Australian Aid

AMEP
Australia Mongolia Extractives Program

Advanced Training for CBM Geologists

Coal and Rock Review

Ulaanbaatar, Mongolia

16 June 2022

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Cipher Doc#: 22-425

Schedule

Advanced Training for CBM Geologists

from	To	total time (hr:min)	Topic
9:00	**9:15**	**0:15**	**Opening Remarks & Introduction**
9:15	10:45	1:30	Origin of Reservoir Properties: from Peat to Pores
10:45	11:00	0:15	Questions/Discussion
11:00	11:15	0:15	Coffee Break
11:15	12:45	1:30	Unconventional Hydrocarbons and Geological Models
12:45	13:00	0:15	Questions/Discussion
13:00	**14:00**	**1:00**	**LUNCH**
14:00	14:45	0:45	CBM Drilling Equipment & Methods
14:45	15:00	0:15	Questions/Discussion
15:00	16:00	1:00	Coal & Rock Review - What and How to Characterise
16:00	16:15	0:15	Questions/Discussion
16:15	16:30	0:15	Coffee Break
16:30	17:30	1:00	Measuring Gas
17:30	18:00	0:30	Critical CBM Reservoir Properties: Know where to Place Your Efforts
18:00	18:15	0:15	Questions/Discussion
18:15	**18:30**	**0:15**	***Closing Remarks***

NOTE: Times are in UB, Mongolian Times

Outline of Talk

- Clastic Rock Types Found in Coal-Bearing sections
- Vertical, Lateral Variations & Models
- Macroscopic Coal Types
- Microscopic Coal Components

The important attributes of rock descriptions

Cipher

Texture: grain size

- conglomerates (cobble, pebble, granule)
- sandstone (coarse, medium, fine)
- siltstone
- mudstone
- claystone

Colour: often composition related

- black
- dark grey/brown
- medium grey/brown
- light grey/brown

Structure: bedding and sedimentary features

- bedding: sedimentation unit
  - thick (60-120cm), thin, very thin etc
  - equal, parallel, wavy, hummocky, flaser etc
- primary sedimentary features
  - massive
  - laminated (horizontal, wavy, cross laminated)
  - graded
  - imbricated
- secondary sedimentary features
  - soft sediment deformation
  - burrowing
  - root penetration

TO BE USED IN CONJUNCTION WITH 3D GEOMETRY!

Rock Types Found in Coal-Bearing Sequences

Rock Types Found in Coal-Bearing Sequences

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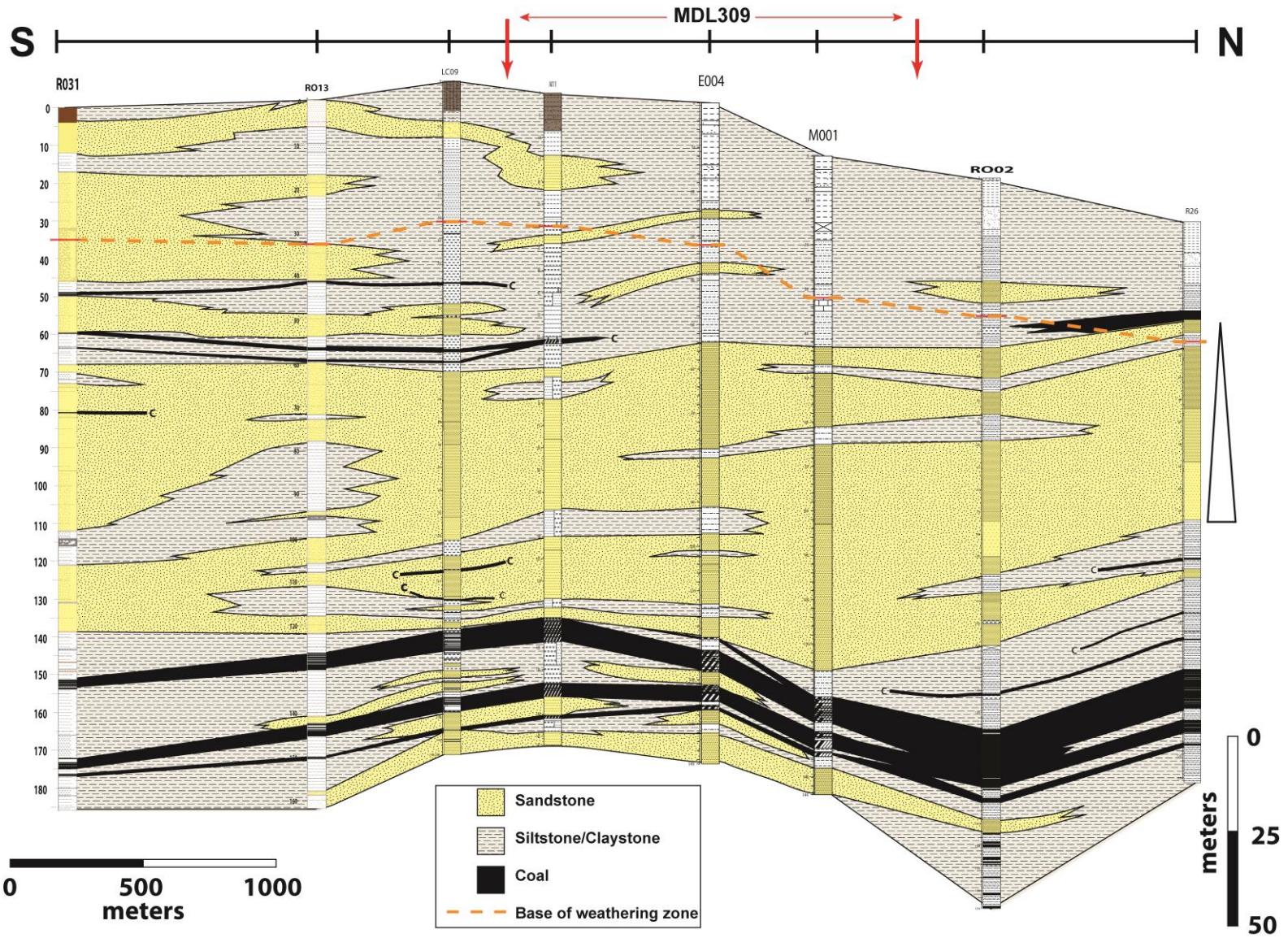
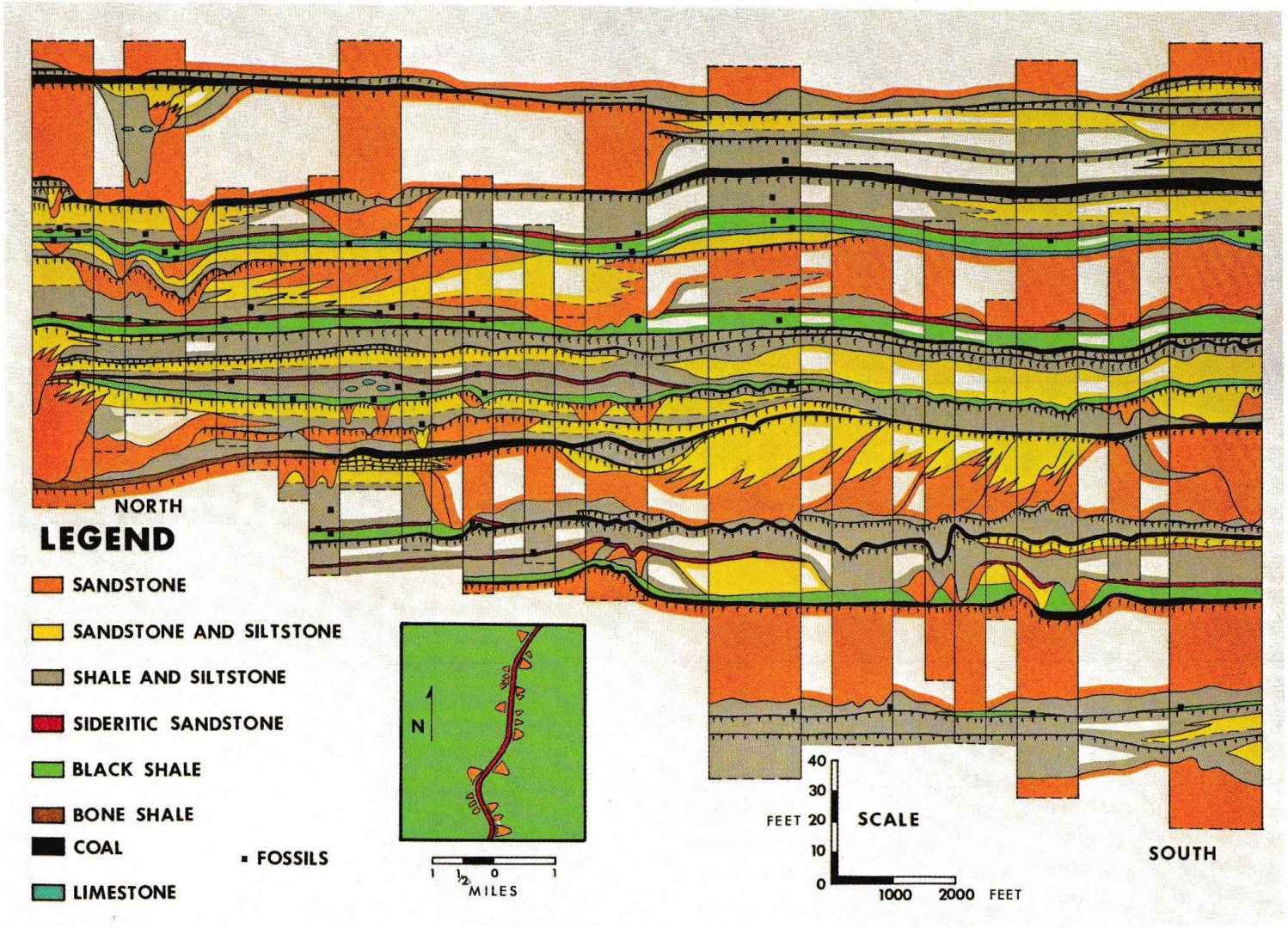
Vertical Variation of Rock Types

Lateral variability of coal & rock



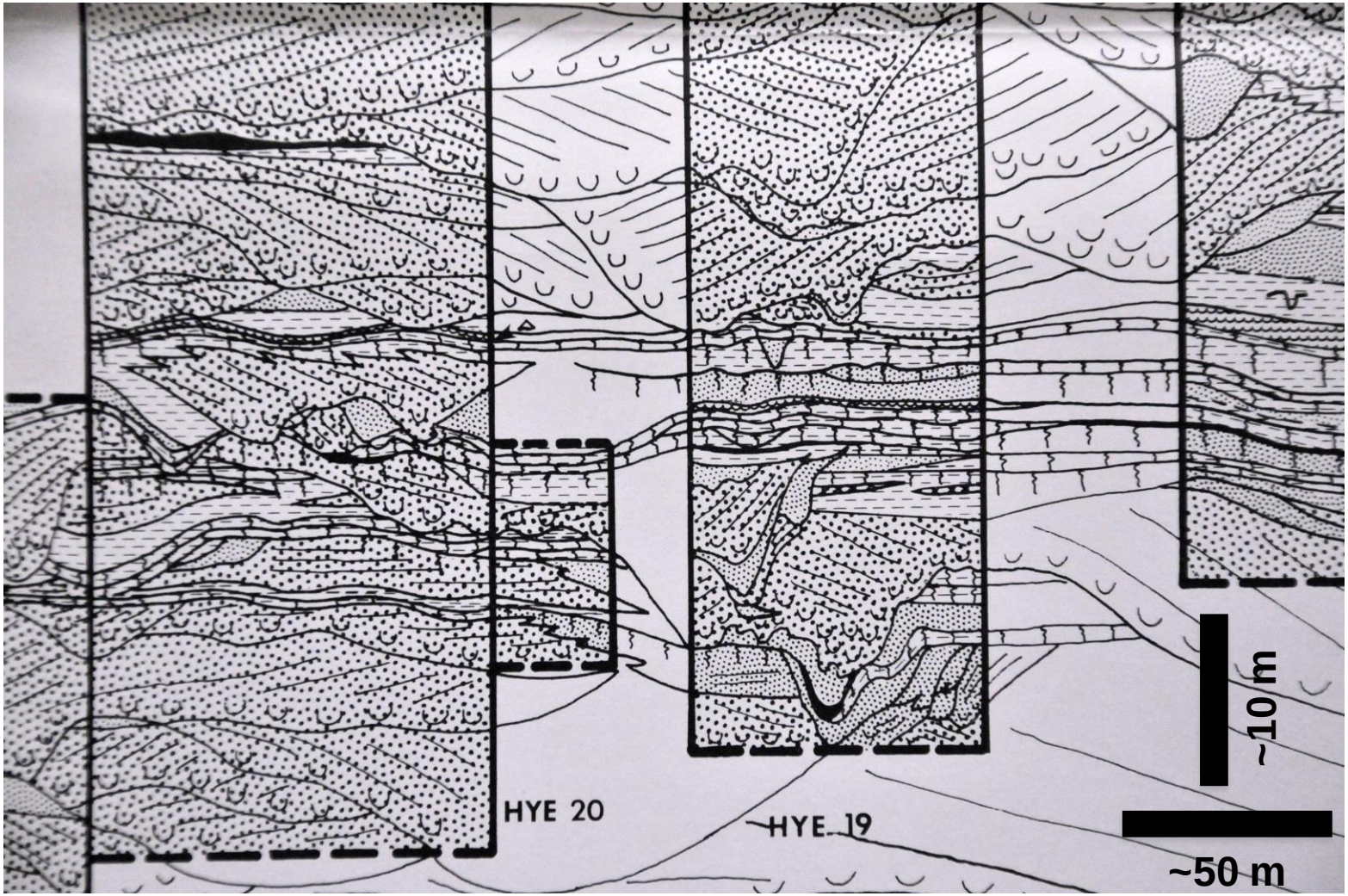
Building Models: Appalachian Basin (Carboniferous)



Outcrop:
The most confidence!

