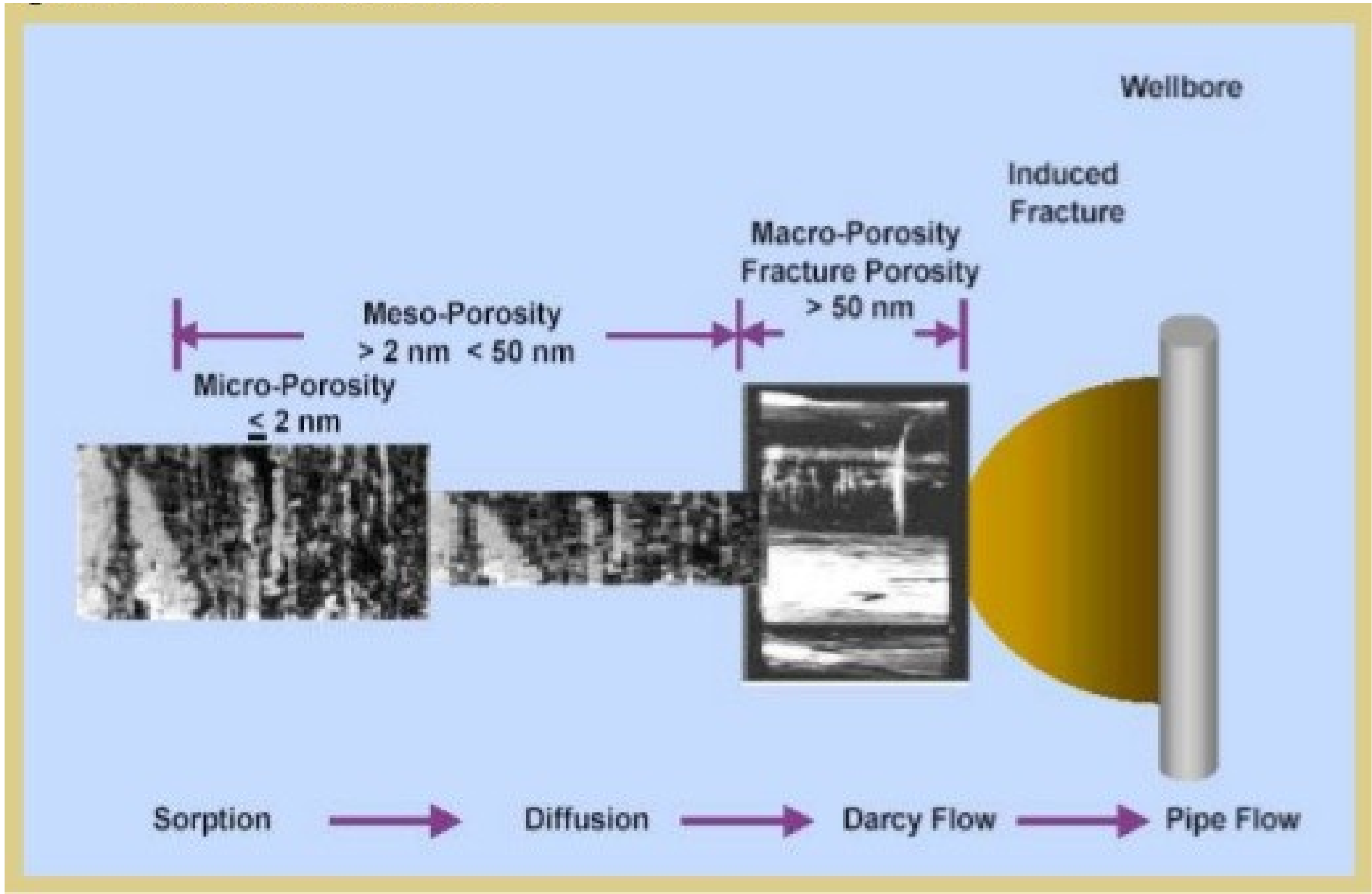
Porosity

Primary porosity→ Micropores

Secondary Porosity→ Macropores/fractures

Porosity in coals with carbon content (*C*) <75% is predominantly due to macropores;

