Fossil Fuels

ESO 213

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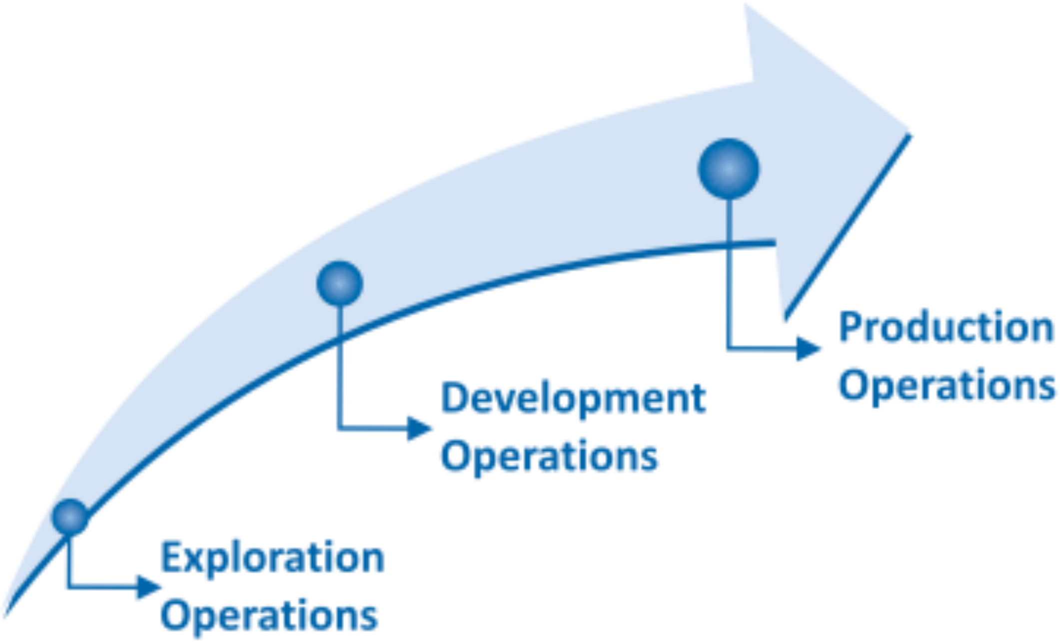
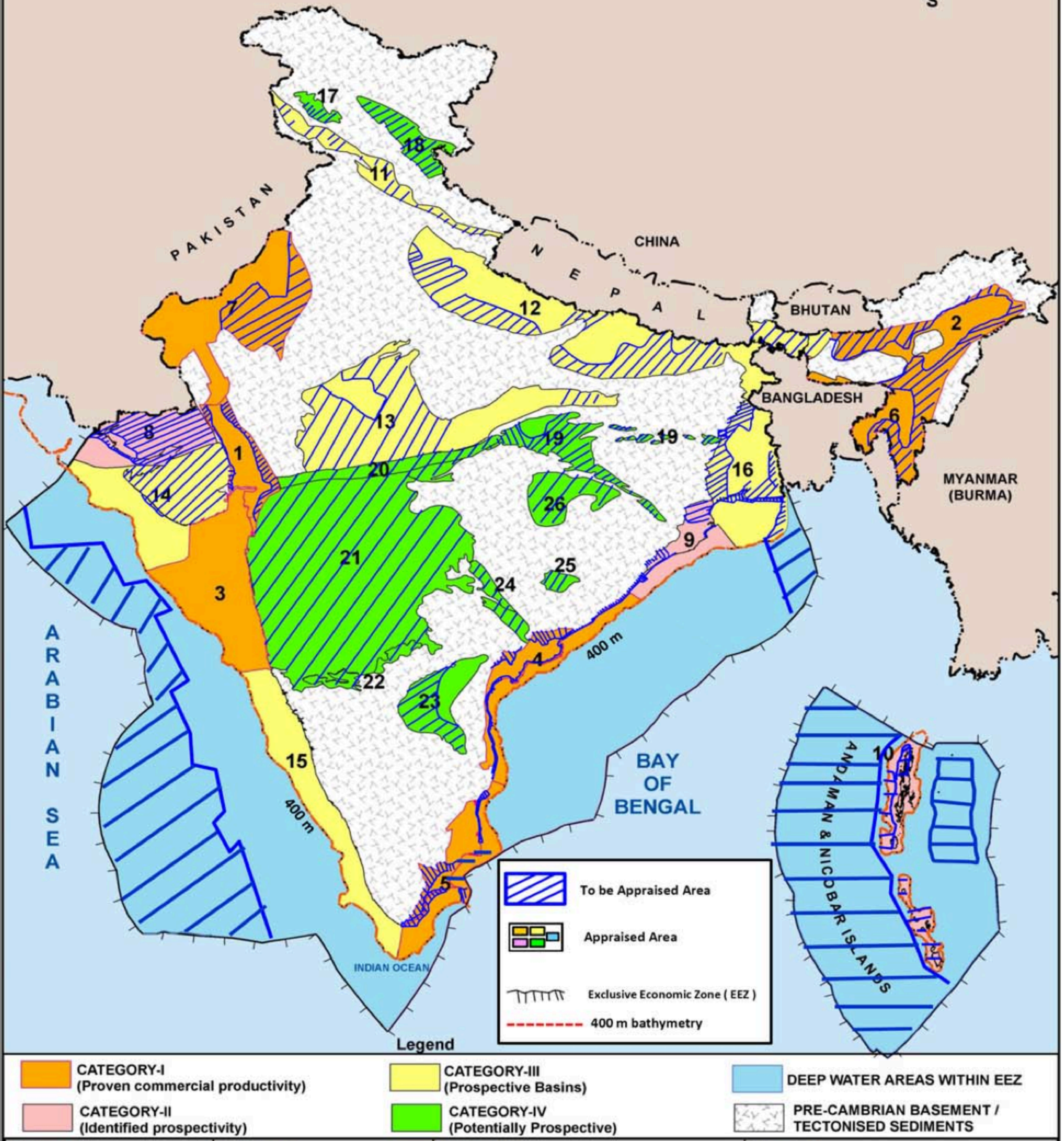
Hydrocarbon Exploration and Production (E&P) operations, also referred to as upstream operations, can be broadly grouped into three categories.



Fossil Fuel: Crude Oil, Coal and Natural Gas



Category I
1. Cambay Basin
2. Assam Shelf Basin
3. Mumbai Offshore Basin
4. Krishna -Godavari Basin
5. Cauvery Basin
6. Assam-Arakan Fold Belt
7. Rajasthan Basin

Category II
8. Kutch Basin
9. Mahanadi Basin
10. Andaman-Nicobar Basin

Category III
11. Himalayan Foreland
12. Ganga Basin
13. Vindhyan Basin
14. Saurashtra Basin
15. Kerala -Konkan -Lakshadweep Basin
16. Bengal Basin

Category IV
17. Karewa Basin
18. Spiti -Zanskar Basin
19. Satpura-South Rewa-Damodar Basin
20. Narmada Basin
21. Deccan Syneclise Basin
22. Bhima -Kaladgi Basin
23. Cuddapah Basin
24. Pranhita- Godavari Basin
25. Bastar Basin
26. Chhattisgarh Basin

Crude Oil/Petroleum

Objectives are to be able to:

- Discuss basic elements of Petroleum Systems
- Describe the origin of petroleum
- Describe source rock/reservoir rock/trap and seal
- Identify hydrocarbon trap types

Petroleum System - A Definition

•A Petroleum System is a dynamic hydrocarbon system that functions in a restricted geologic space and time scale.

•A Petroleum System requires timely convergence of geologic events essential to the formation of petroleum deposits.