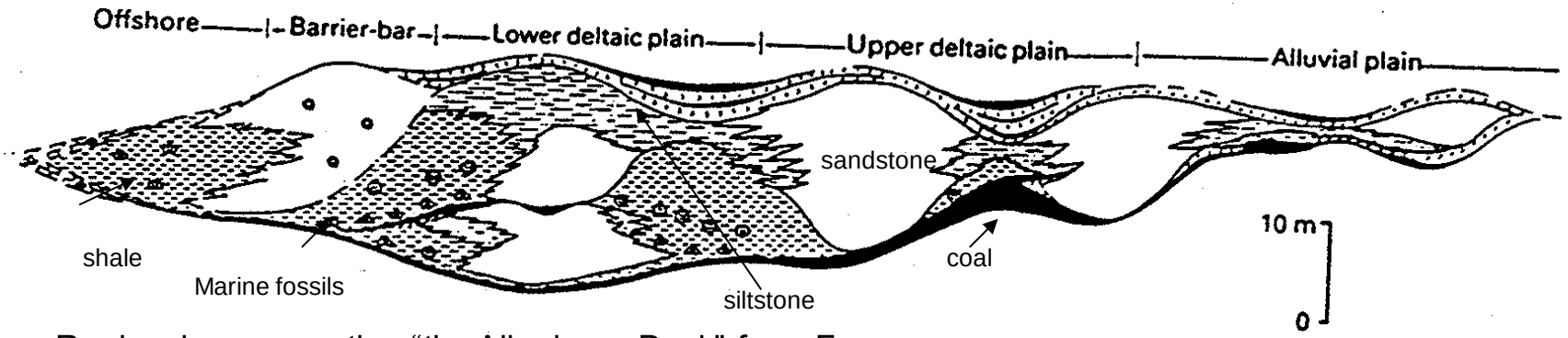
from Ferm et al., 1979

Outcrops show even higher detail of variability

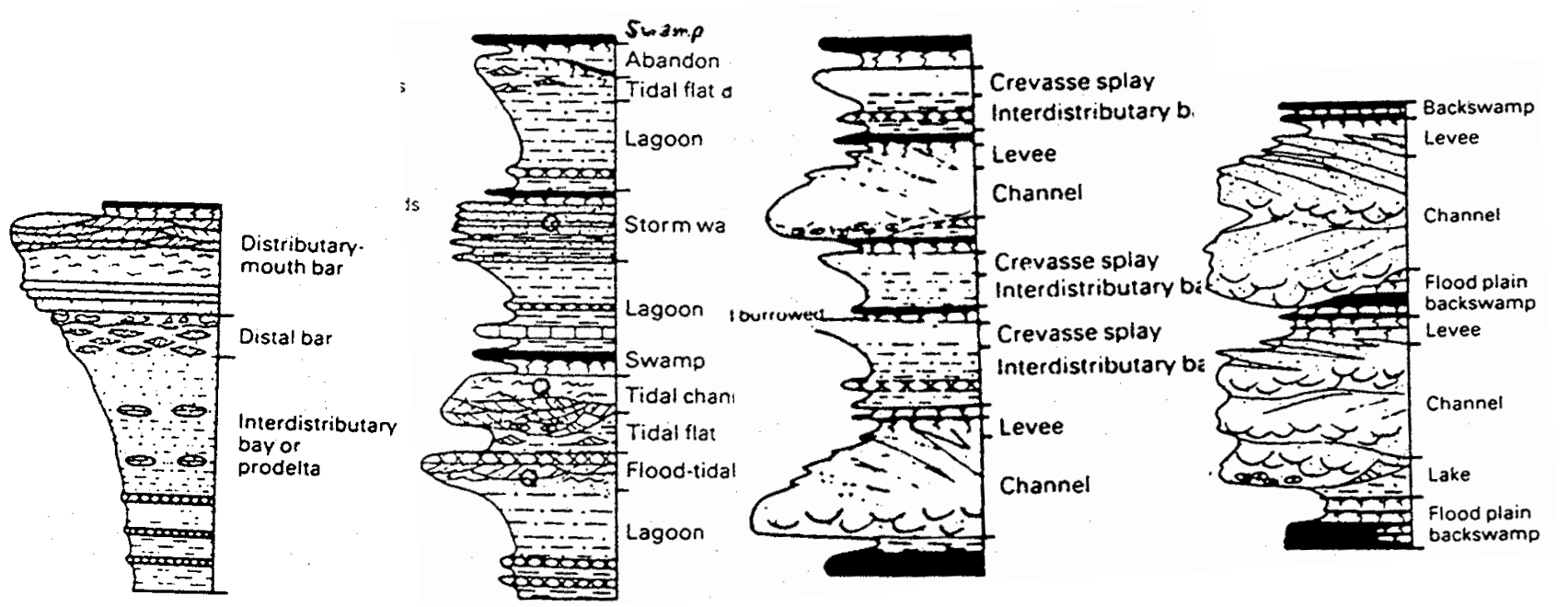


from Horne 1978

COMMONLY OCCURRING SEDIMENTARY ENVIRONMENTS IN COAL MEASURES



Regional cross section “the Allegheny Duck” from Ferm



Examples of measured sections demonstrating variability in overburden resulting from different sedimentary environments (from Horne, 1978) **THESE ARE NOT THE ONLY ONES!**

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BASIC FACTS

COAL is not just a BLACK ROCK!

Coal character varies…..

- **Within seams**
- **across pits**
- **between different mine sites**
- **Between seams**

WHY?

- **Different starting ingredients (composition)** → **GRADE**
  - ***plants, water, mineral matter***
- **Different levels of decay of plant ingredients in the peat mire** → **TYPE**
  - ***death, decay, humification***
- **Different ranks (thermal maturity or coalification)** → **RANK**
  - ***heat, pressure, time***

Starting Ingredients, i.e. the plants change through time due to palaeogeography and evolution

Seam Level Terminology

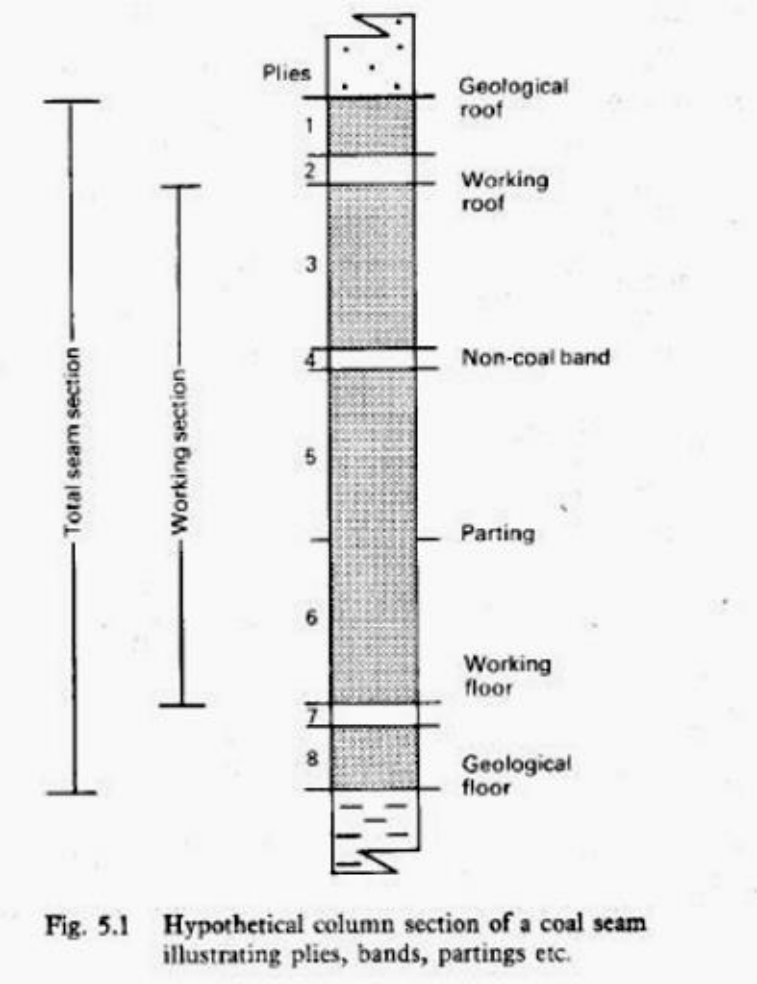


Fig. 5.1 Hypothetical column section of a coal seam illustrating plies, bands, partings etc.

from Ward, 1984

Coal Seam

a stratum or bed of coal; upper contact with rock called "roof", lower contact called "floor"

Ply/Bench (of coal)

a mineable section of coal or a unit of a coal seam that can be traced laterally for some distance; it is usually bounded by mappable rock partings or a significant change in lithotype; generally used as a basis for sampling. Synonomous with the term ply

Parting

a rock band or thin bed within a coal seam; often rock partings become thick and create a divergence of the coal beds known as a split.

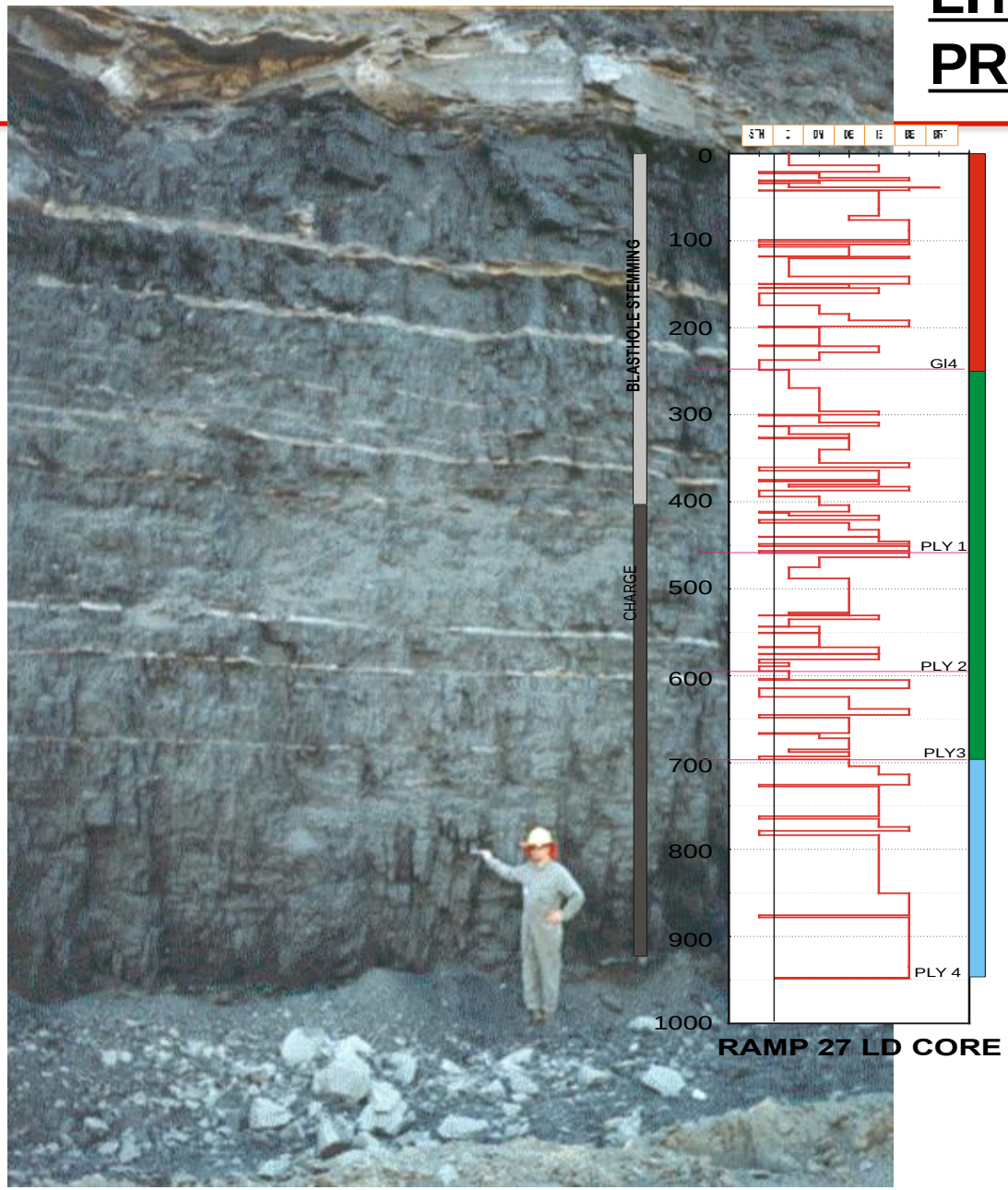
Band

A significant layer within a seam or ply; if non-coal often referred to as "clay band" or "dirt band" or "tuff band". Colloquial term "penny band" denotes thickness. Also used to describe the organic units within coal lithotypes.

Coal Type

a classification of coal distinguished on the basis of the constituent plant materials; megascopic classification is a "lithotype".

LITHOTYPE PROFILES

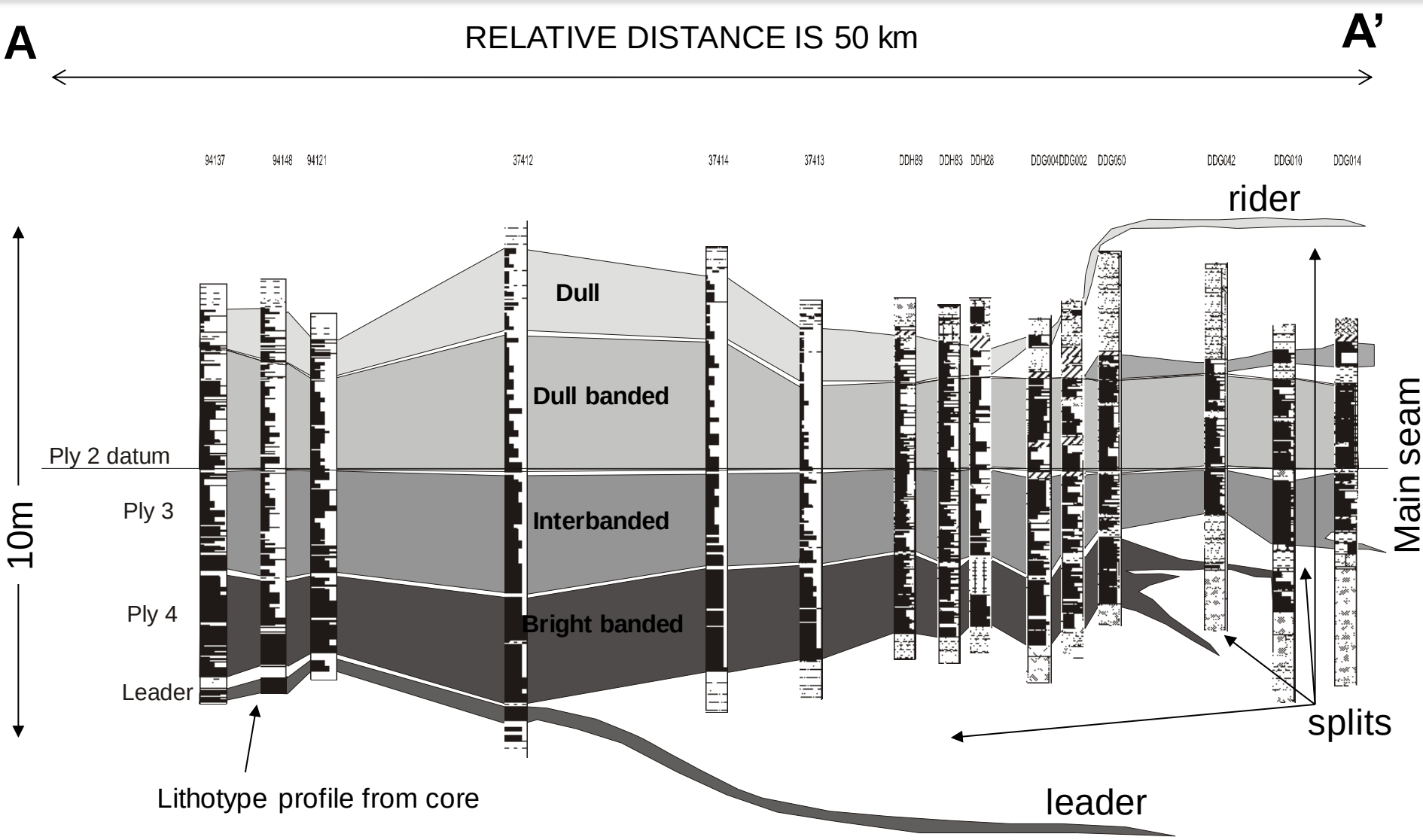


- AT FACE OR IN CORE
- SEPARATE COAL SEAM INTO MAPPABLE "PLIES" OR "BENCHES"
- WHY?
  - SEAM CORRELATION
  - SELECTIVE MINING
  - QUALITY CONTROL
  - GEOTECHNICAL PROPERTIES

Band width rule
5mm Australian system
3 mm US system
10 mm European system

LATERAL CORRELATION OF LITHOTYPE PROFILES IN THE GOONYELLA MIDDLE SEAM

Cipher



Can the composition of the plies change laterally?