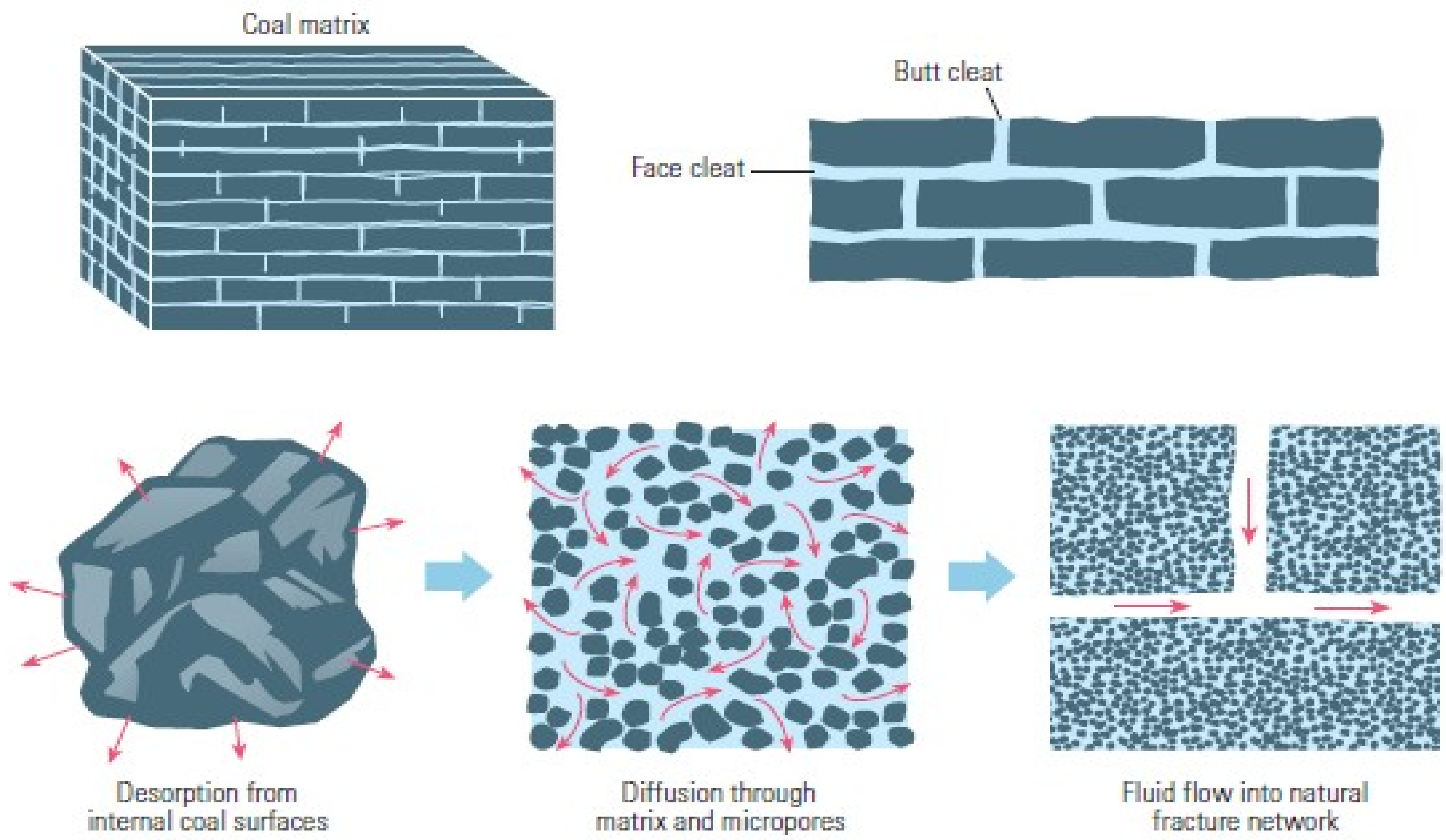
- **Porosity in coals with carbon content (*C*) 85–91% is predominantly due to micropores;**
- **Porosity in coals with carbon content (*C*) 75–84% is associated with significant proportions of macro meso and microporosity.**



Flow mechanism
Source: https://www.google.co.in/search?q=CBM+ppt

Transport of gas in coal

- Gas held in coal by hydrostatic pressure
- Cannot be economically produced without open fractures(provides the pathways for the desorbed gas to migrate to the well.)
- Coal cleats and fractures are usually saturated with water, and therefore the hydrostatic pressure in the coal seam must be lowered before the gas will migrate.
- Lowering the hydrostatic pressure in the coal seam accelerates the desorption process.
- The gas then diffuses through the matrix, migrates into the cleats and fractures, and eventually reaches the wellbore.