These Include:

- Mature source rock
- Hydrocarbon expulsion
- Hydrocarbon migration
- Hydrocarbon accumulation
- Hydrocarbon retention

(modified from Demaison and Huizinga, 1994)

Petroleum Systems

Elements

- Source Rock
- Migration Route
- Reservoir Rock
- Seal Rock
- Trap

Processes

- Generation
- Migration
- Accumulation
- Preservation

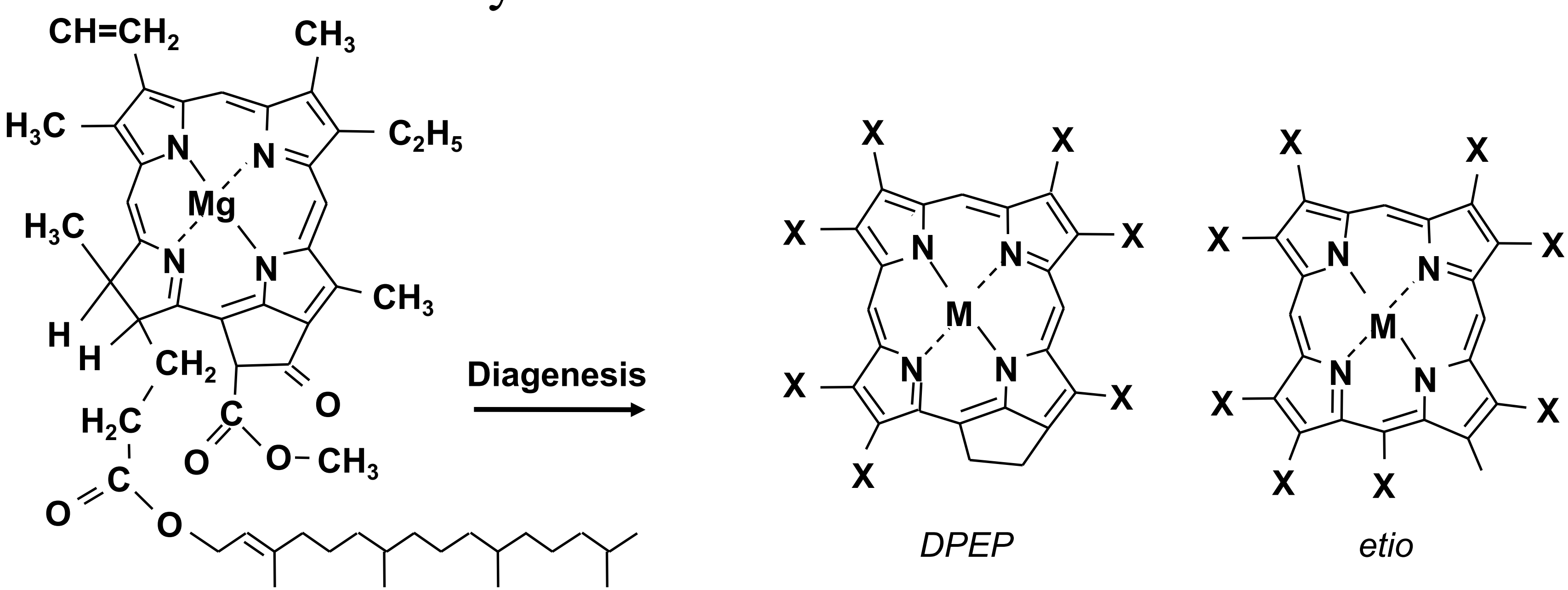
1. SEDIMENTERY BASIN

2. BASIN-SOURCE ROCK DEPOSITION-PRESERVATION-GENERATION-PRIMARY MIGRATION-SECONDARY MIGRATION-ACCUMULATION

Origin and preservation of Organic Matter

Biomarkers or Biological Markers: Complex organic compounds composed primarily of carbon and hydrogen.

- Principal structural characteristics of biomarkers are chemically stable during sedimentation and early burial



Generalized Progression from Living Organisms to Petroleum

Life

(death)

↓

Preservation of Organic Remains

(diagenesis)

↓

Formation of Kerogen

(maturation; catagenesis)

↓

Generation of Petroleum from Kerogen

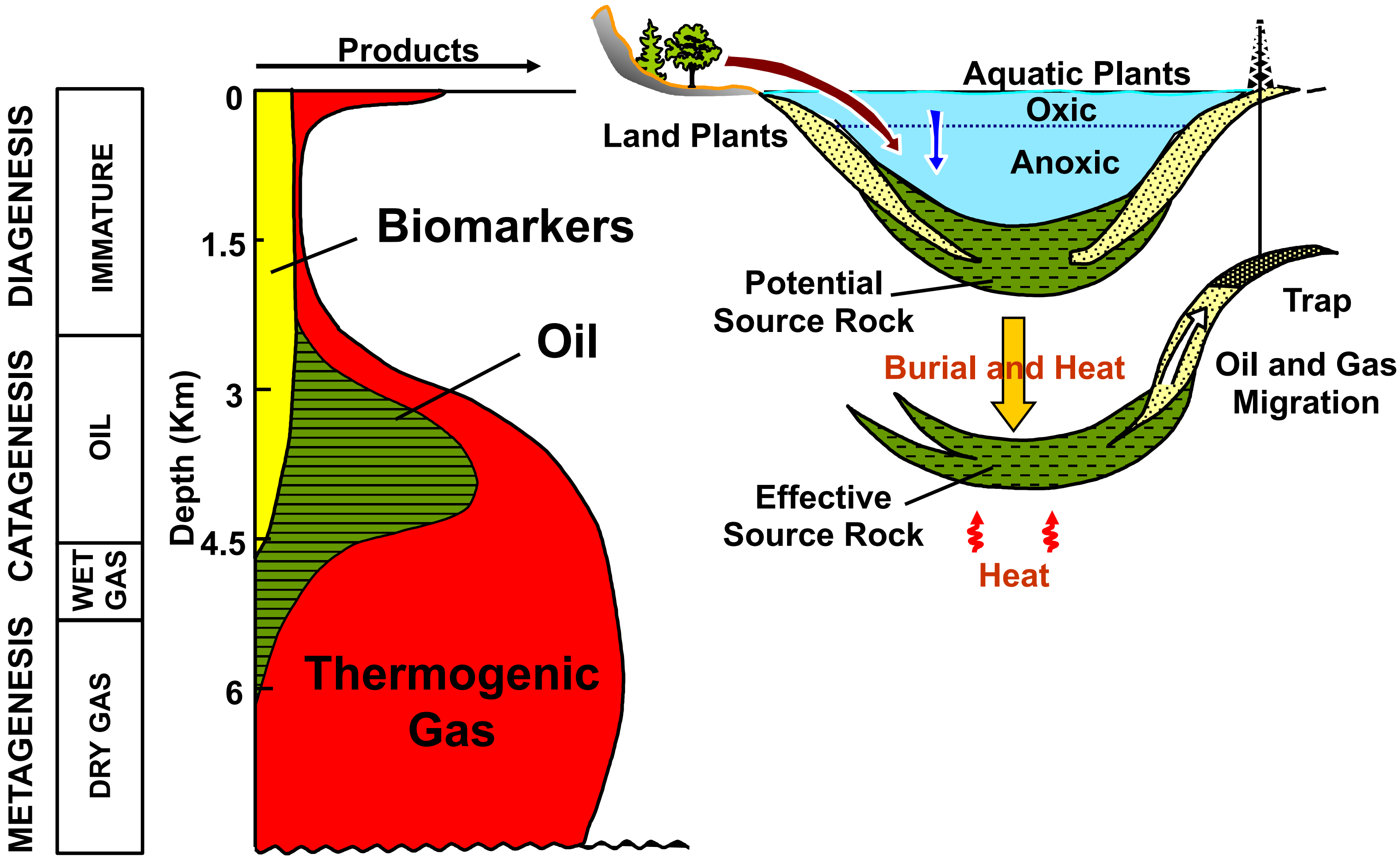
Kerogen:

Portion of sedimentary organic matter that <u>IS NOT</u> soluble in common organic solvents (complex; high mol. wt.)

Bitumen:

Portion of sedimentary organic matter that <u>IS</u> soluble in common organic solvents ("oil-like" fraction)

Biomarkers Survive Throughout Much of the Oil Generative Window



What controls the quality of the source rock?