MACROSCOPIC CLASSIFICATION

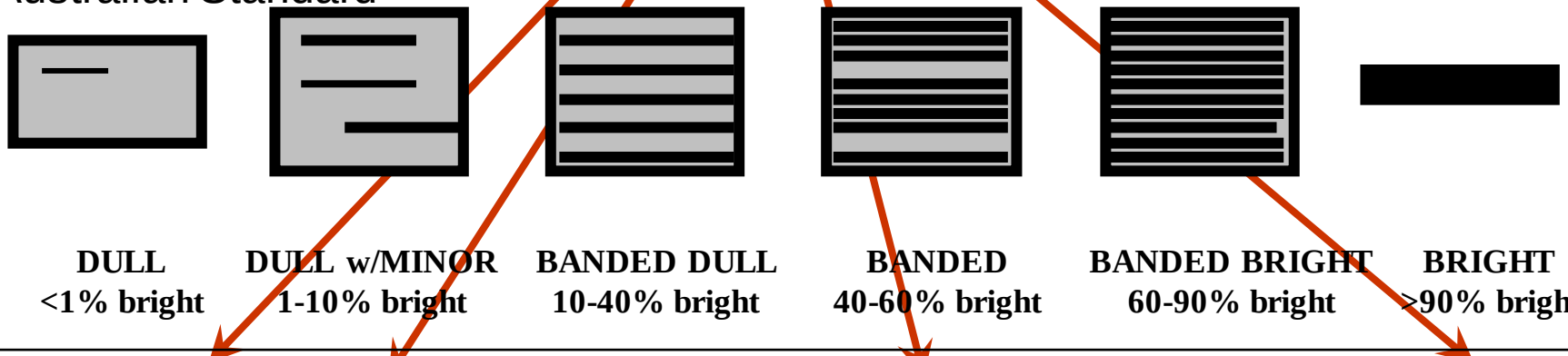
COAL LITHOTYPES (not including stone partings)

Cipher

first coined by Marie Stopes 1919- "On the Four Visible Ingredients of Banded Bituminous* Coal"

DULL → BRIGHT

Australian Standard



	DULL <1% bright	DULL w/MINOR 1-10% bright	BANDED DULL 10-40% bright	BANDED 40-60% bright	BANDED BRIGHT 60-90% bright	BRIGHT >90% bright
ICCP	FUSAIN	DURAIN	DURO-CLARAIN	CLARAIN	VITRO CLARAIN	VITRAIN
ASTM	FUSAIN	DURAIN	DULL CLARAIN	CLARAIN	BRIGHT CLARAIN	VITRAIN

Others: fibrous coal=fusain=charcoal=mother coal
shaley coal=bone
coaly shale=carbonaceous mudstone
cannel coal

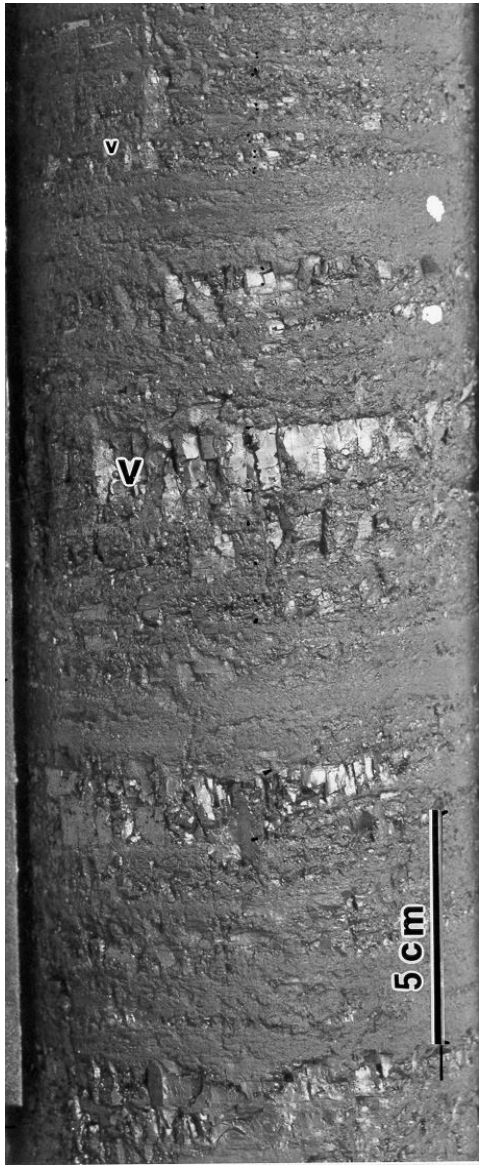
**there's another one for brown coal*

Australian Standard descriptions for coal lithotypes

Lithotype		Description
Bright coal (vitrain)	B (Br)	Vitreous to subvitreous lustre; even to conchoidal fracture; brittle; may contain up to 10% dull coal bands less than 5mm thick.
Banded bright coal (bright clarain)	Bb	Mainly bright coal containing thin (less than 5mm) dull coal bands ranging in proportion between 10 and 40%; even fracture.l
Banded coal (clarain)	BD (IB)	Contains bright and dull coal bands (all less than 5mm) ranging in proportion between 40 and 60% each.
Banded dull coal (Clarodurain)	Db	Mainly dull coal containing thin (less than 5mm) bright bands in proportion between 10 and 40%; uneven fracture.
Dull coal (durain)	D (DM)	Matt lustre and uneven fracture; may contain 10% of bright coal bands less than 5mm thick.
Fibrous coal (fusain)	F	Dull with satin sheen; friable; may contain up to 10% of other coal lithotypes less than 5 mm thick.
Shaly coal	Cs	Contains between 30 and 60% of clay and silt either in intimate mixture with coal or in separate bands each less than 5mm thick.
Coaly shale, mudstone, sandstone etc.		Any sediment containing 60 to 90% finely disseminated carbonaceous matter.
Shale, mudstone, siltstone, sandstone, etc.		Any sediment containing less than 10% carbonaceous matter.

COAL TYPE-SCALES OF CHARACTERISATION

MACROSCOPIC



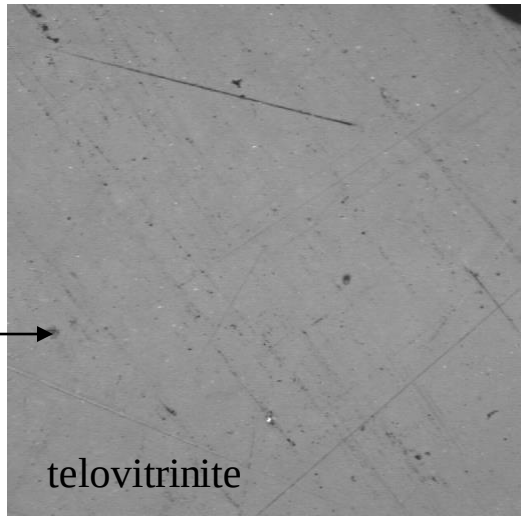
MACROSCOPIC

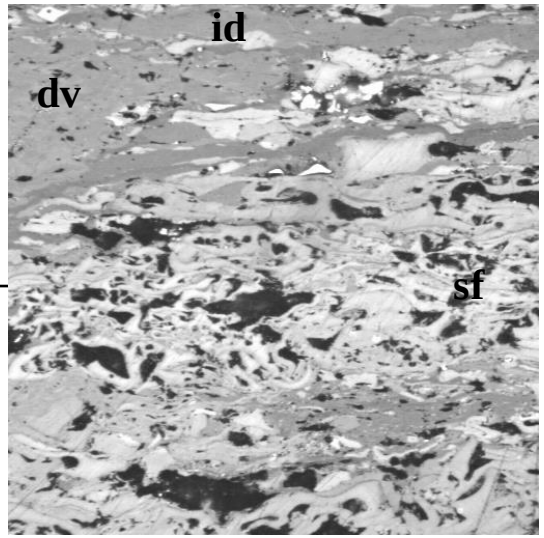
BRIGHT BANDED

DULL

50 mm

MICROSCOPIC





250 microns

COAL TYPE AND FRACTURE/CLEAT

Bright banded coal
highly cleated
thin to thick vitrain

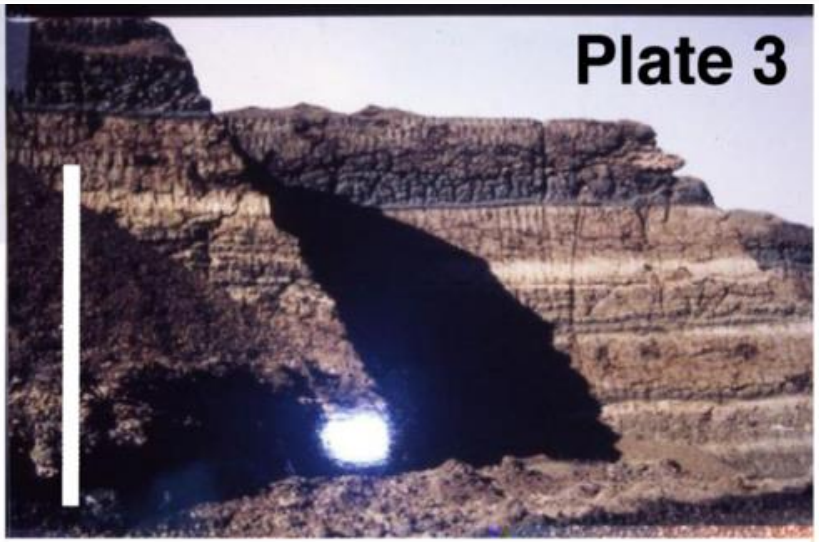
Dull coal
poorly cleated
minor thin vitrain

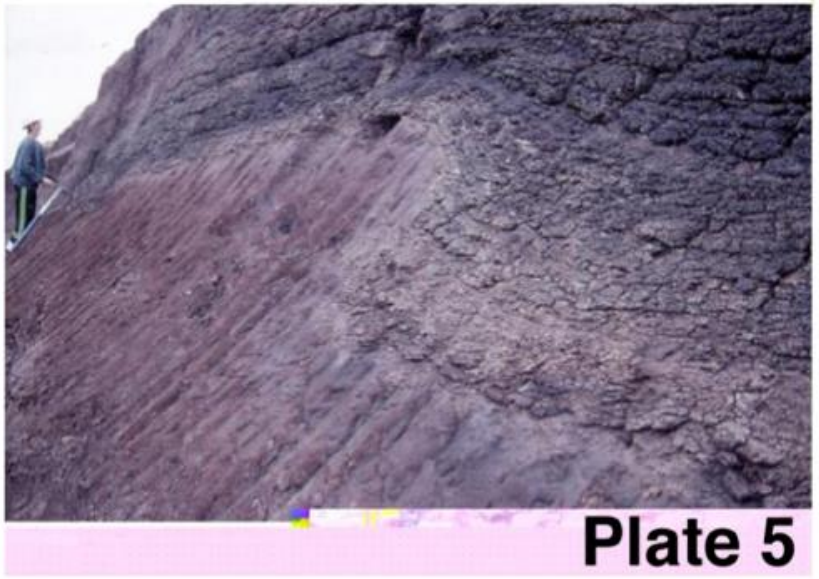
WHICH WILL BE MORE FRIABLE?
WHICH WILL BE MORE PERMEABLE?
(assuming the cleats are not mineralised)

Cleat: The network of micro fractures coals develop when subjected to changes in stress or uplift.