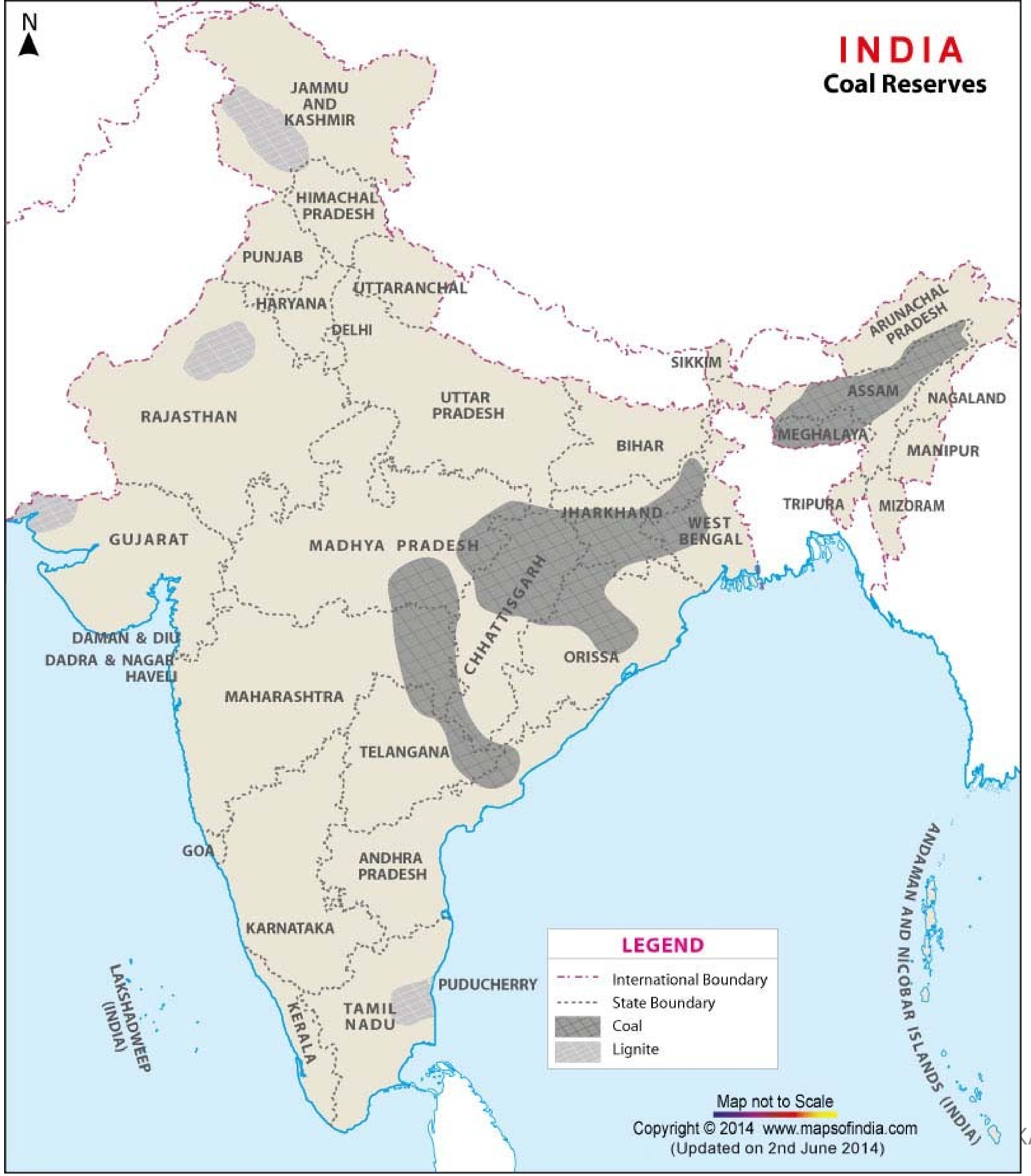


- Adsorption and desorption. During coalification the matrix shrinks, creating orthogonal fractures called cleats.
- Generally, water fills the void spaces of the coal matrix. As the water is produced and the formation pressure decreases, methane, adsorbed on the surfaces of the coal matrix and stored in the micropores, is liberated.
- The gas then diffuses through the matrix, migrates into the cleats and fractures, and eventually reaches the wellbore.