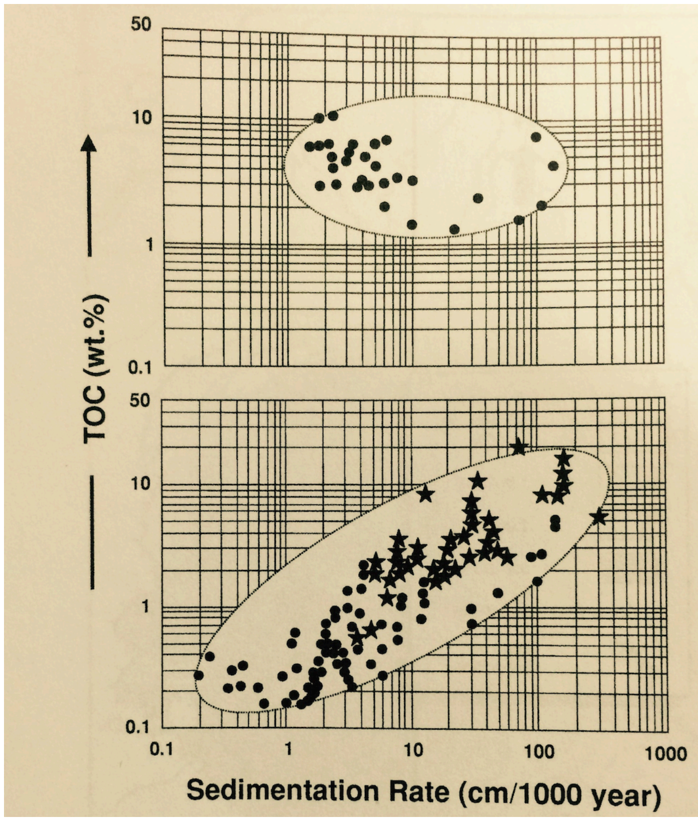
- Depositional Environment
- Grain Size
- Kerogen Type

Kerogen Types

- Type I (Algal)
  - High H:C ~1.65, Low O:C
  - Rich in lipids (mostly saturated)
  - Oil prone
- Type II (Liptinic)
  - Intermediate H:C ~1.25, Interm O:C
  - Algal+Zooplancton
  - Oil and Gas prone
- Type III (Humic)
  - Low H:C ~0.84, High O:C
  - Rich in aromatic compounds
  - Plant material and coal
  - GasProne

Sedimentation Rate and Grain Size?

- OM is preferentially deposited with fine grained mud
- Rapid burial improves preservation by reducing the residence time of OM in zones of bioturbation and degradation



Anoxic environment

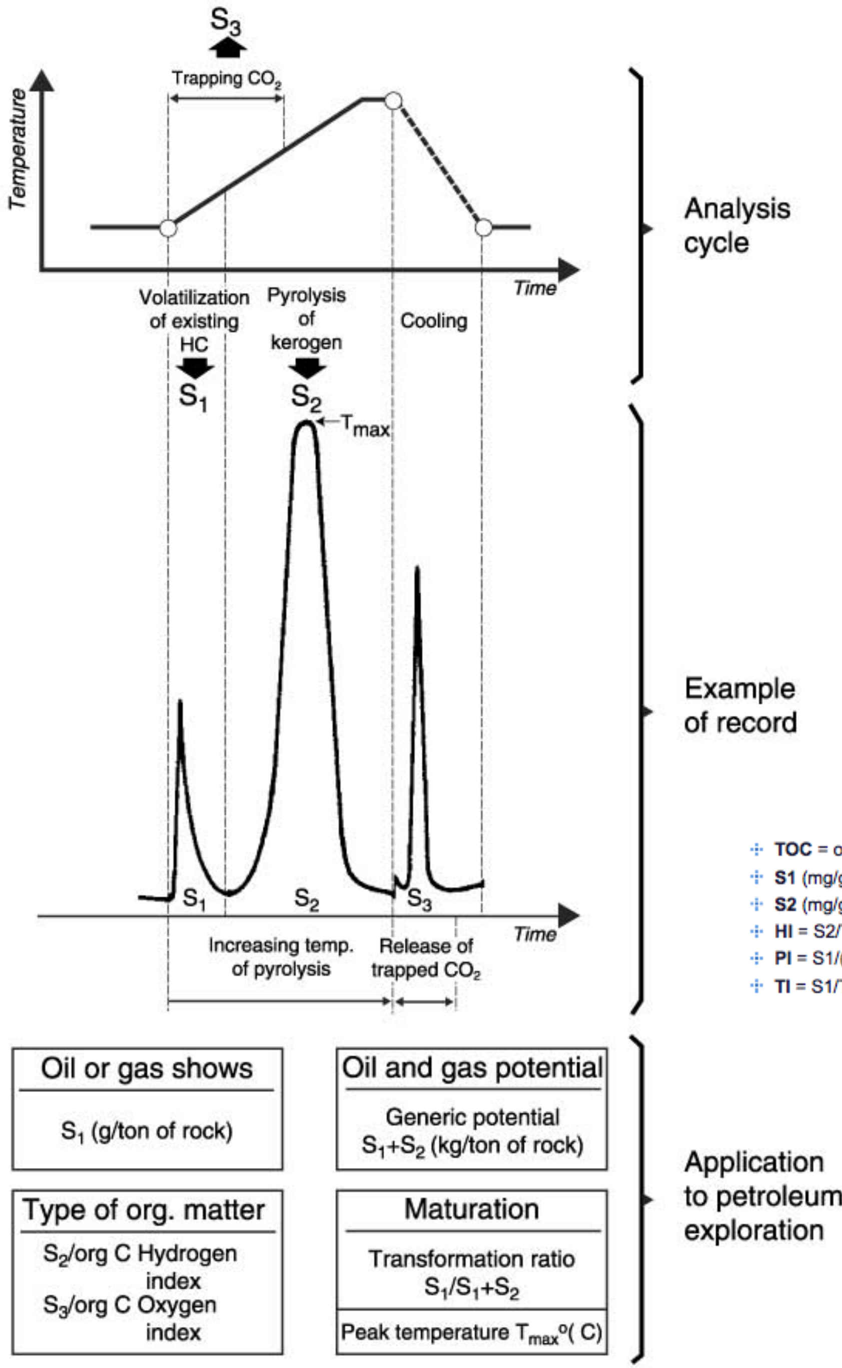
Oxic environment

Higher sedimentation ~ dilute the OM signal

Sedimentation rate enhances TOC preservation at only ≤ 5 cm/1000 years in oxic regime

How do we determine the quality of source rock

ROCK EVAL PYROLYSIS



- **TOC** = organic carbon content (percent weight) of source rock.
- **S1** (mg/g rock) Liquid hydrocarbon residual measured during Rock Eval (peak 1)
- **S2** (mg/g rock) Liquid hydrocarbon generated by Rock Eval (peak 2)
- **HI** = S2/TOC (mg HC/g TOC) --- describes how much of the organic matter can be converted to hydrocarbons.
- **PI** = S1/(S1+S2) a measure of maturity.
- **TI** = S1/TOC (mg/g TOC), represents existing hydrocarbons before source rock matures.