Brown Coal Lithotypes

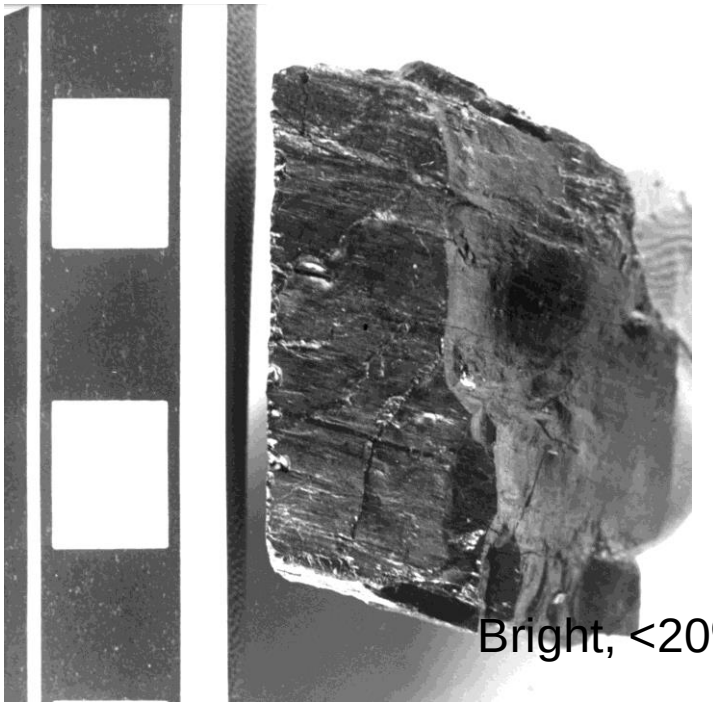
Brown Coal Lithotypes: Mine highwalls



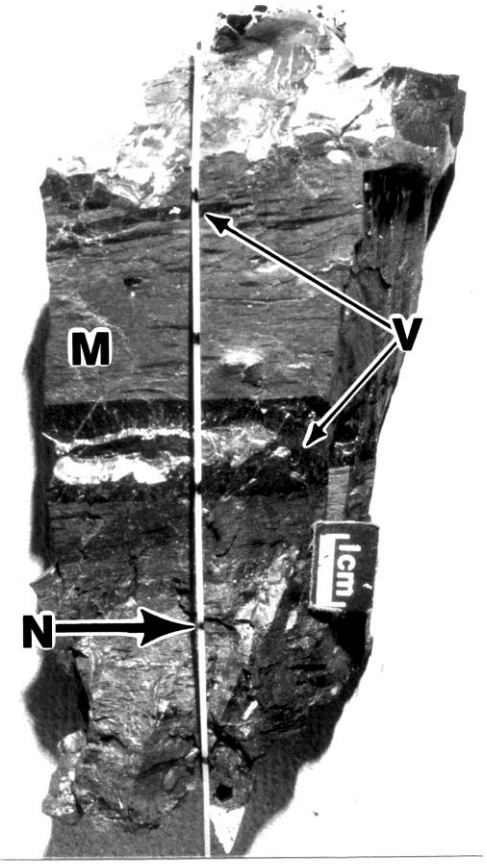


Macroscopic characterisation of coal

Bright, nonbanded

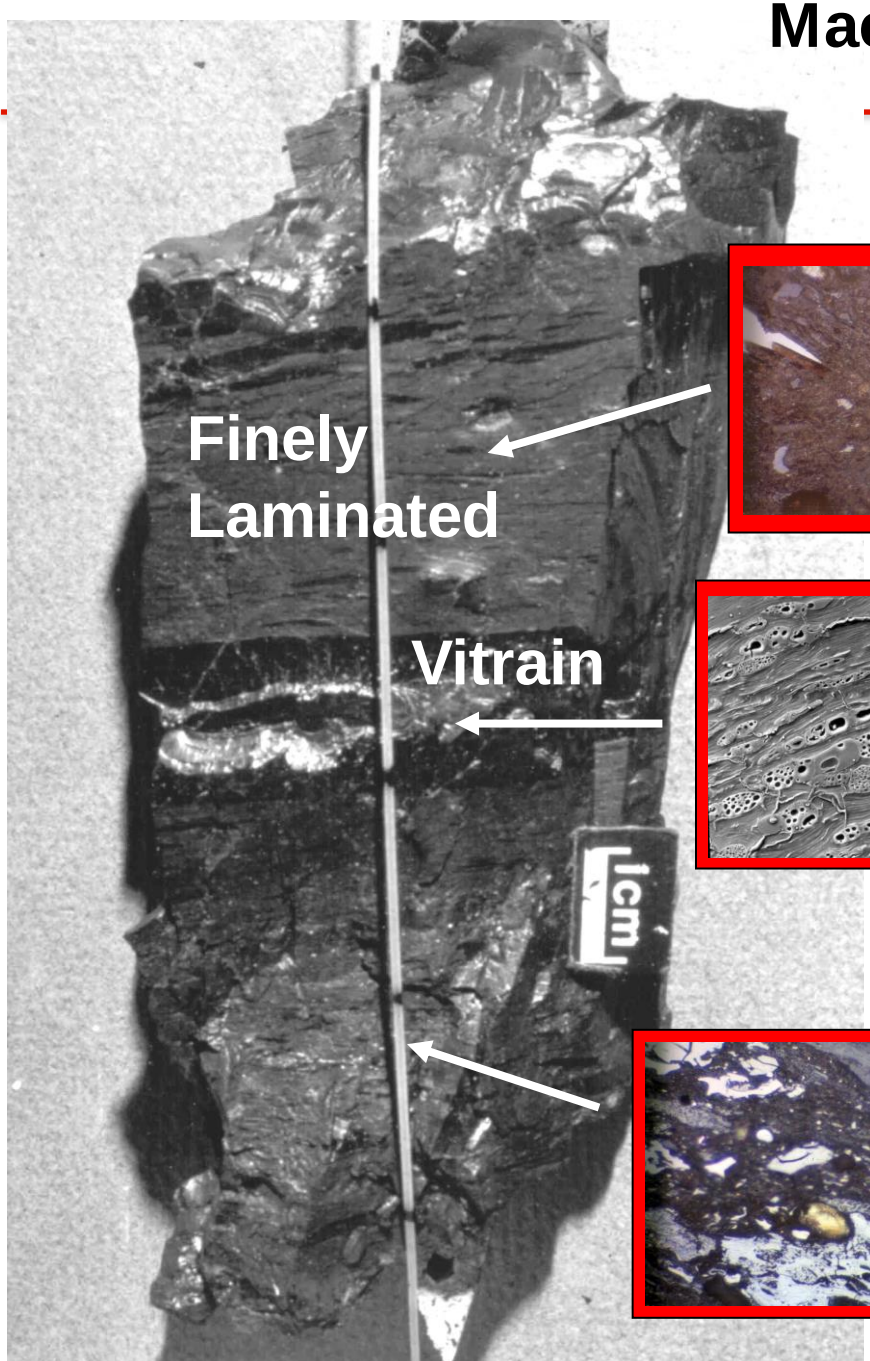


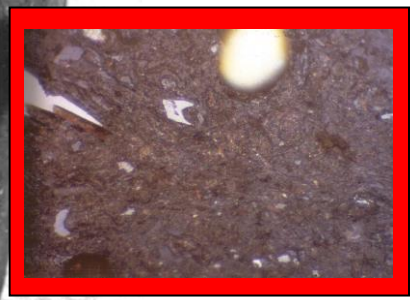
Bright, <20% banded

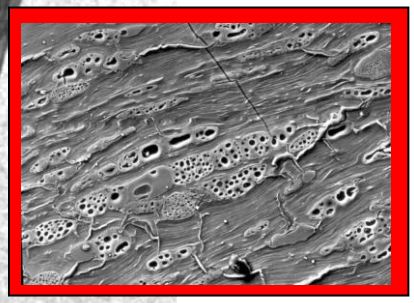


Bright, >20% banded

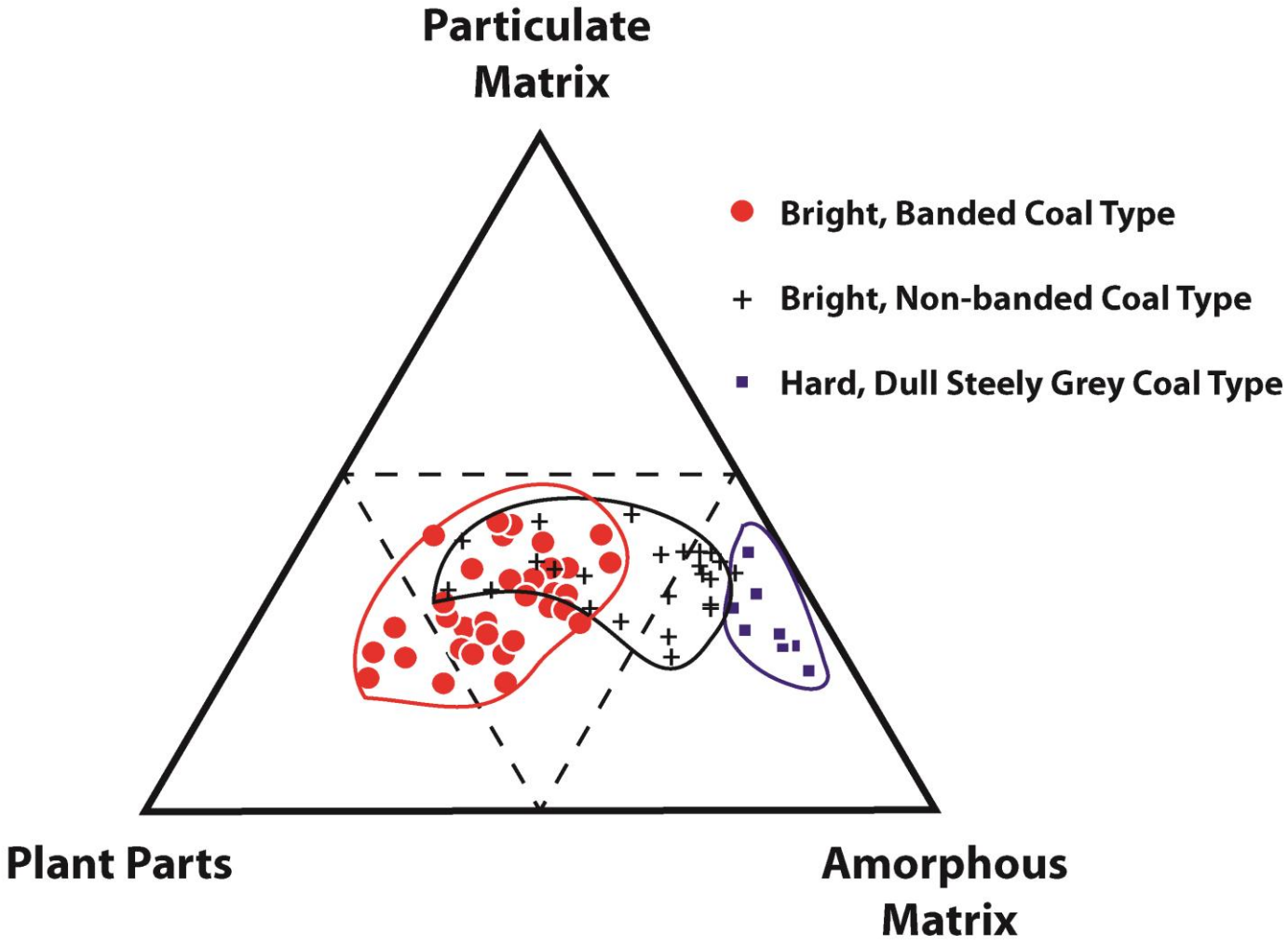
Macro- & Microscopic





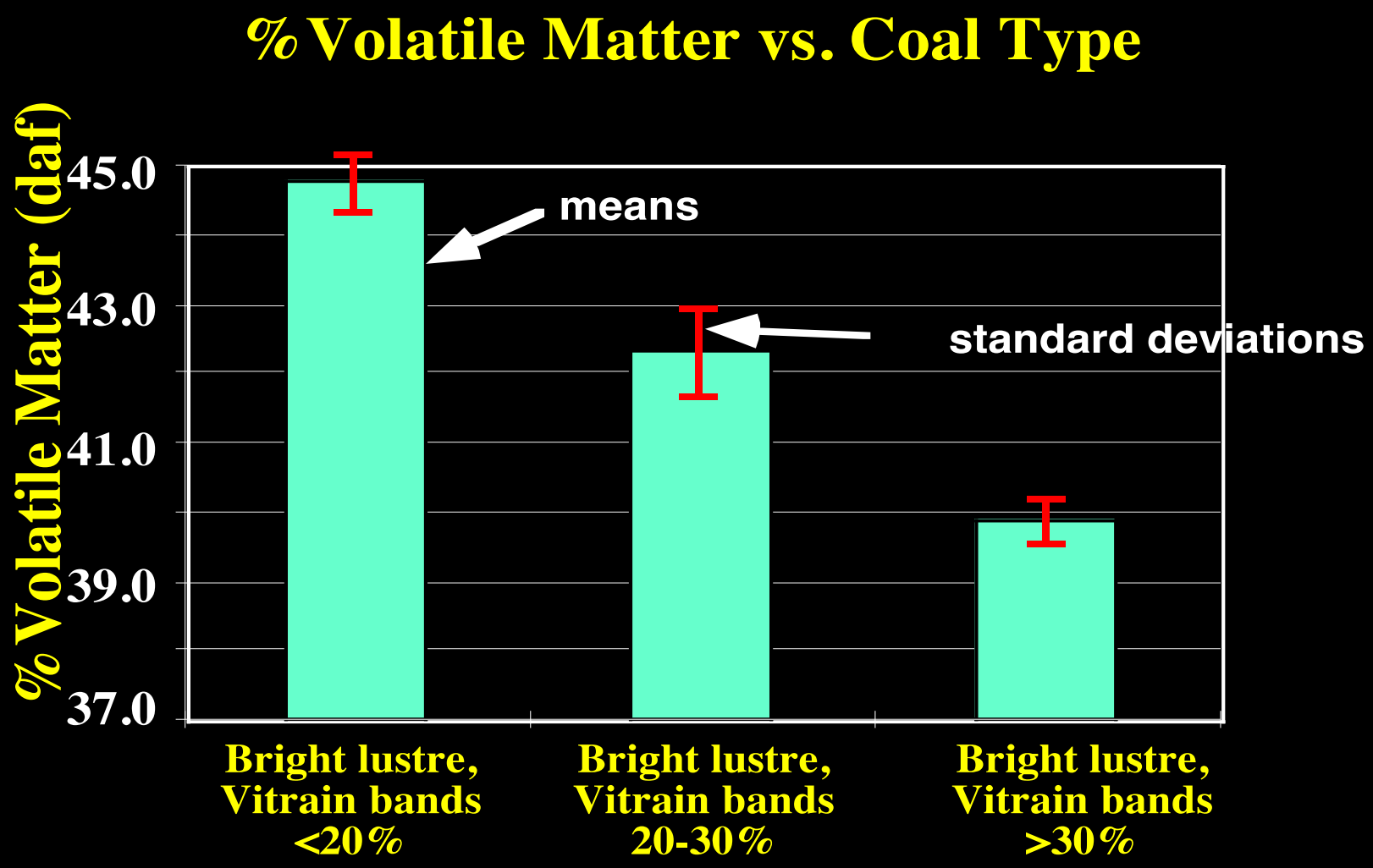


Macroscopic predicts microscopic



from Moore, 2016

Coal type and coal properties



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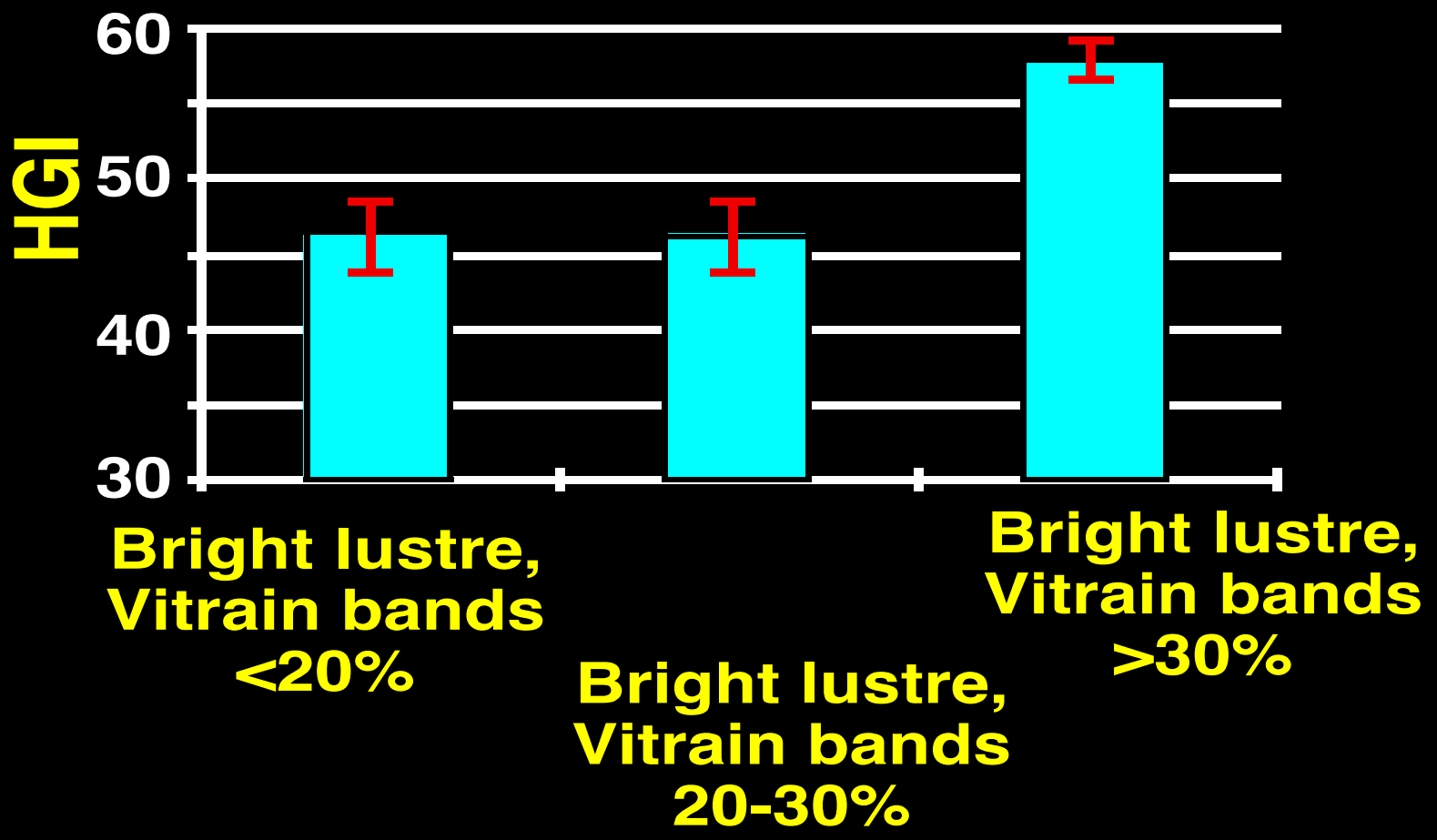
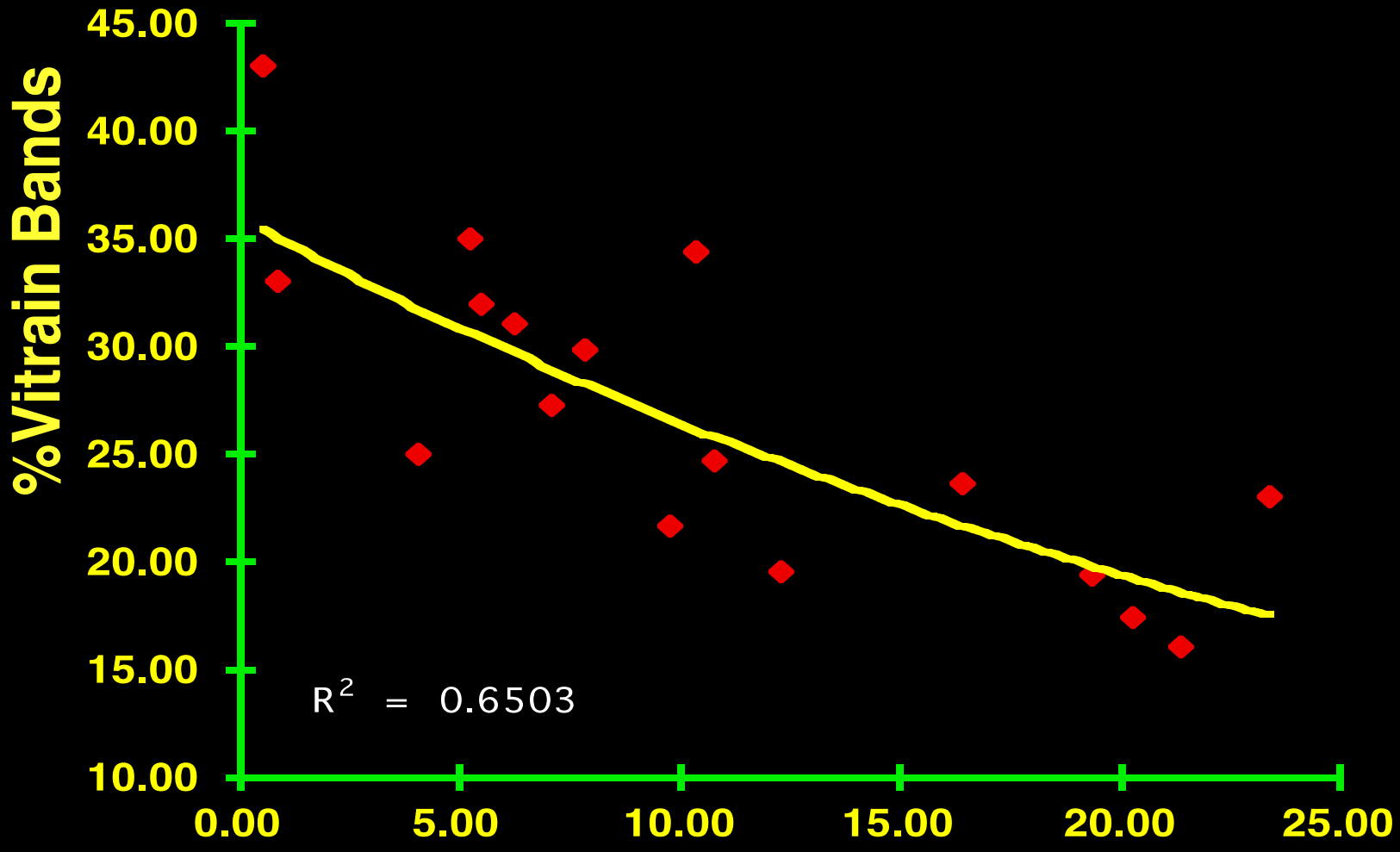
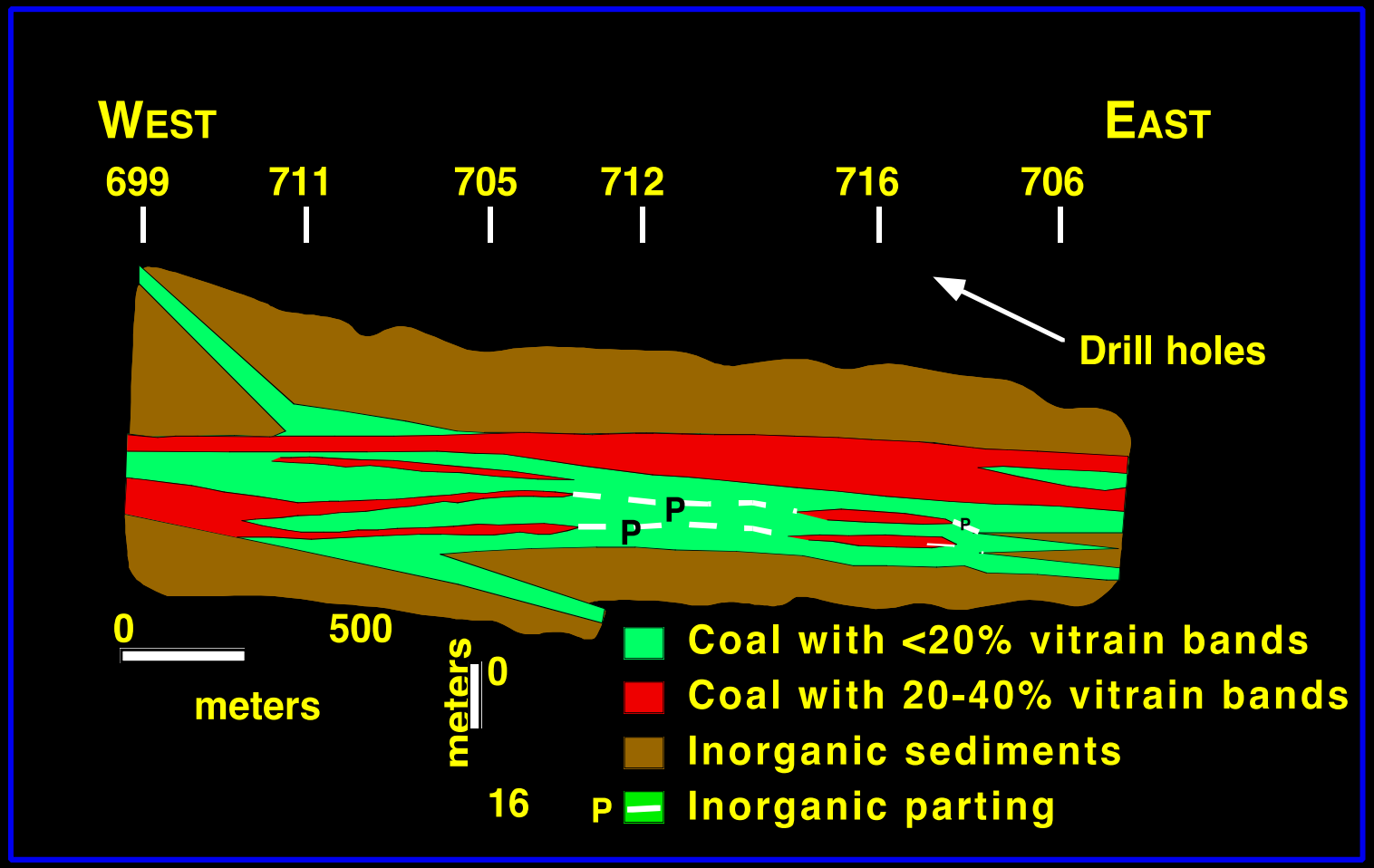