Source: Jabouri et al, 2009

DISTRIBUTION OF COALFIELDS IN INDIA

Coal type	Coalfields
Gondwana coals ranking high volatile bituminous A and above.	Jharia, East and West Bokaro, Raniganj and North Karanpura Coalfields
Gondwana coals ranking high volatile bituminous A and below.	South Karanpura, Raniganj, Pench-Kanhan and Sohagpur Coalfields.
Low rank Gondwana coals	Talchir, Ib, Pranhita-Godavari Valley, Wardha Valley Coalfields.
Tertiary Coals/Lignite	Assam-Arakan, Himalayan Foothills, Cambay, Barmer-Sanchor, Bikaner- Nagaur and Cauvery basins.



KARASU

DISTRIBUTION OF COALFIELDS IN INDIA

Source : http://www.mapsofindia.com/maps/india/coalreserves.htm

Types of Indian coal

Coking

Prime – Prime Low volatile bituminous coals , Coke type G7 or better

Ro(mean) = 1.2. Upper Barakar seams in Jharia coalfield

Medium - Medium Low to high volatile bituminous coals, Coke type FG6,

Ro(mean) = 1.1-1.4. Lower Barakar & Raniganj seams in Jharia, Barakar seams in Raniganj, Bokaro, parts of Ramgarh, Karanpura, Sohagpur and Pench- Kanhan coalfields

Semi – High volatile, Coke type D-F,

Ro(mean) = 0.7.Lower Raniganj seams in Raniganj, Barakar seams in parts of Ramgarh and Sonhat coalfields

Types of Indian coal

Non-coking

Superior – Superior High volatile bituminous B-C coals.

Mainly in Raniganj seams of Raniganj coalfield

Inferior – Inferior High volatile sub-bituminous coals. All coalfields

High Sulphur

Tertiary coalfields of Northeastern Region

Cumulative total of 301.56 Billion tonnes of Geological Resources of Coal have so far been estimated in the country as on 1.4.2014

STATE	PROVED	INDICATED	INFERRED	TOTAL
Total	125909	142506	33149	301564
West Bengal	13403	13022	4893	31318
Jharkhand	41377	32780	6559	80716
Bihar	0	0	160	160
Madhya Pradesh	10411	12382	2879	25673
Chhattisgarh	16052	33253	3228	52533
Uttar Pradesh	884	178	0	1062
Maharashtra	5667	3186	2110	10964
Odisha	27791	37873	9408	75073
Andhra Pradesh	9729	9670	3068	22468
Assam	465	47	3	515
Sikkim	0	58	43	101
Arunachal Pradesh	31	40	19	90
Meghalaya	89	17	471	576
Nagaland	9	0	307	315

Source: Ministry of mines

Proximate Analysis

- **Moisture:** Moisture is the water that exists in the coal at the site, time, and under the conditions it is sampled. Experts determine the amount of moisture in your samples by measuring the loss in mass between an as-mined sample and a sample that has been heated under controlled conditions to drive off the water that is not contained within the chemical structure of the coal.
- **Sulfur:** It is important to measure the sulfur content in coal samples to evaluate the potential sulfur emissions from coal combustion, or for contract specifications purposes.
- **Volatile Matter:** Volatile matter includes the components of coal, except for water, which are liberated at high temperature in the absence of oxygen. Volatile matter is a key health and safety concern as coals high in volatiles have an increased risk of spontaneous combustion. Scientists determine the volatile matter in coal sample by measuring the mass of volatiles before and after weight analysis under strictly controlled conditions.
- **Fixed Carbon**: The fixed carbon content of coal is determined by subtracting the percentages of moisture, volatile matter and ash from the original mass of the coal sample: the solid combustible residue that remains after a coal has had the volatiles driven off.
- **ASH:** Ash analysis tests are done

Significance of Various Parameters in Proximate Analysis

a) Fixed carbon→gives a rough estimate of heating value of coal

b) Volatile Matter:

- Volatile matters is an index of the gaseous fuels present.
- Typical range of volatile matter is 20 to 35%.
- Volatile Matter proportionately increases flame length, helps in easier ignition of coal,
- Sets of minimum limit on the furnace height and volume,
- Influences secondary air requirement and distribution aspects, Influences secondary oil support

Significance of Various Parameters in Proximate Analysis

c) Ash Content:

- Ash is an impurity that will not burn. Typical range is 5 to 40%.
- Ash reduces handling and burning capacity,
- increases handling costs, affects combustion efficiency and boiler efficiency, causes clinkering and slagging.

d) Moisture Content: Moisture in coal must be transported, handled and stored.