Pyrolysis

Hydrocarbons already in the rock

Hydrocarbons generated during pyrolysis (remnant potential)

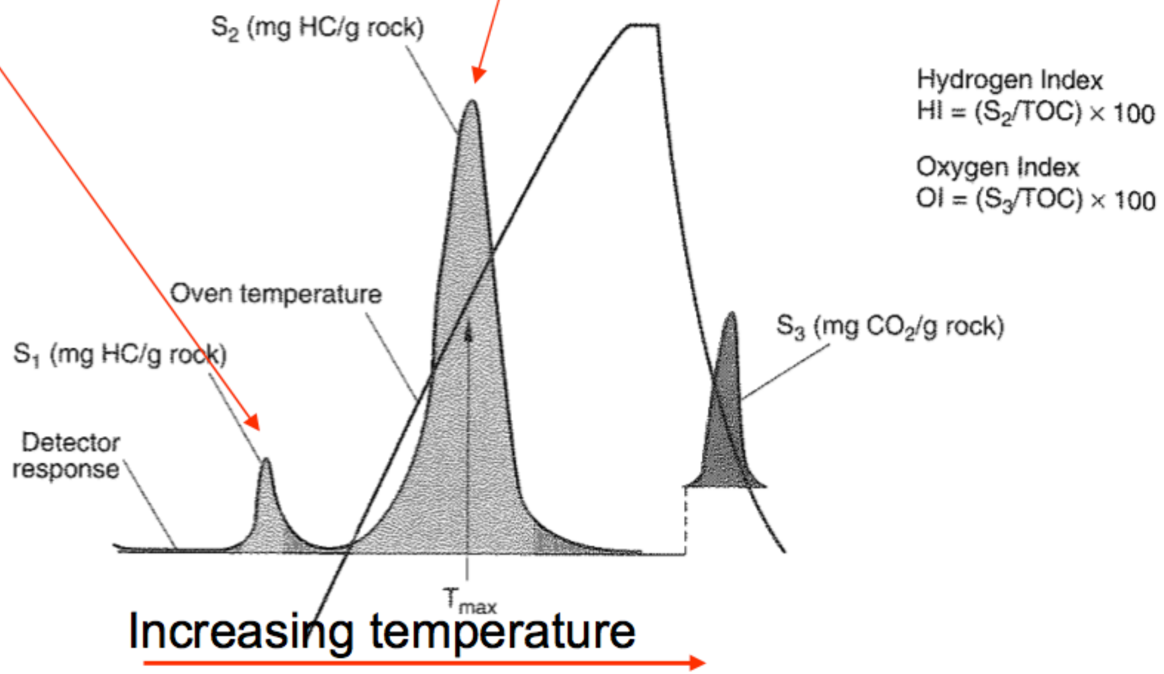
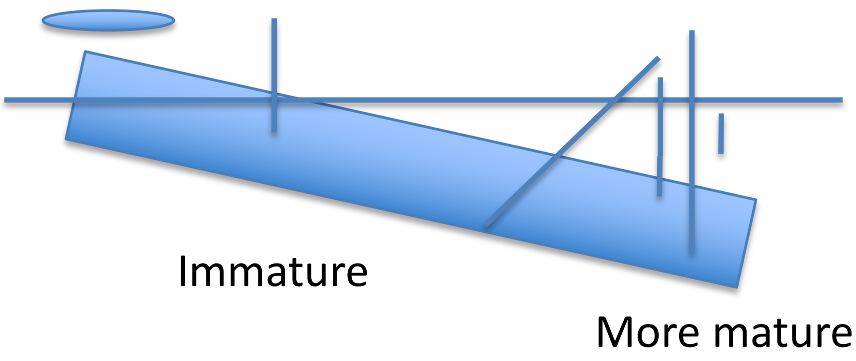


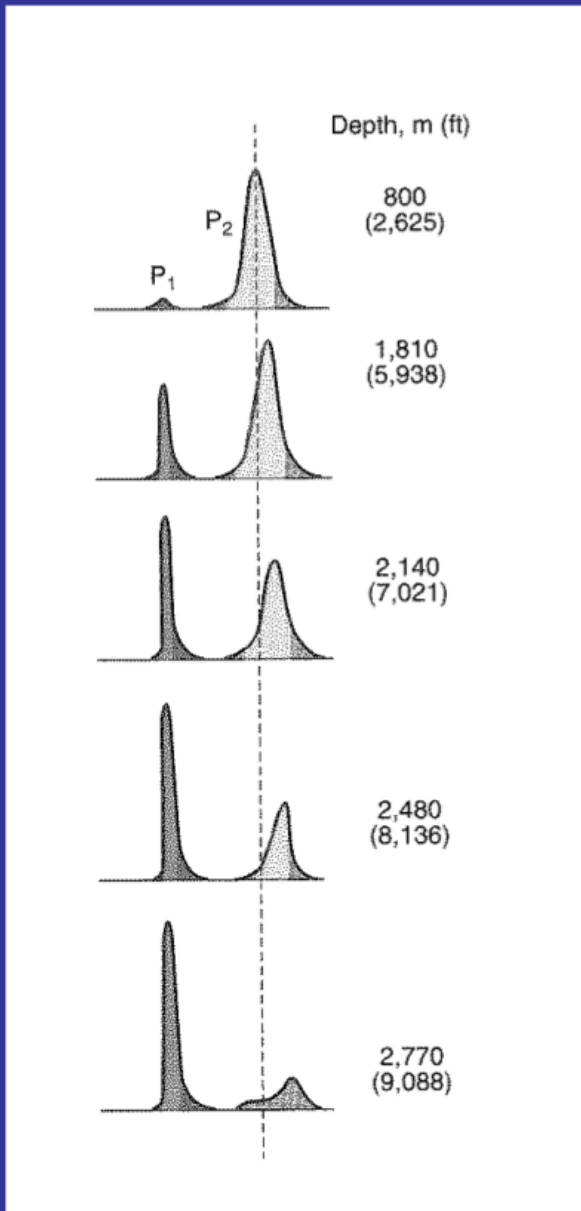
Figure 10-7

Schematic of pyrogram showing the evolution of hydrocarbons and CO_2 from a rock sample during heating (increasing time and temperature from left to right). Important measurements include S_1, S_2, S_3, and T_{max}. Hydrogen and oxygen indices are calculated as shown. [Peters 1986]