%Vitrain Bands vs Coal Thickness



Coal type distribution



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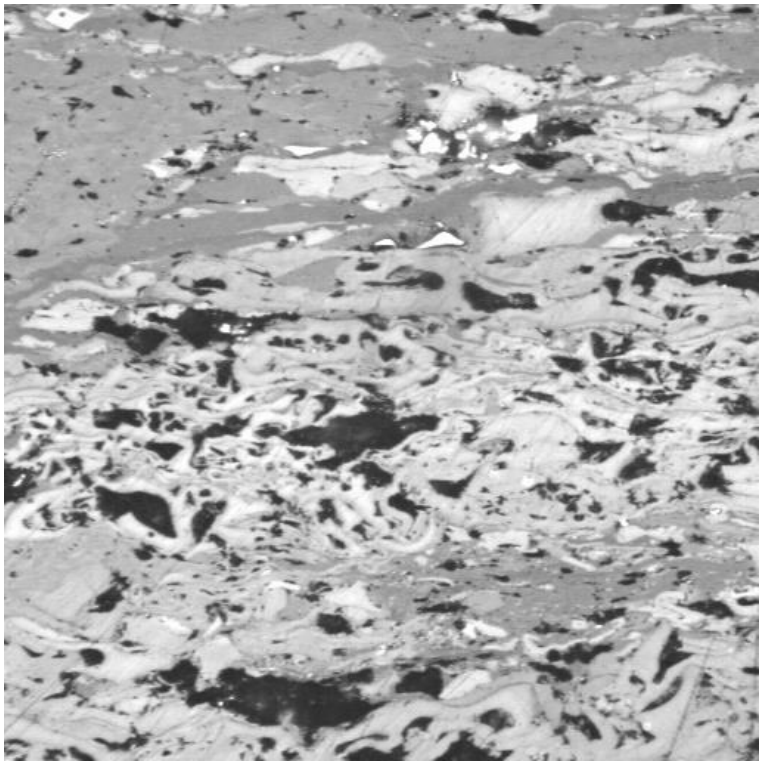
Organic Components



250 um

What controls the taste of the muffin????

…..the ingredients!!!

€ipher

MICROSCOPIC CLASSIFICATION-COAL MACERALS

ENCYCLOPÆDIA BRITANNICA maceral definition

microscopic organic component of coal consisting of an irregular mixture of different chemical compounds. Macerals are analogous to minerals in inorganic rocks, but they differ from minerals in that they have no fixed chemical composition and lack a definite crystalline structure. Macerals change progressively both chemically and physically as the rank of coal advances. *(Rank constitutes position in the lignite-to-anthracite series and is primarily based on increasing carbon content and increasing fuel value.)*

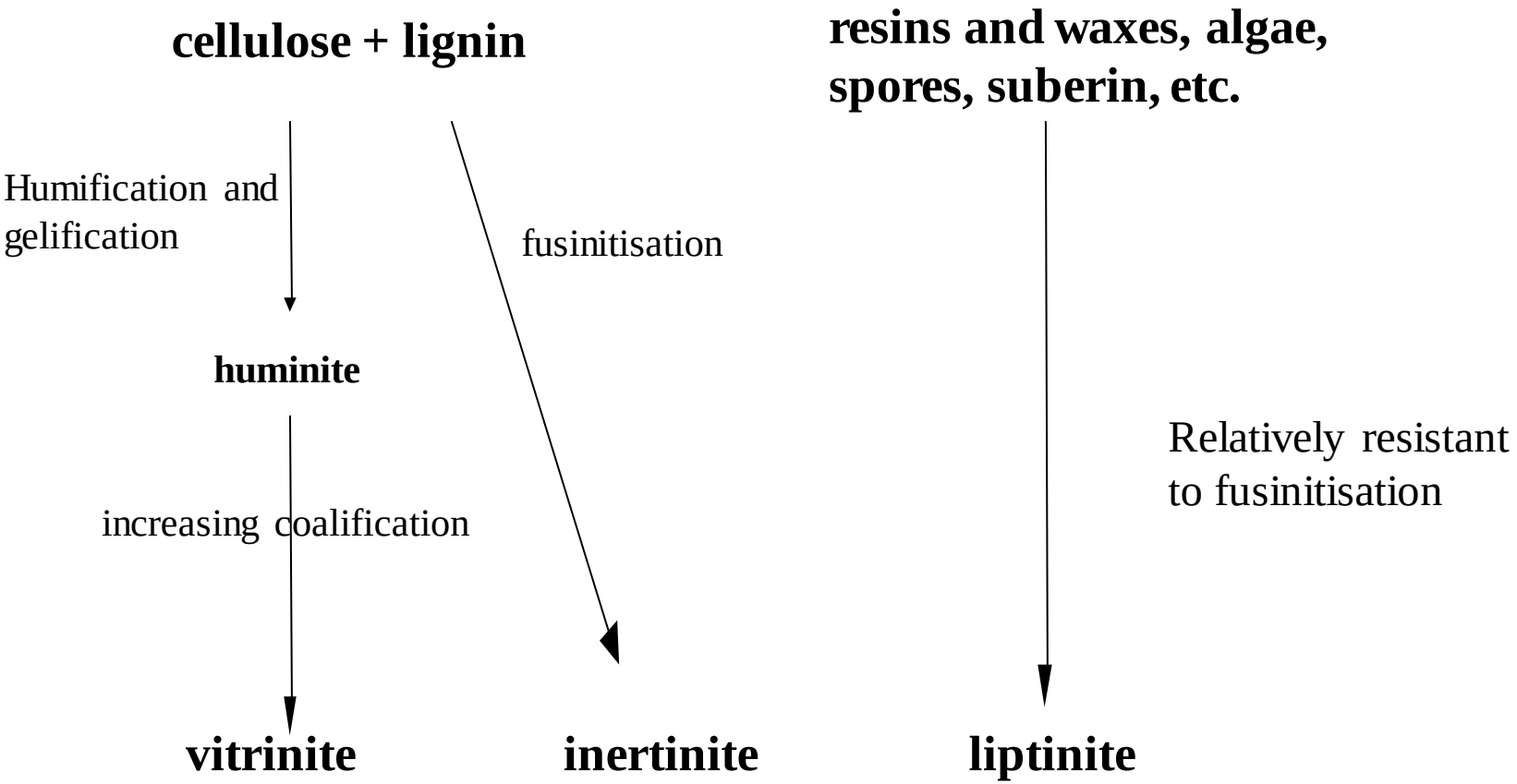
Macerals for "black coal", i.e. bituminous coal, are classified into three major groups: vitrinite, inertinite, and liptinite (exinite)

Vitrinite (Huminite is the term used for brown coals and lignites)
is derived from woody plant tissue and includes the macerals collinite and telinite. Most coals have a high percentage of vitrinites.

Inertinite
group comprises fusinite, micrinite, sclerotinite, and semi-fusinite [and inertodetrinite, macrinite], which are all rich in carbon [due to primary oxidation from mouldering or charring].

Liptinite
macerals, characterized by a high hydrogen content, include alginite, cutinite, resinite, and sporinite [liptodetrinite, suberinite, exudatinite, bituminite, fluorinite….].

Schematic pathways of maceral genesis



van Krevelen, 1993

Australian Standard 2856-1986/1995 bituminous coals *brown coal only

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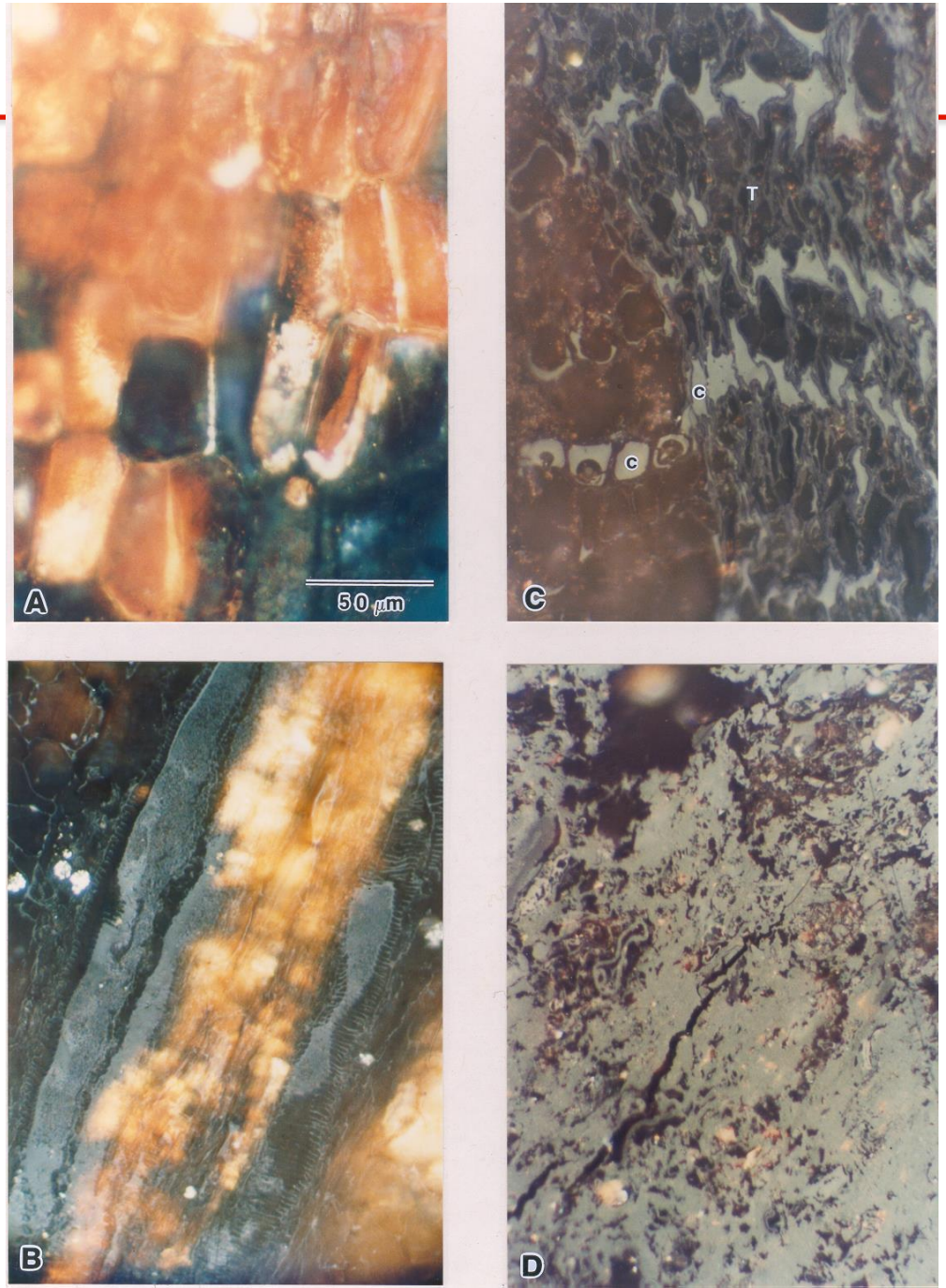
Criteria for recognition
- colour
- reflectance
- morphology
- size
- polished relief
- fluorescence

Simple steps
- Is it grey, black or white?
- Is it Structured (telo), unstructured attrital (detro) or gelified (gelo)?
- <20um grey? <30um white?