- It decreases the heat content per kg of coal.
- Typical range is 0.5 to 10%.
- Moisture increases heat loss, due to evaporation and superheating of vapour, helps, to a limit, in binding fines. aids radiation heat transfer.

e) Sulphur Content: Typical range is 0.5 to 0.8% normally.

- Sulphur affects clinkering and slagging tendencies,
- Corrodes chimney and other equipment such as air heaters and economisers, limits exit flue gas temperature.

Ultimate Analysis

The ultimate analysis indicates the various elemental chemical constituents such as **Carbon, Hydrogen, Oxygen, Sulphur,** etc.

No: **0705** | Course Code: **MTIGT**

BHARATHIDASAN UNIVERSITY

6 Year Integrated M.Tech. Programme (November – 2018)

(For the candidates admitted from the academic years 2017-2018 onwards)

Semester – VII

Coal Geology

Time : 3 Hours | Maximum Marks:75

Section –A (10X2=20 Marks)

Answer all the Questions.

1. Define Indian coal and lignite.
2. List the varieties of coal.
3. What is a maceral?
4. Write the carbon composition of Lignite and Anthrasite.
5. What are Indian grade or rank of a coal?
6. What is non coking coal?
7. Name any eight coal fields in India.
8. What is Coal carbonization?
9. Write the composition of lignite and coal (empirical formula).
10. Distinguish between proved reserves and probable reserves.

Section – B (5X5= 25 Marks)
Answer all questions.

- a) Write short notes on the Coalification process.
(or)
b) Write short notes on micro lithotypes of coal and their usage in interpretation.
- a) Outline the application of coal geology in hydrocarbon exploration.
(or)
b) Write brief notes on maceral analysis.
- a) Briefly describe proximate analysis of Coal.
(or)
b) Briefly describe ultimatee analysis of Coal.
- a) Elucidate the Liquefaction of coal.
(or)
b) Elucidate the Gasification of coal.
- a) Write a note on new Lignite explorations in Cauvery basin.
(or)
b) Write an outline on the Indian coal resources.

Section –C (10X3=30 Marks)

Answer any three questions.

16. Enlighten the origin of Coal in detail.
17. Discuss the concept of coal maturity through ranks of coal
18. Elucidate the classification of coal.
19. Describe the exploration and production of Coal Bed Methane.
20. Write an account on the Neyveli lignite deposits.

CENTRE FOR REMOTE SENSING
BHARATHIDASAN UNIVERSITY
MTIGT708-COAL GEOLOGY
Six Year Intgrated M.Tech. Course. First Internal Examination, August, 2018
Time 2hrs Maximum 50Marks

PART-A

Answer any Ten Questions (10 ×2 = 20)

1. Define the origin of coal.
2. Briefly state the classification of coal.
3. What is the chemical composition of coal and lignite?
4. What are the parameters in ultimate analysis?
5. What are the parameters in Proximate analysis?
6. Which is the leading state in coal production, as per 2012-‘13?

a) Andhra Pradesh b) Chhattisgarh
c) Jharkhand d) Madhya Pradesh

7.Which one of the following coal mining companies produces the largest quantity of coal in India?

a) Coal India b) Singaneri Collieries Company
c) South Eastern Coalfields d) Tata Steel

9. Describe coalification process and its causes.
10. Write about the application of coal. 11. Where is Ranikanj coal field in India?
12. Where is Talchir coalfield in India?

PART-B (2X5=10)

Answer any Two Questions

13. Explain the lignite deposit in Gujarat state.
14. Write about Godavari Basin coal field.
15. Explain about the Wardha Valley Coalfield coalfields in India
16. Define coking and noncoking coal.

PART-C (2X10=20

Answer any Two Questions

17. Write about Cauvery Basin and its mineral solid fuel deposits.

18. Describe the tertiary lignite field of Gujarat and Rajesthan.

19. List out coal and lignite mines in India with brief a note.

20. Elucidate the Gondawana coal in Godawari Basin, Andhra Presh.