Immature
More mature

Pyrolysis vs depth



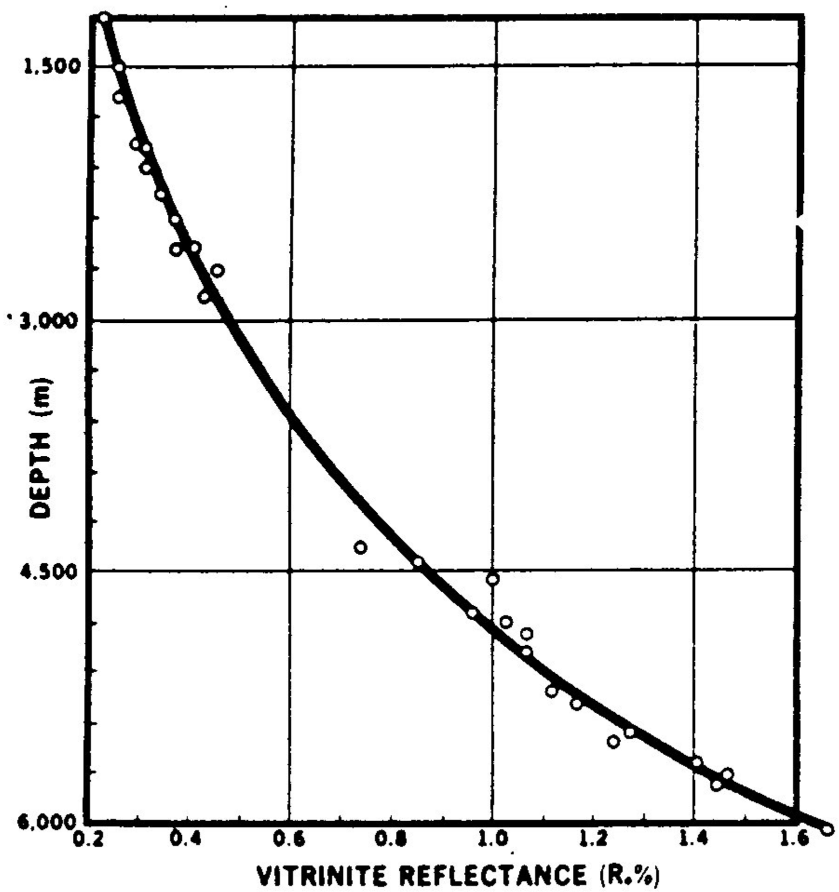
Immature Source Rock

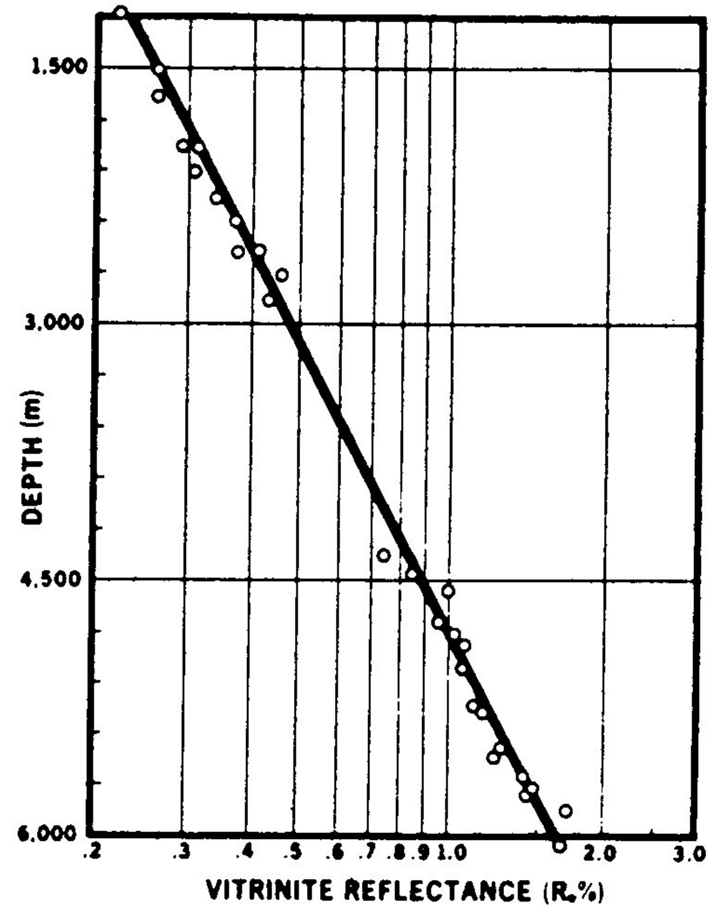
Mature Source Rock

Over mature Source Rock

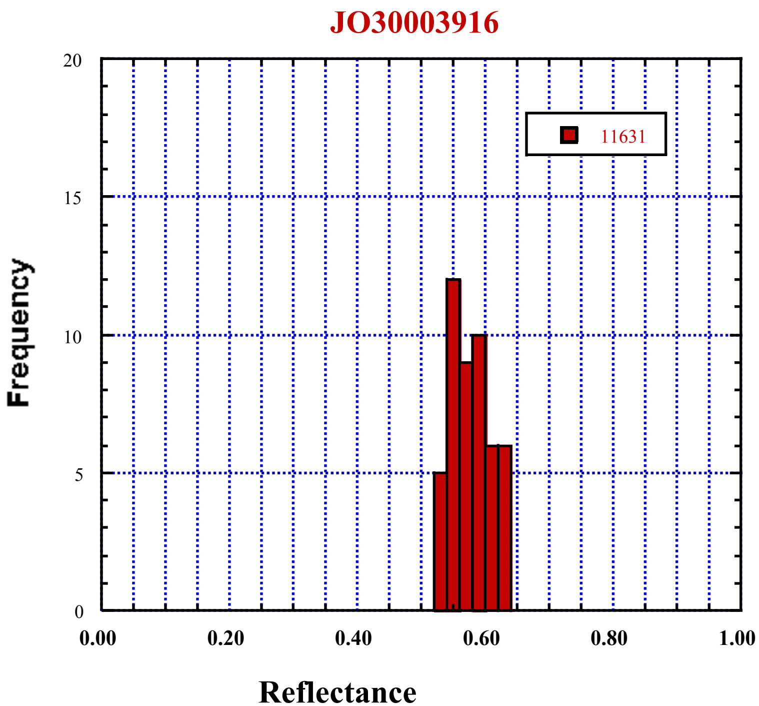
Vitrinite Reflectance

Kerogen Maturation Profile, Louisiana Gulf Coast

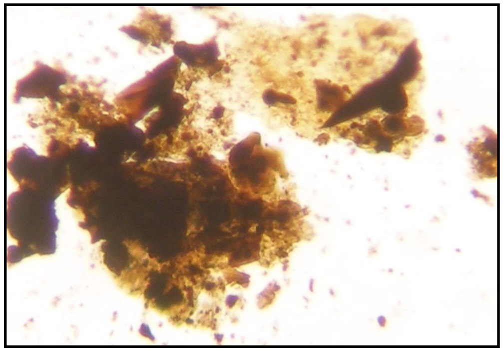




Why reflectance increases with maturation?



238023H	11631
Minimum	0.52
Maximum	0.63
Points	48
Std Deviation	0.03
Mean	**0.57**



Comments: Organic matter in this sample consists predominantly of very finely dispersed humic debris associated with significant amounts of amorphous (sapropelic) material. The amorphous OM appears to be liptinite-rich and oil-prone. Some of the amorphous fine material may be degraded humic debris. Vitrinite particles large enough to measure are common and exhibit a narrow range of reflectance values. Based on 48 measurements of the better preserved, lower reflecting vitrinite, the average Ro is 0.57%. Plant spores, which are good indicators of thermal maturity throughout the oil window, are absent. However, the orange color of the liptinite-rich amorphous OM (see microphotograph) suggests a TAI value of about 2.5-2.6 (Chevron Scale), which is consistent with a measured average Ro of 0.57% These data suggest the OM in this sample has just reached the beginning generation stage of thermal maturity for oil-prone OM.

Ordered Ro Values *(Std. = 0.907% Ro.)*

0.52	0.52	0.52	0.53	0.53	0.54	0.54	0.54	0.54	0.54	0.54	0.54
0.54	0.55	0.55	0.55	0.55	0.56	0.56	0.56	0.56	0.56	0.57	0.57
0.57	0.57	0.58	0.58	0.58	0.58	0.59	0.59	0.59	0.59	0.59	0.59
0.60	0.60	0.60	0.60	0.60	0.61	0.62	0.62	0.63	0.63	0.63	0.63

Visual Kerogen Analysis

Client ID	Sample ID	Depth	% Alg.	% Lip.	% Vit.	% Inert.	Liptinite Fluores.	% Oil Prone	% Gas Prone	TAI	Spore Color
238023H	EM004514	11,631		30	60	10	fair	30	60	2.5-2.6	no plant spores