Reflected light, oil immersion lenses

MACERAL GROUP	MACERAL SUBGROUP	MACERAL	ORIGINS
VITRINITE	TELOVITRINITE Occurs as bands or lenses	Textinite*	Well preserved cell wall
		Texto-ulminite*	Partially gelified cell wall
		Eu-ulminite*	Completely gelified cell wall
		Telocollinite	Gelified cell wall and filling
	DETROVITRINITE Occurs in matrix	Attrinite*	Sparsely packed matrix of cell fragments
		Densinite*	Finely packed matrix of cell fragments
		Desmocollinite	Gelified humic matrix
	GELOVITRINITE Occurs in matrix	Corpocollinite	Gelified cell filling in tissue (CT) in matrix (CM)
		Porigelinite*	Vesicular humic gel in matrix
		Poricorpocollinite	Vesicular humic gelified cell filling
		Eugelinite	Humic gel
LIPTINITE	LIPTINITE Occurs in matrix	Sporinite, cutinite, resinite, liptodetrinite alginite, suberinite, fluorinite, exsudatinite, bituminite	Spores, waxes, resin, cuticle, suberin, algae, expulsed lipid, etc
INERTINITE	TELO-INERTINITE Occurs as lenses	Semifusinite	Partially oxidised tissue of low and moderate reflectance (mouldering, char?)
		Fusinite	Oxidised tissue (char)
		Sclerotinite/Funginite	Fungal spore/test/stalk
	DETRO-INERTINITE Occurs in matrix	Inertodetrinite	Oxidised cell wall fragment or cell filling of moderate to high reflectance
		Micrinite	Fine grained oxidised material (<5microns)
	GELO-INERTINITE Occurs in matrix	Macrinite	Oxidised gel

Photomicrographs of polished peat sections showing different levels of decay



a. Undecomposed plant cell walls rich in cellulose

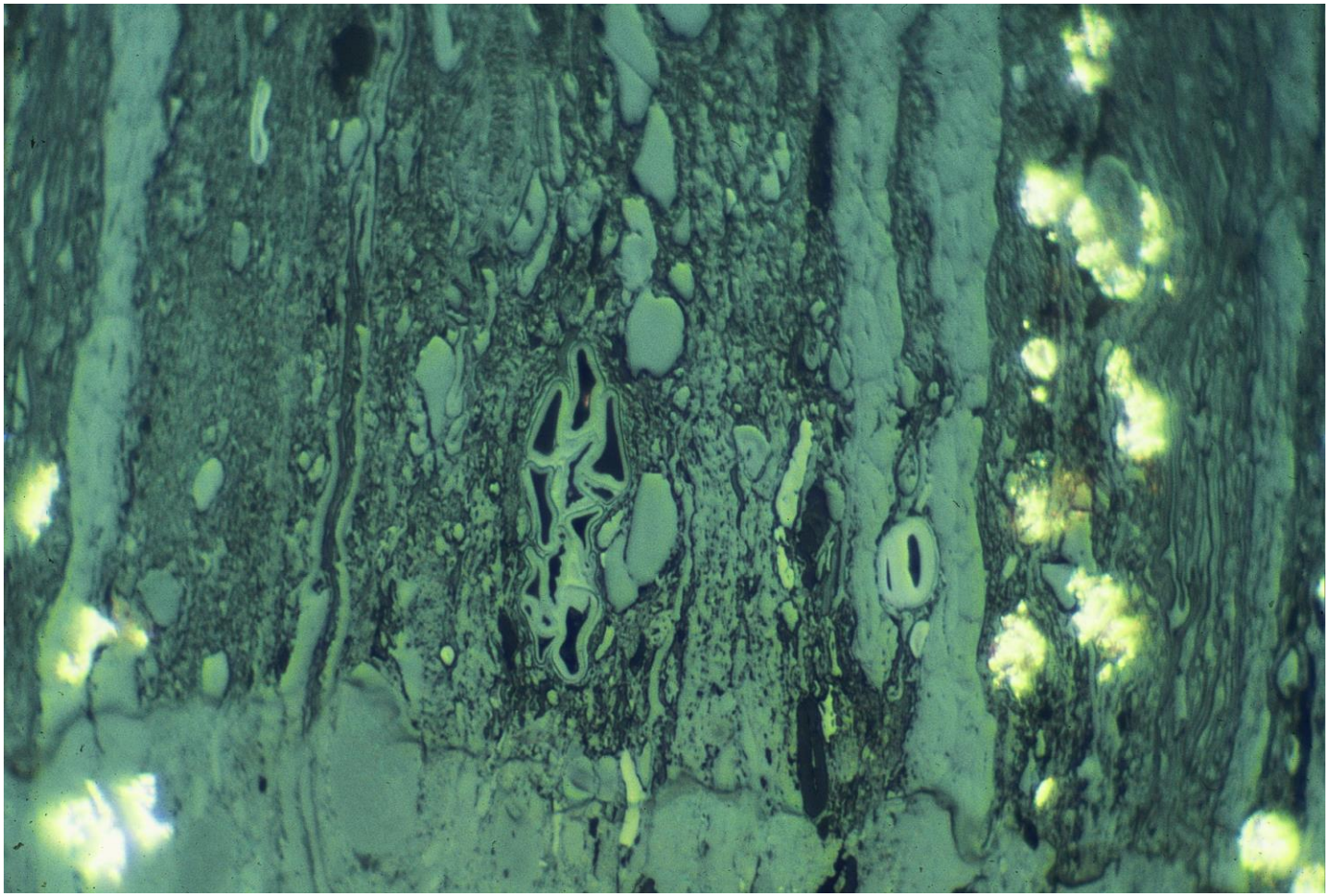
b. Partially humified plant cell walls; longitudinal section through a stem

c. Humified plant cell walls and cell fillings; radial section through a stem and its bark

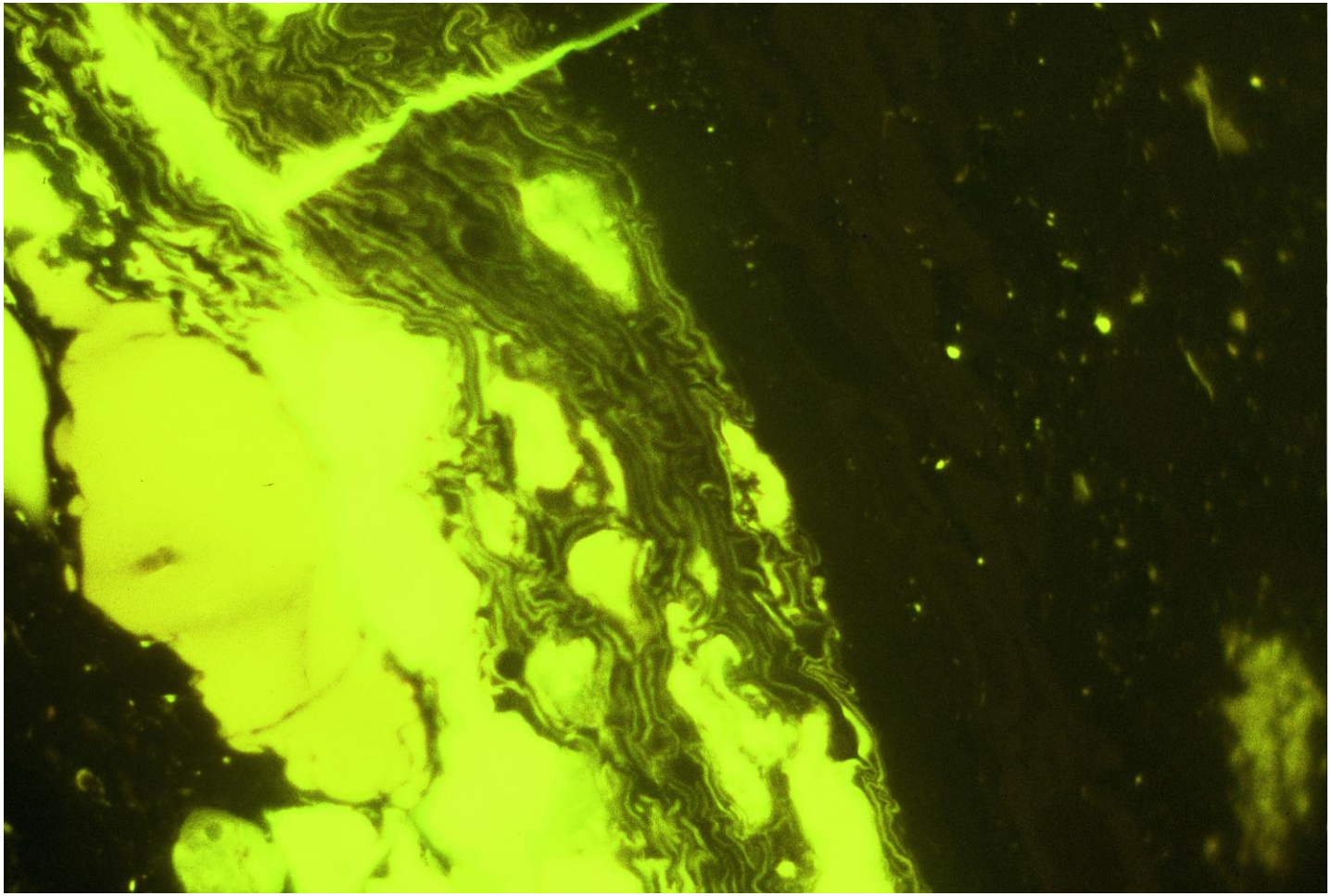
d. Gelified plant material; forming matrix

All photomicrographs under reflected light, oil immersion

Photomicrographs of coal



Photomicrographs of coal



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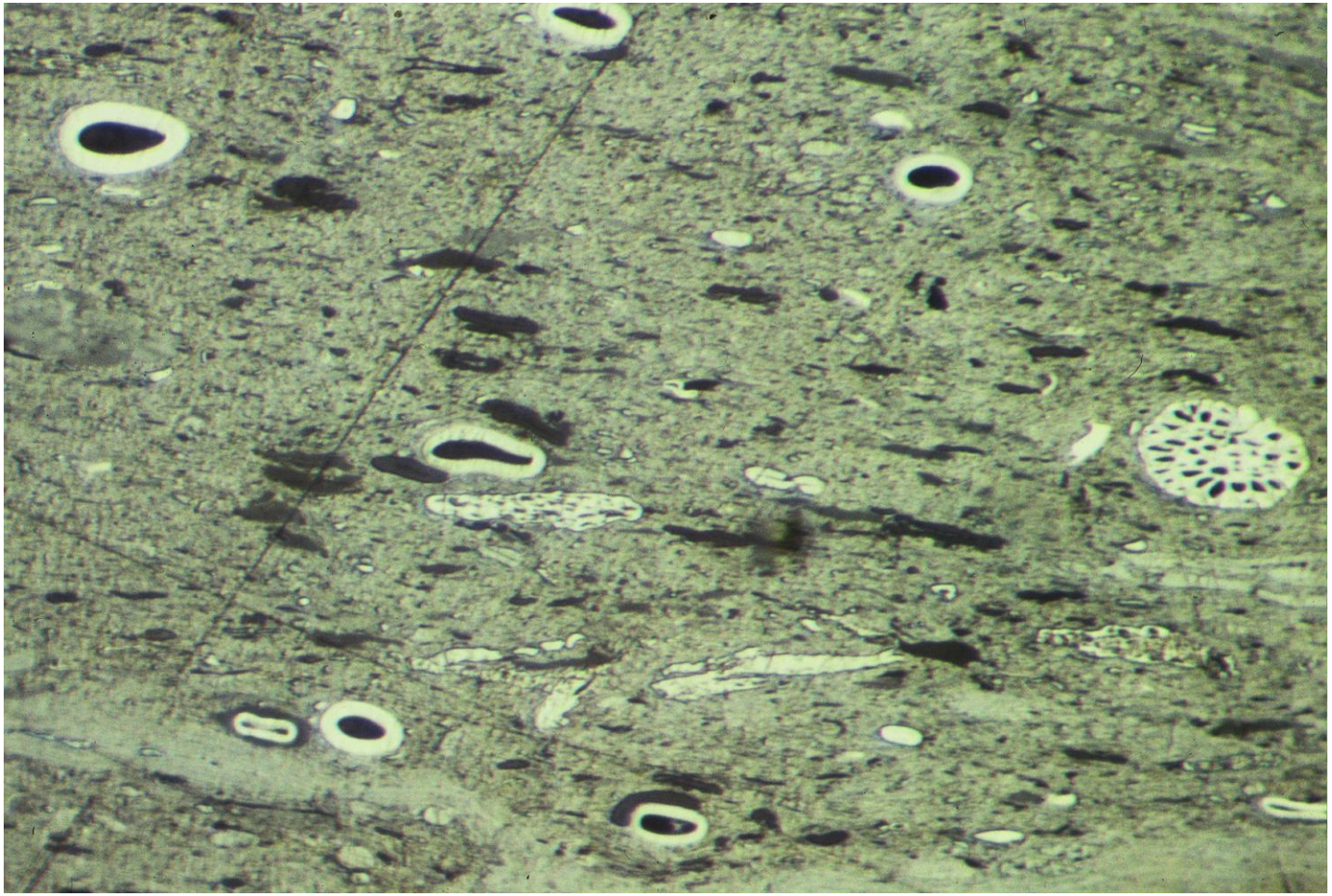
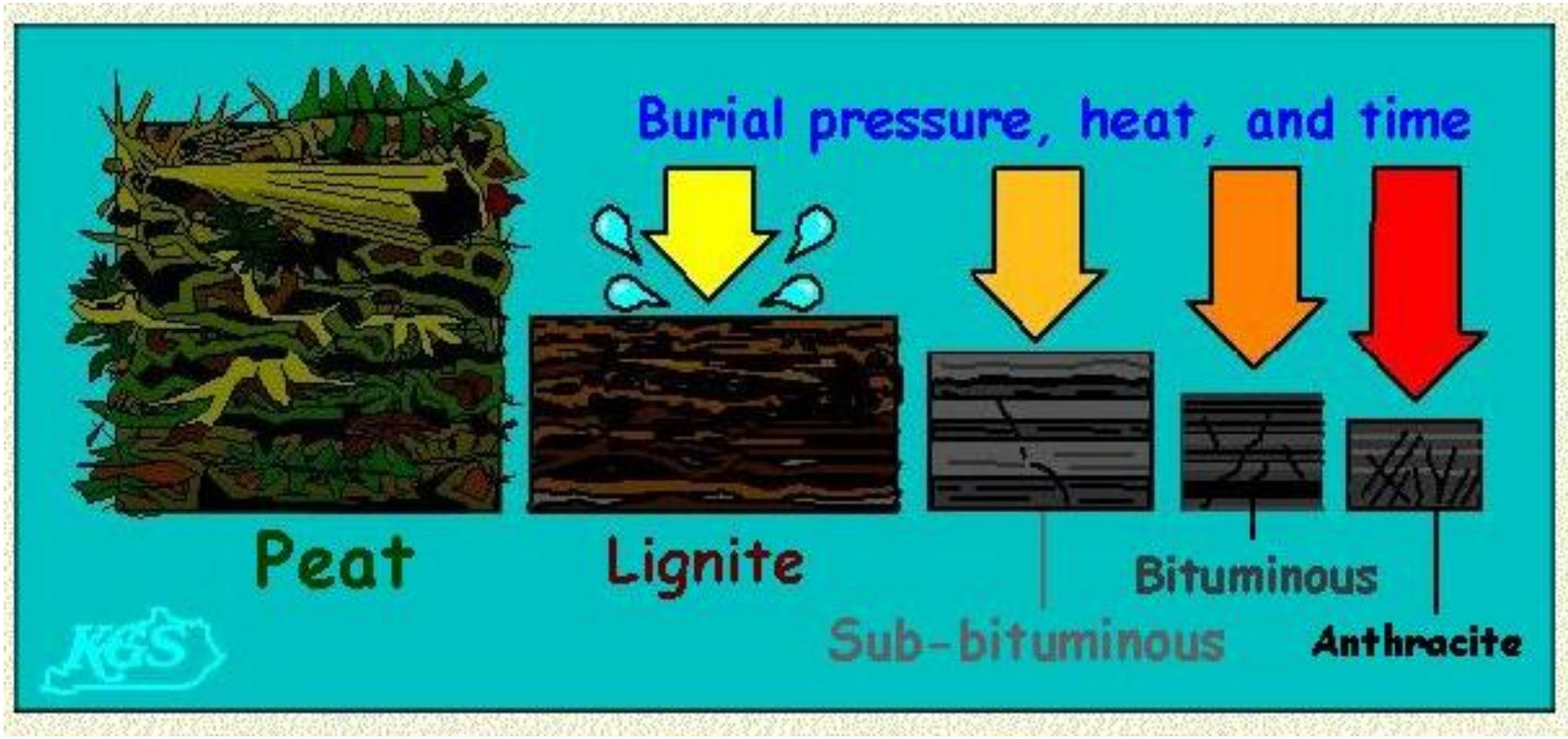