Source rock maturity measured by vitrinite reflectance of coal

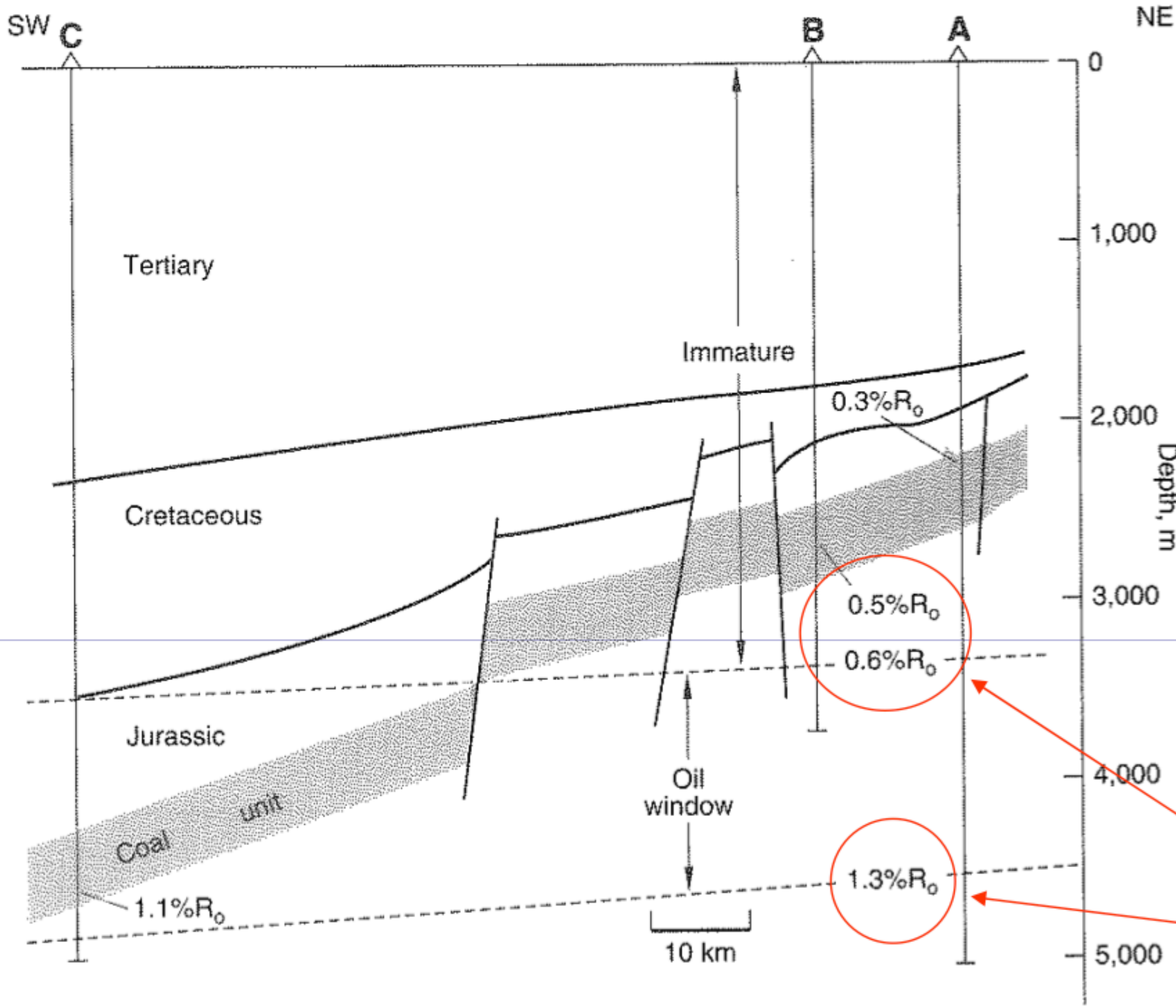


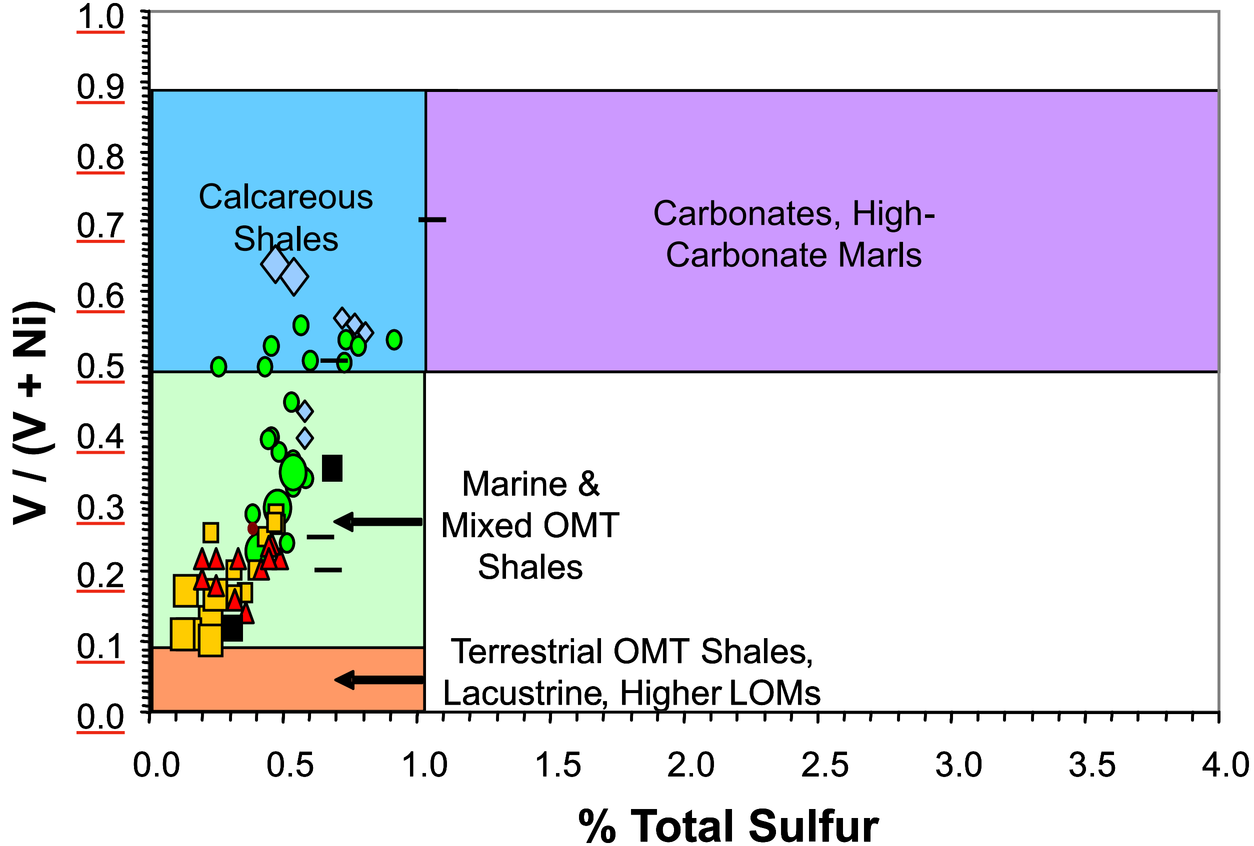
Figure 10-29

Regional variation in the maturity of coal and the location of the oil window in relation to the geological structure, Haltenbanken area, North Sea. The coal unit is immature in wells A and B but mature in well C, where it is nearing the end of the oil window. [Pittion and Gouadain 1985]

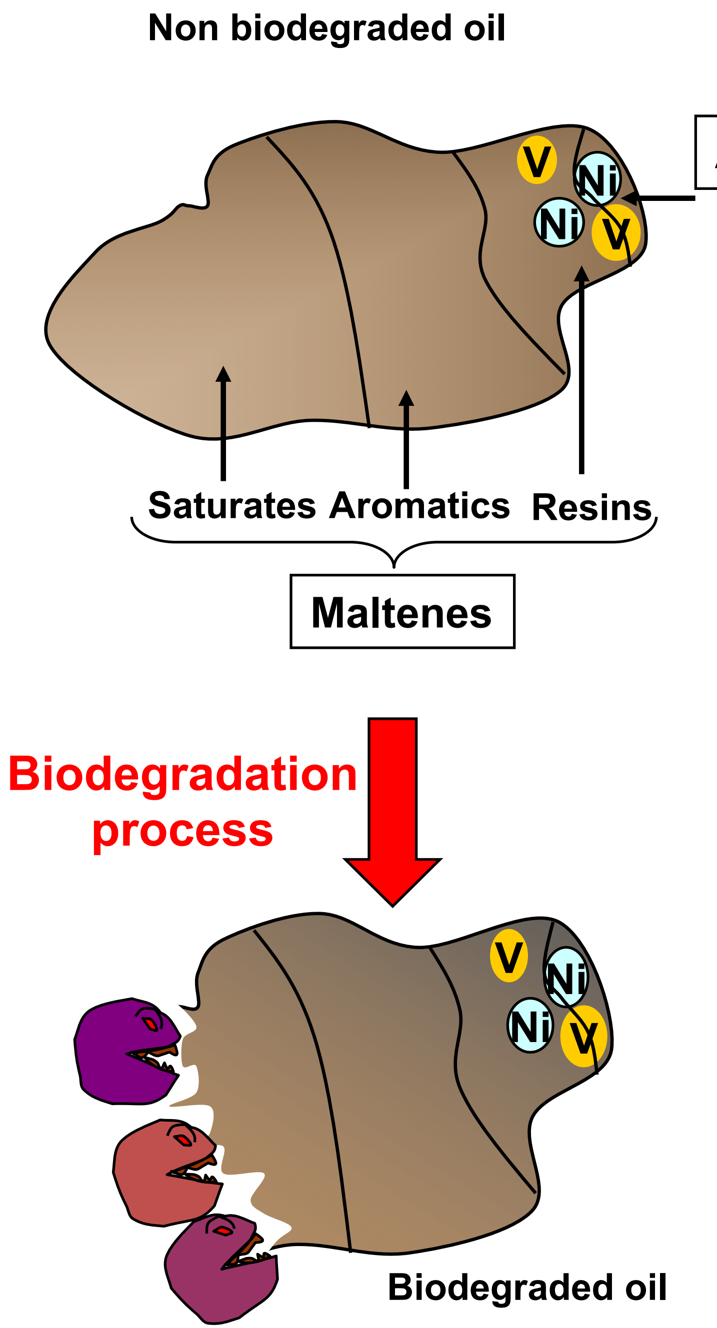
Vitrinite reflectance

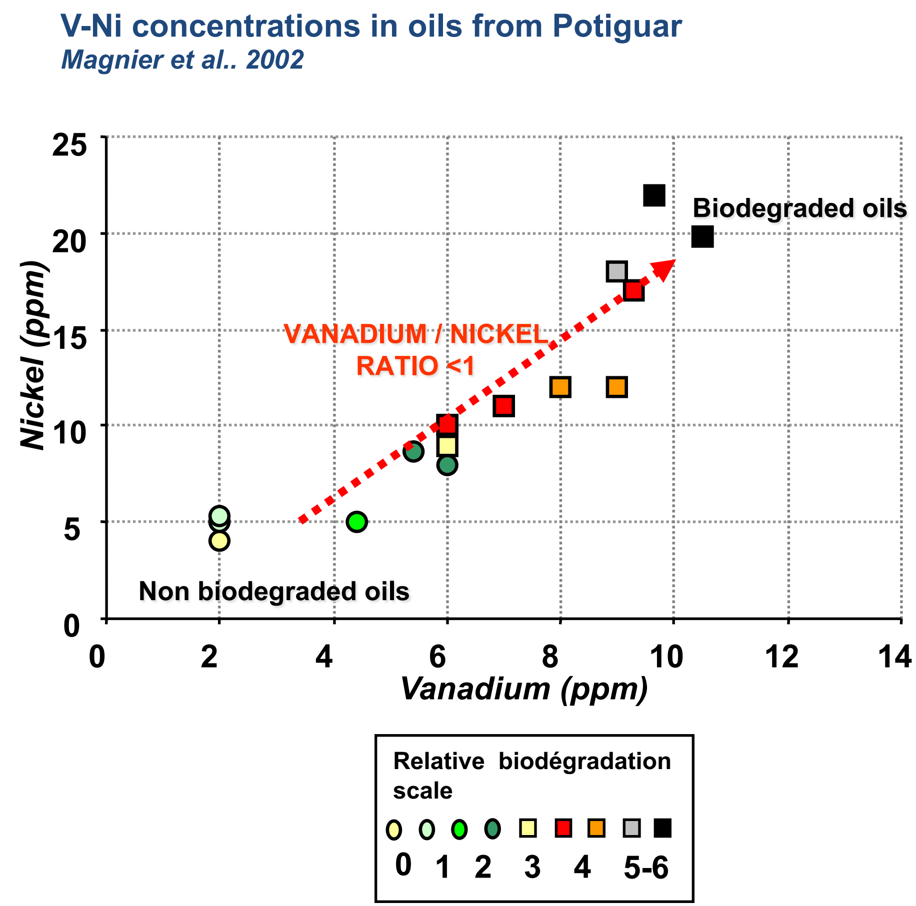
Redox conditions in source rock depositional environment control Ni and V distributions

- Eh-pH of environments of deposition control availability of metal species
- Regimes dependant on source rock depositional environment (availability of Fe to react with bacterial H_2S in marine environments)