Stages and Causes of Coalification



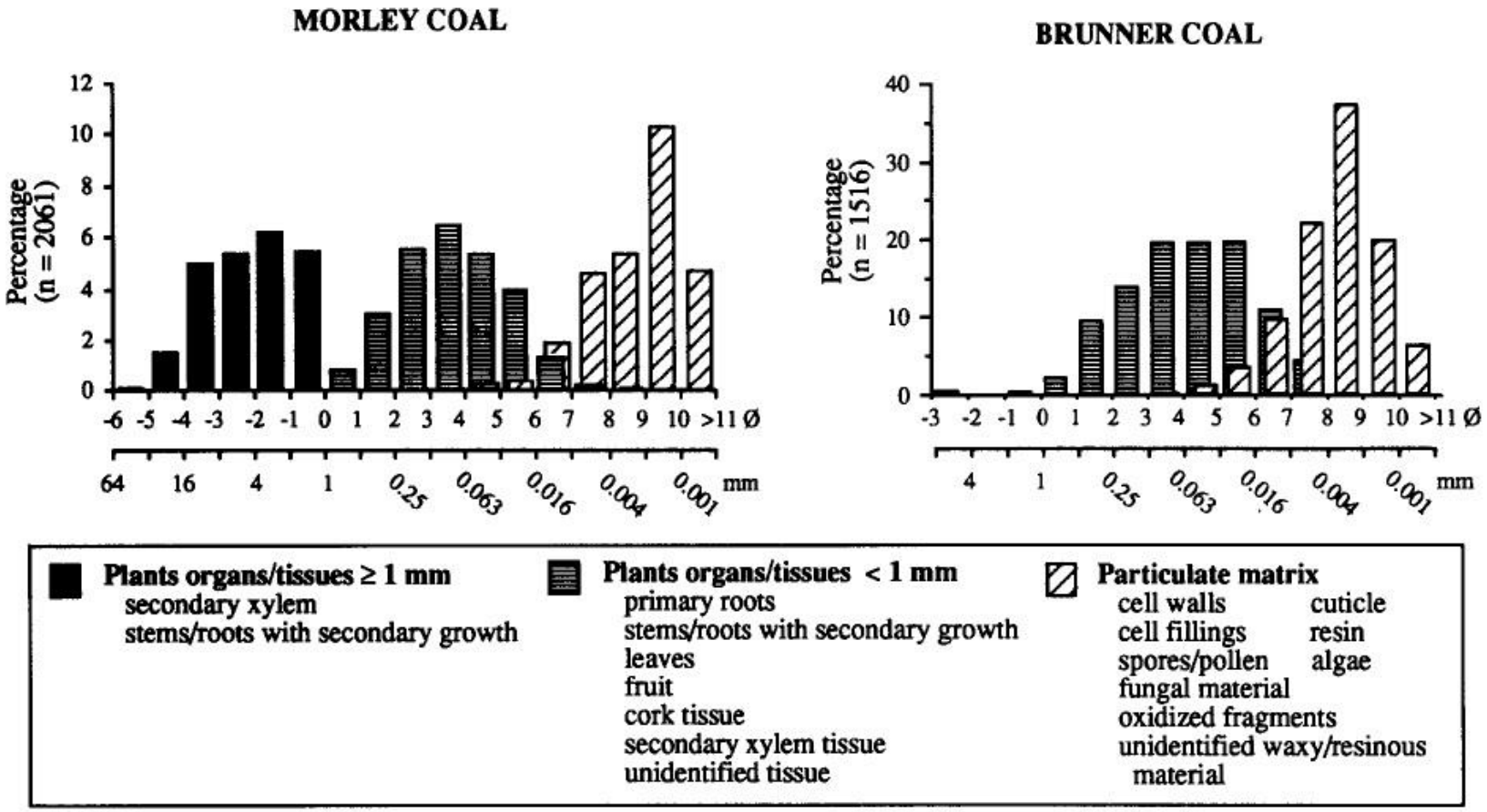
Physical Changes

Compaction
Loss of moisture

Chemical Changes

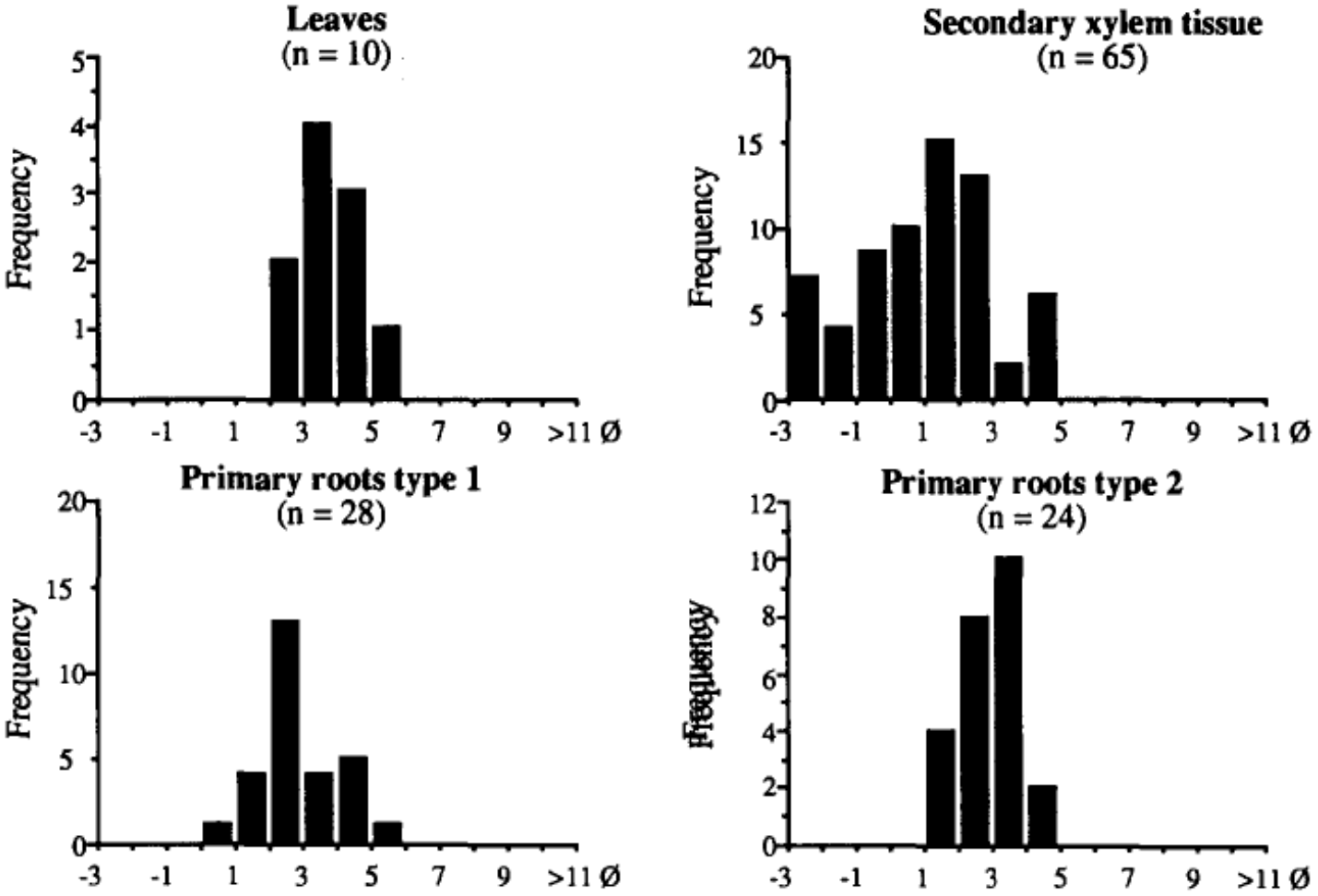
Loss of volatile matter
Decrease hydrogen content
Increase carbon content

Organics and Size Distribution - COAL



from Shearer & Moore, 1994

Organics and Size Distribution - COAL



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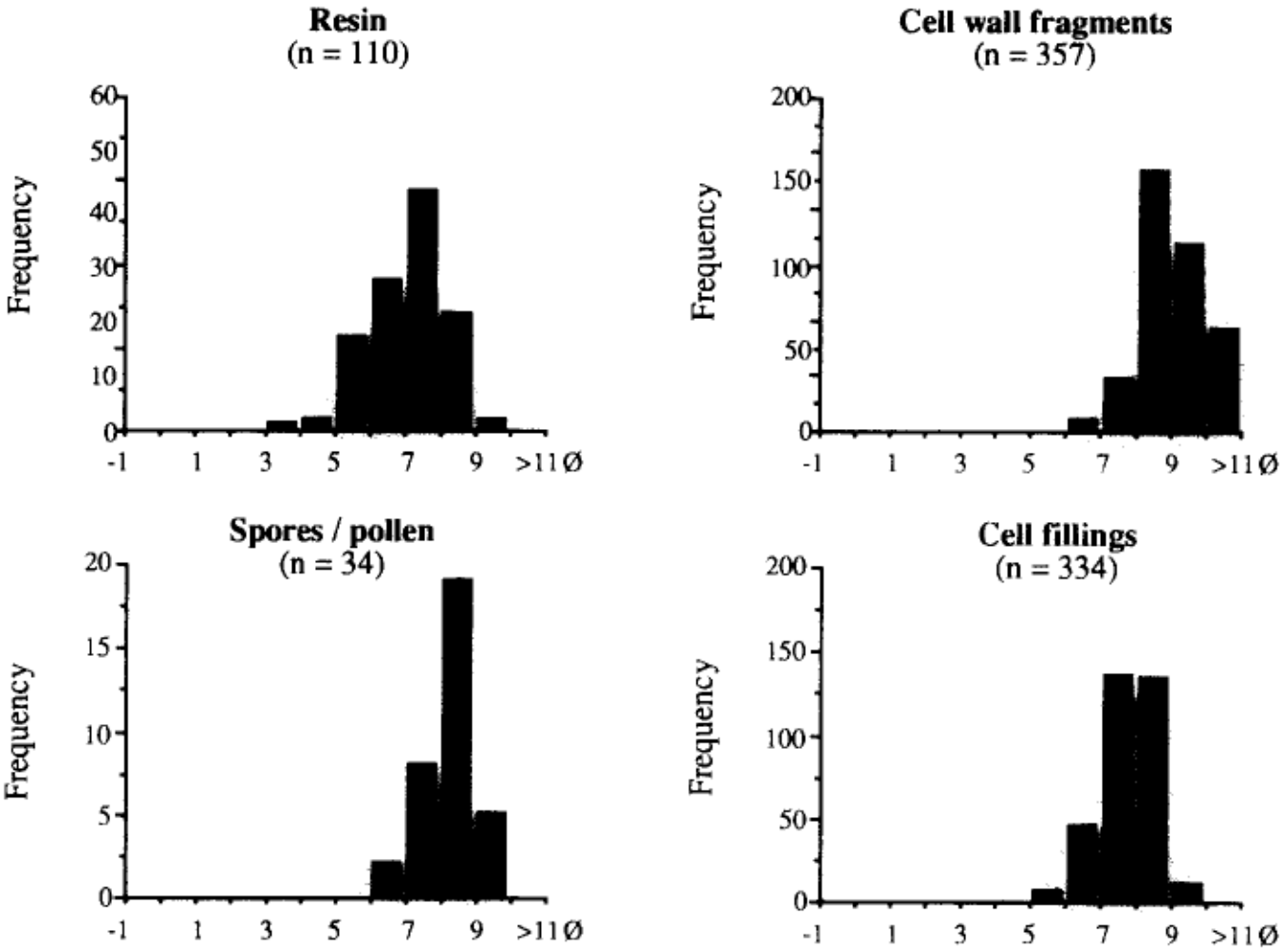
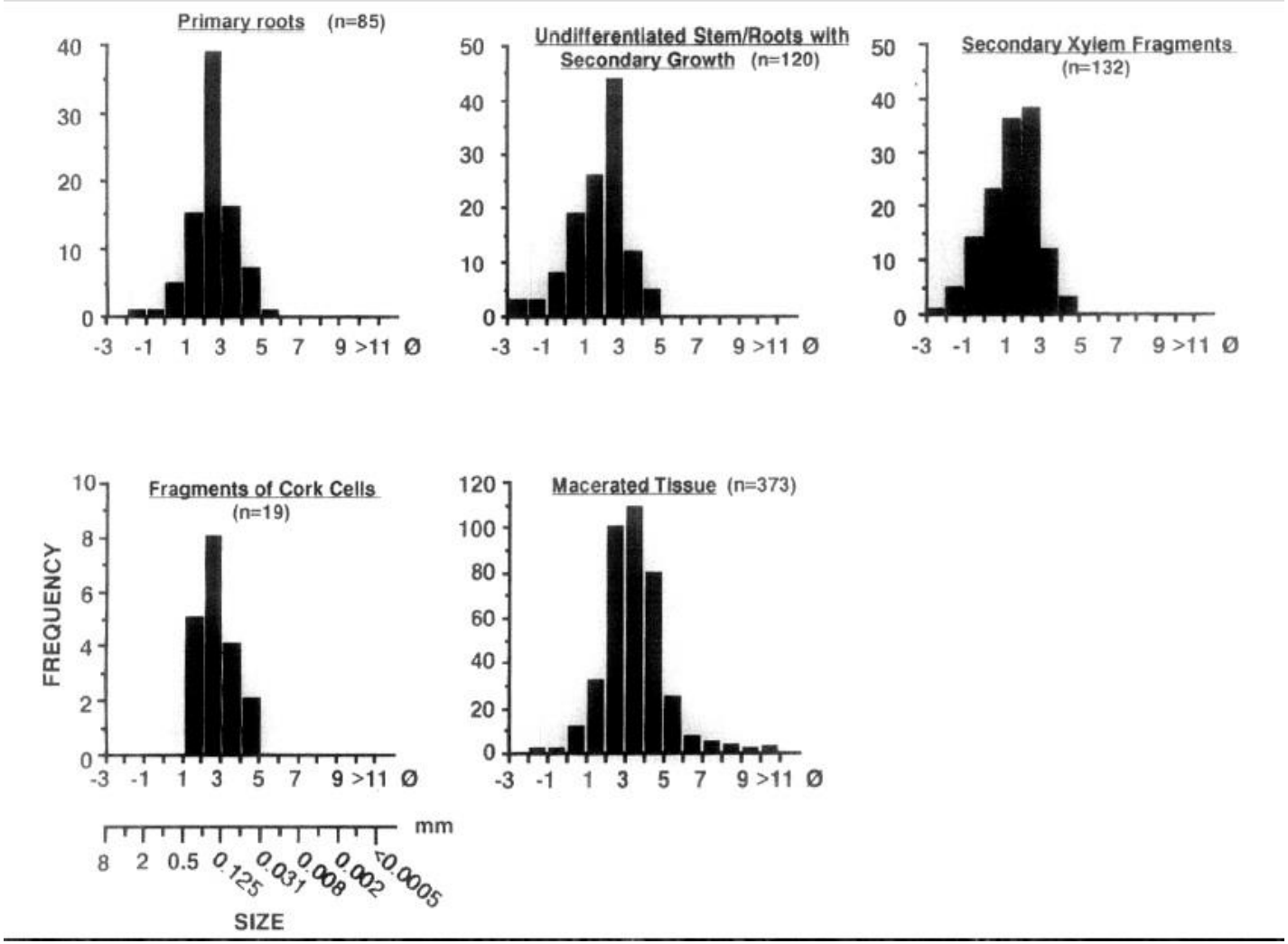
Organics and Size Distribution - COAL