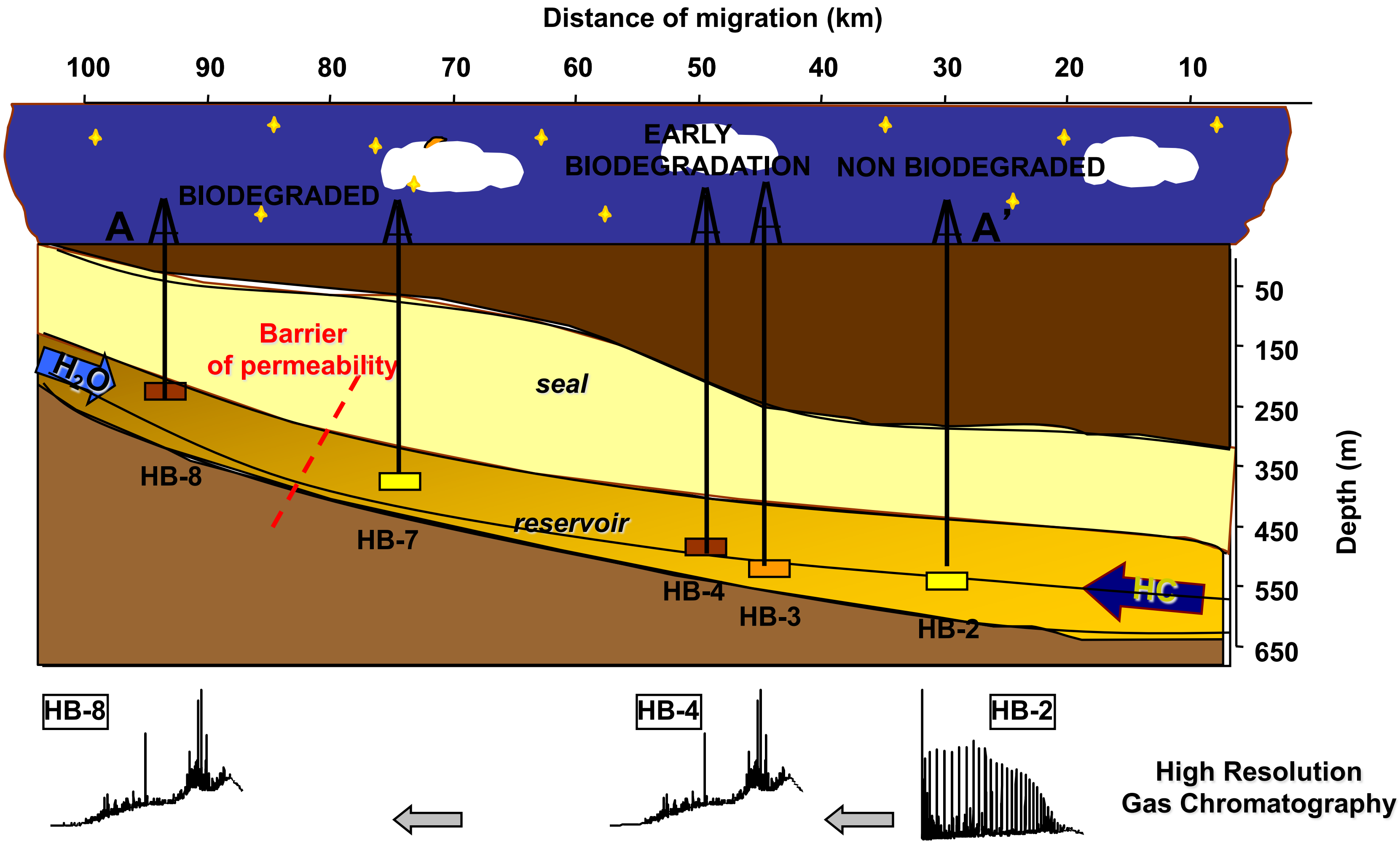


Application of Ni and V in biodegradation studies



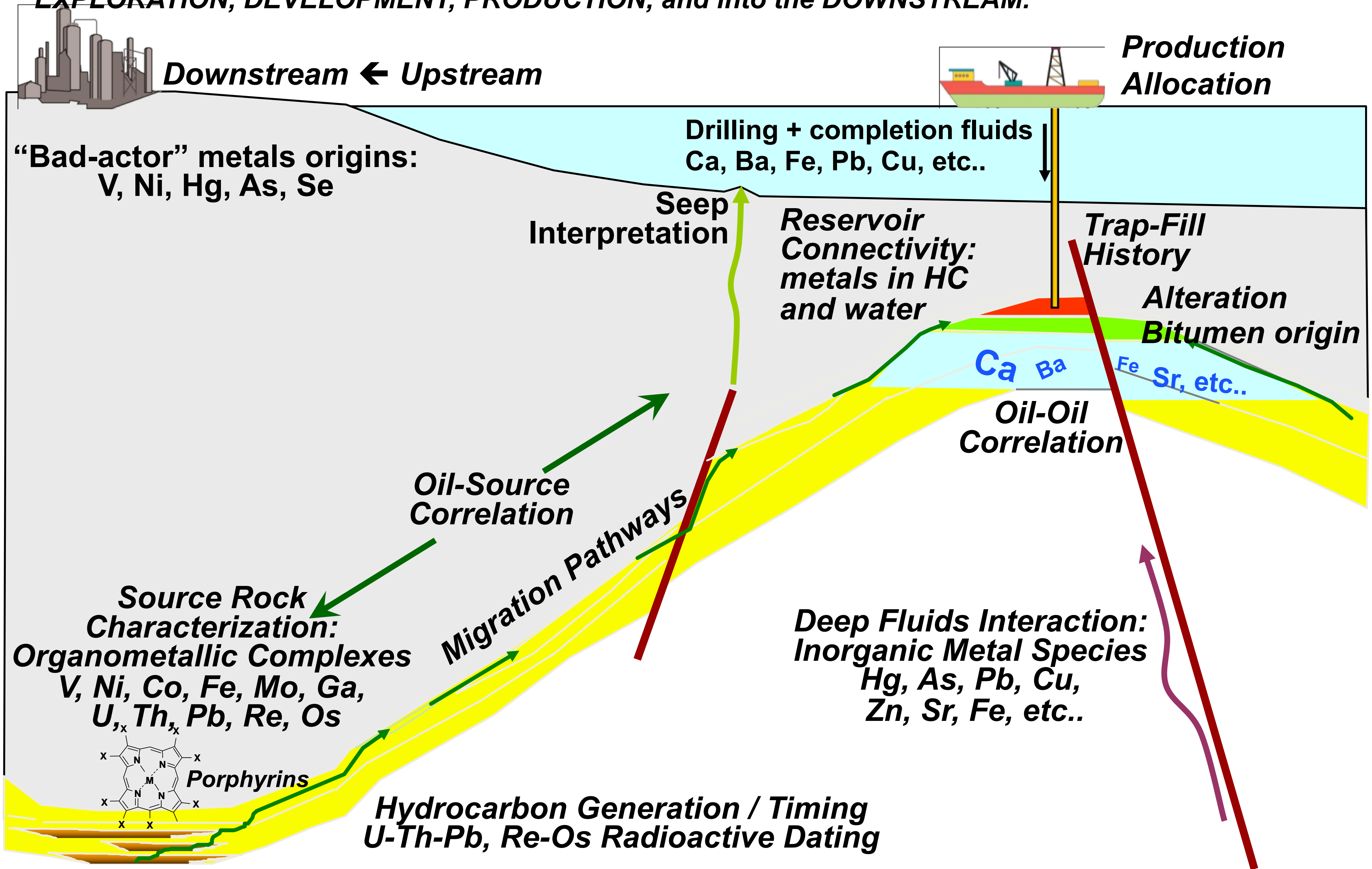


Hydrocarbon migration in the Potiguar Basin



Petroleum Geology– Applications in E, D & P

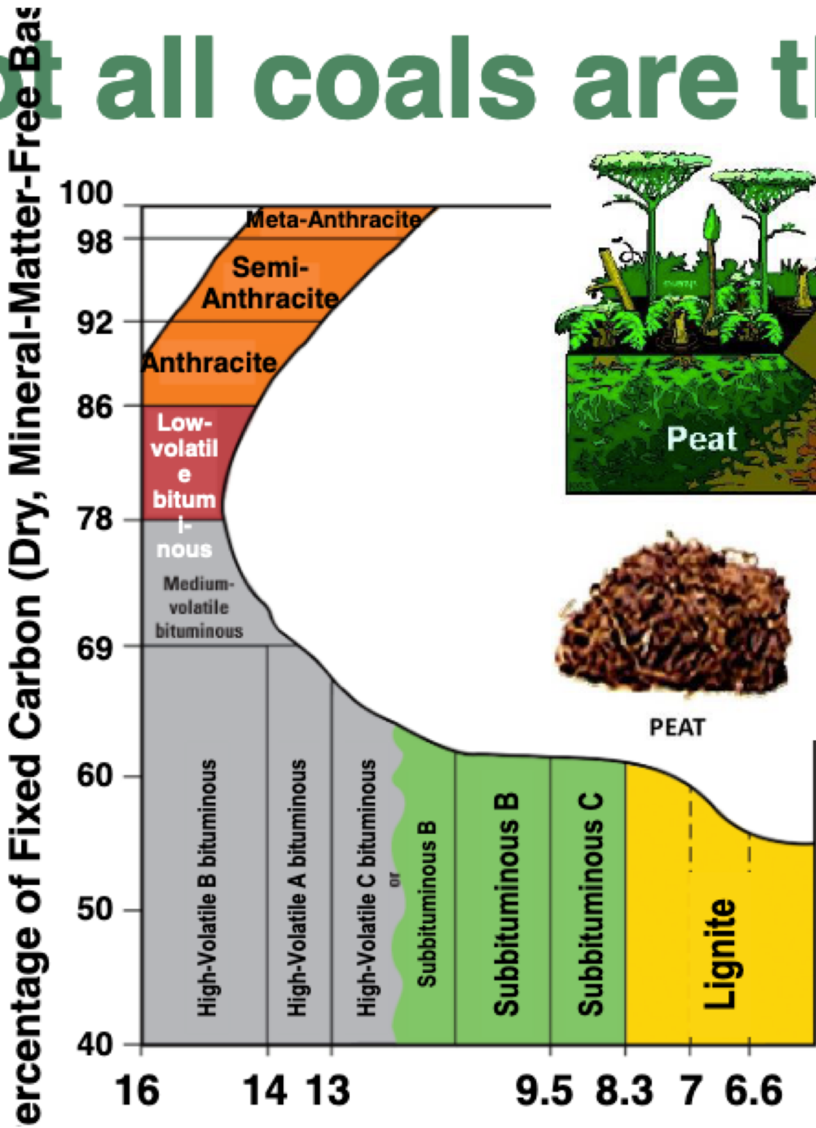
Applications of trace element are wide and diverse, and have high potential for impact in EXPLORATION, DEVELOPMENT, PRODUCTION, and into the DOWNSTREAM.

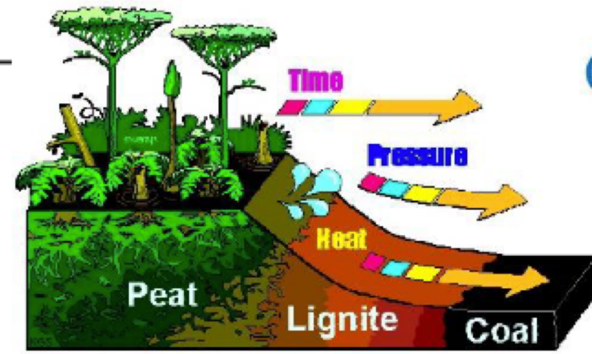


What is Coal?

- Coal:
  - A sedimentary rock that burns
  - Mineralized vetegatative material deposited over a long period of time (although miniscule geologically)
  - altered chemical composition
  - Formed by increased T and P
  - Partial decay resulting from restricted access to oxygen

Not all coals are the same!





Coal – Stages of Formation

Fossil Fuels. Energy Information Association

Distribution of Coal in India

- **Gondwana coal fields [250 million years old]**
- **Tertiary coal fields [15 – 60 million years old]**