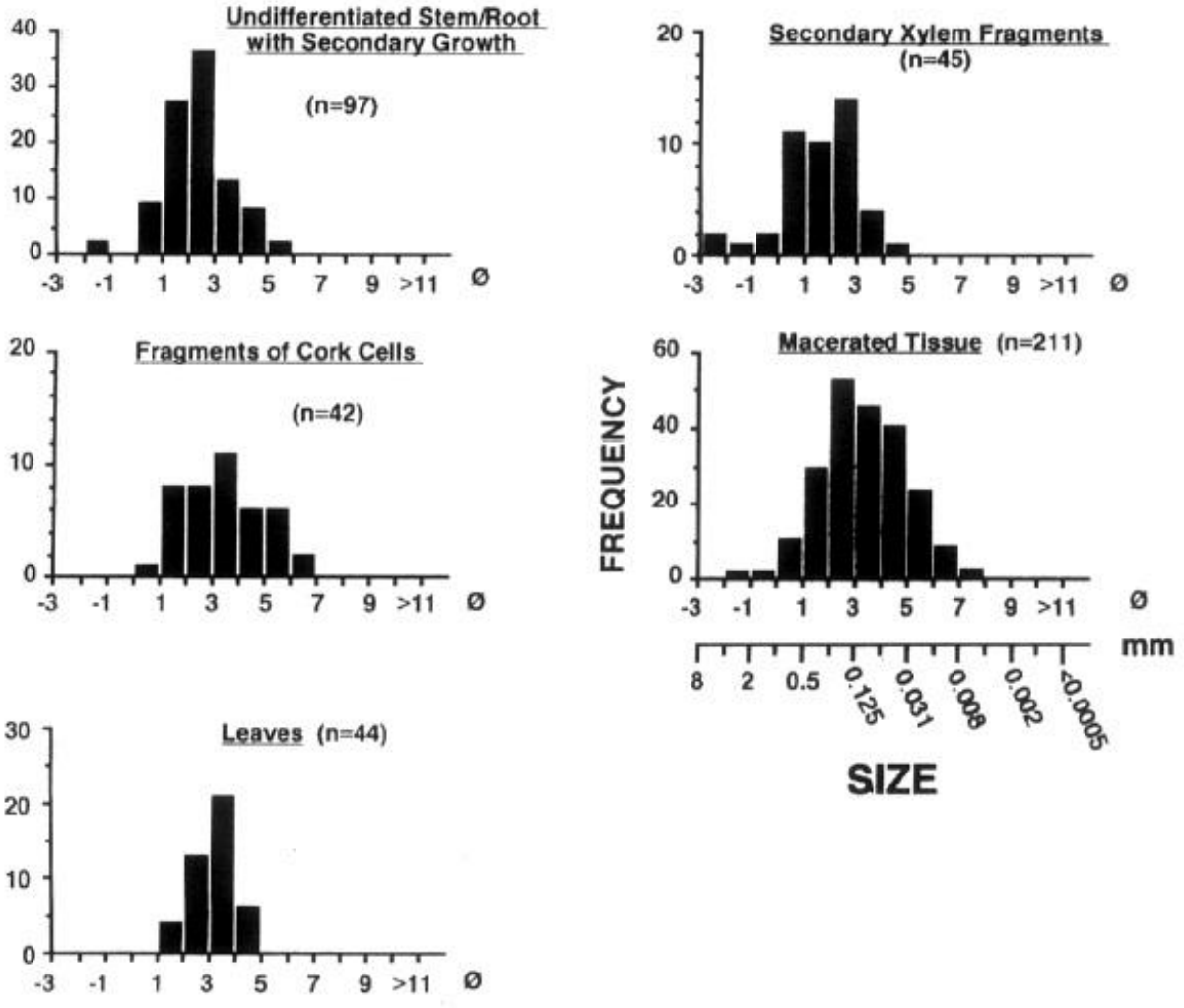
from Shearer & Moore, 1994

Organics and Size Distribution - Peat



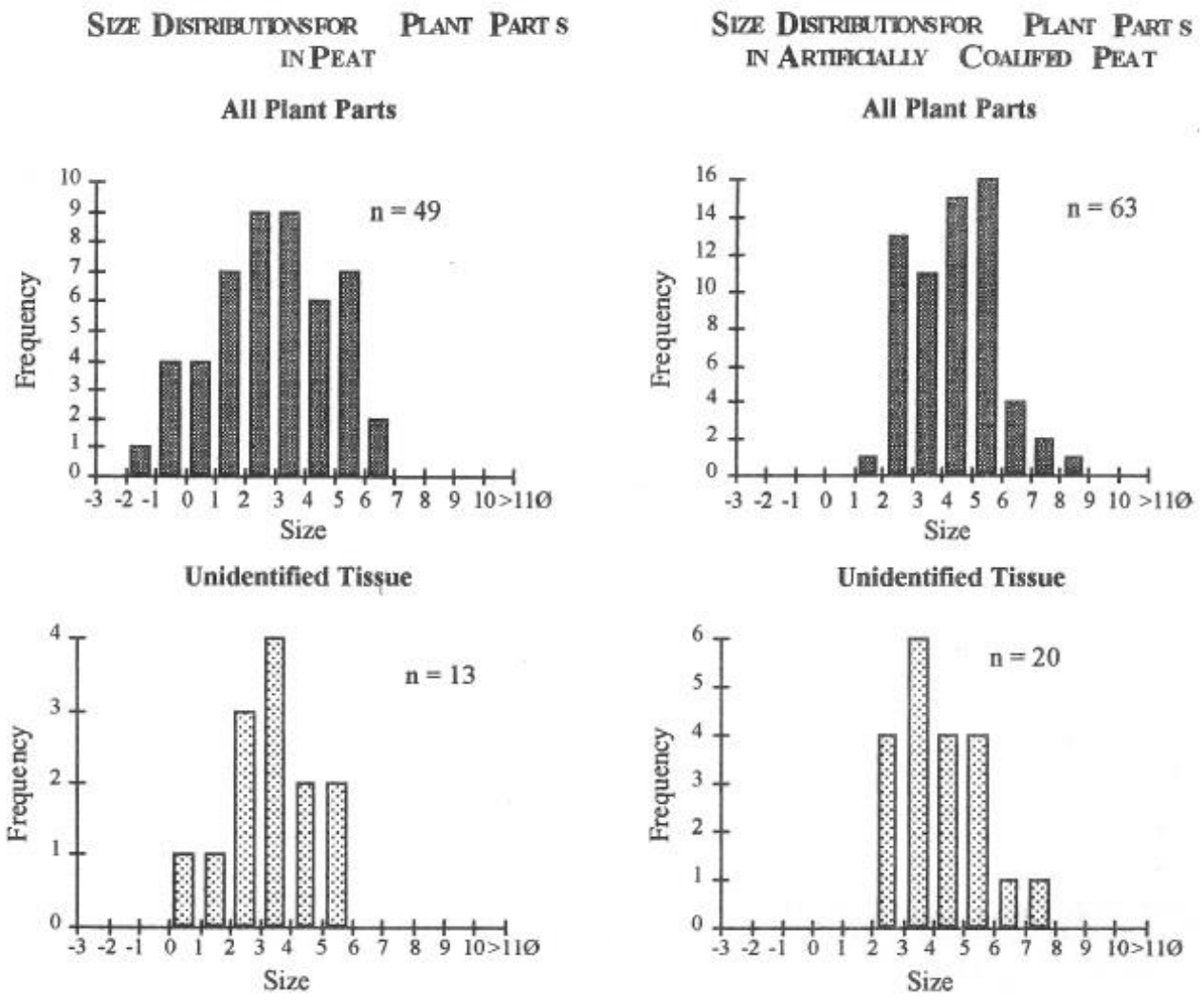
from Moore & Hilbert , 1992

Organics and Size Distribution - Miocene



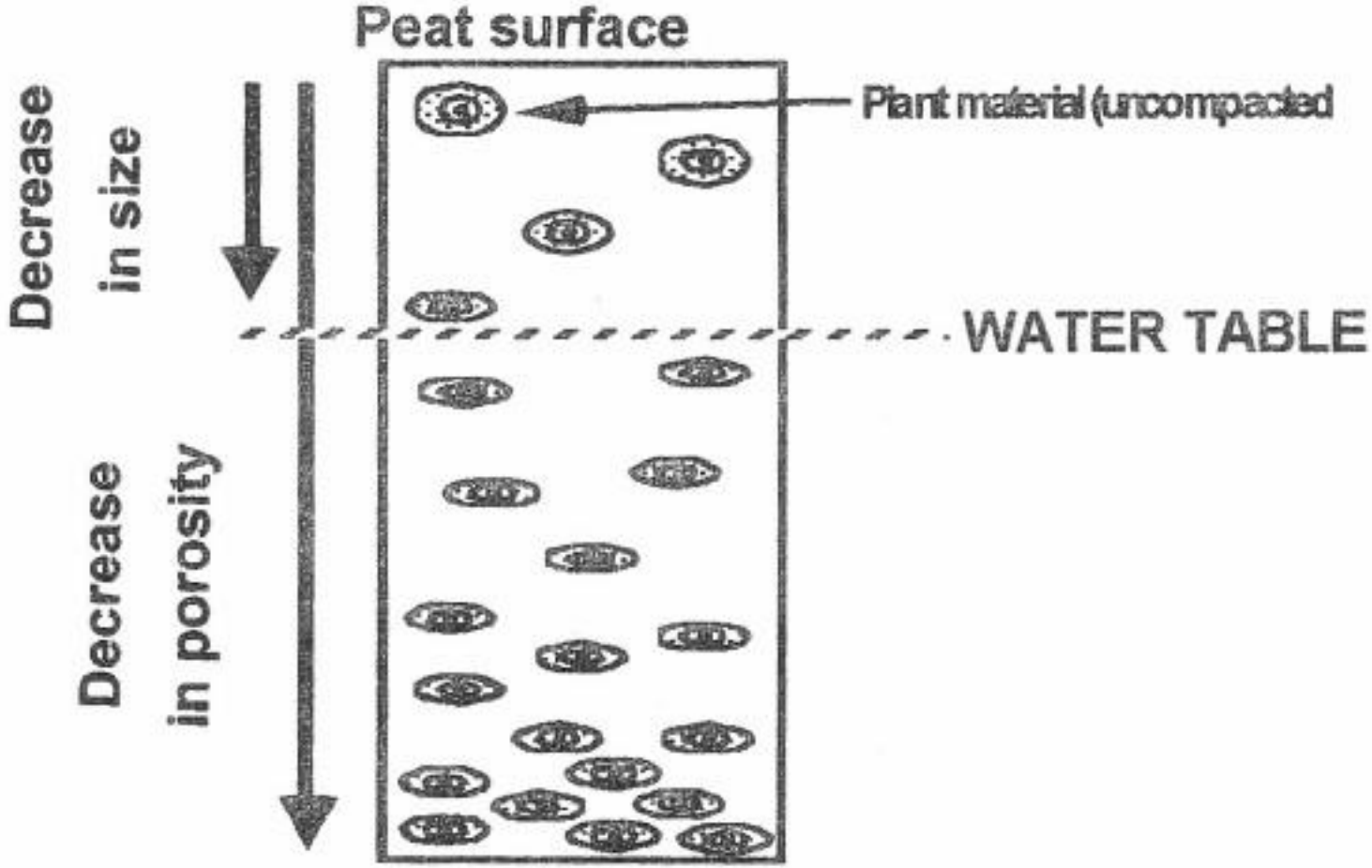
from Moore & Hilbert , 1992

Organics and Size Distribution – Artificial Coal



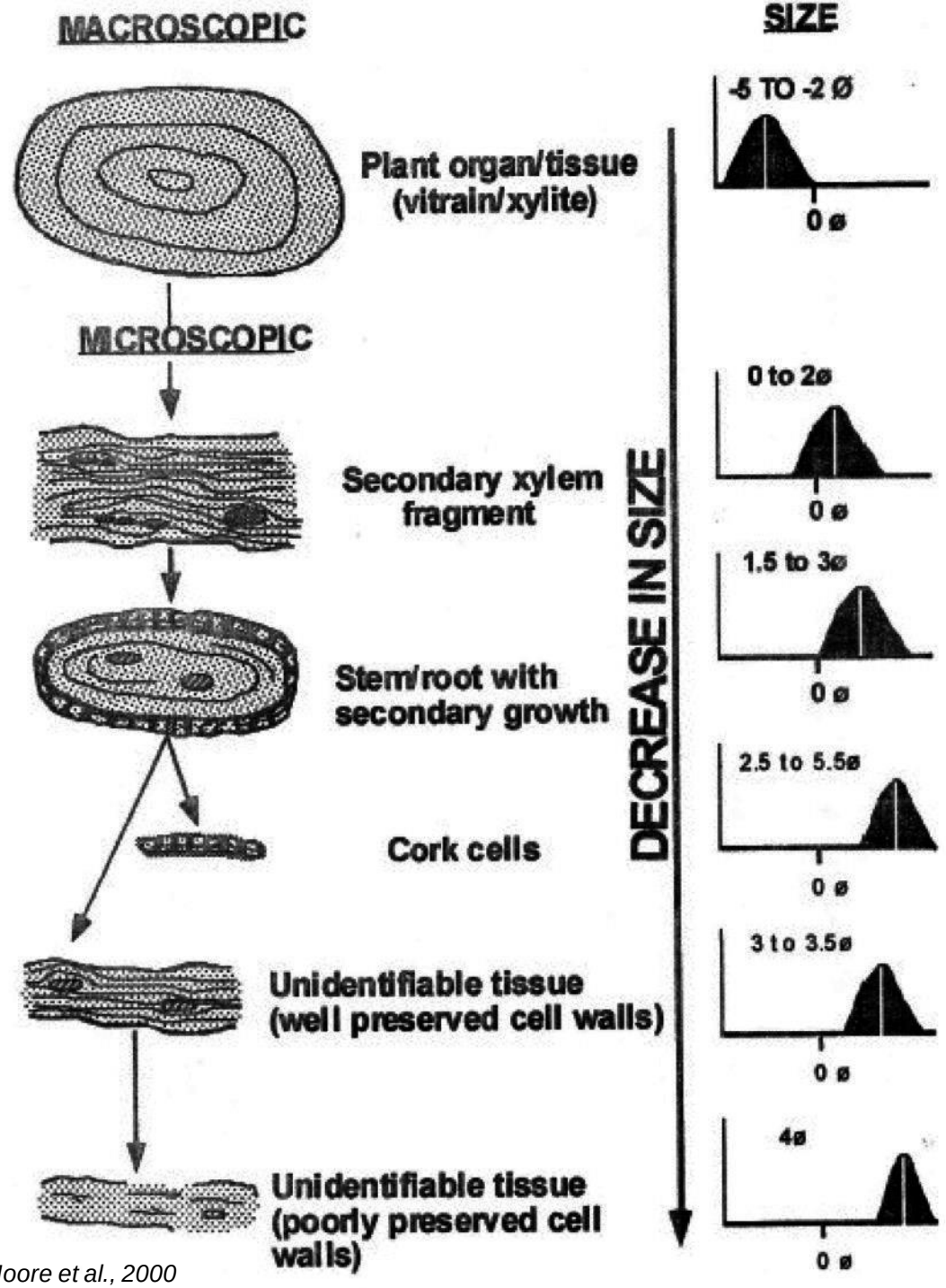
from Shearer & Moore, 1996

Organics and Size Distribution – Size in Peat Bog



from Moore et al., 2000

Organics and Size Distribution



from Moore et al., 2000

Summary

1. Vertical and lateral rock types in coal-bearing sediments aid in basin modeling

2. There are several macroscopic classifications for coal – important to use the right one

3. Macroscopic coal type are directly related to coal property type

4. Microscopically coal is very heterogenous

5. Coal texture is mostly defined in the peat stage

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Got Questions?

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