Advanced Training for CBM Geologists

Origin of Reservoir Properties: Peat to Pores

Ulaanbaatar, Mongolia

16 June 2022

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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

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Outline of Talk

- **Peat Processes**
- **Depositional Systems**
- **Peat Types into Coal Types**
- **Relevance to Coal**

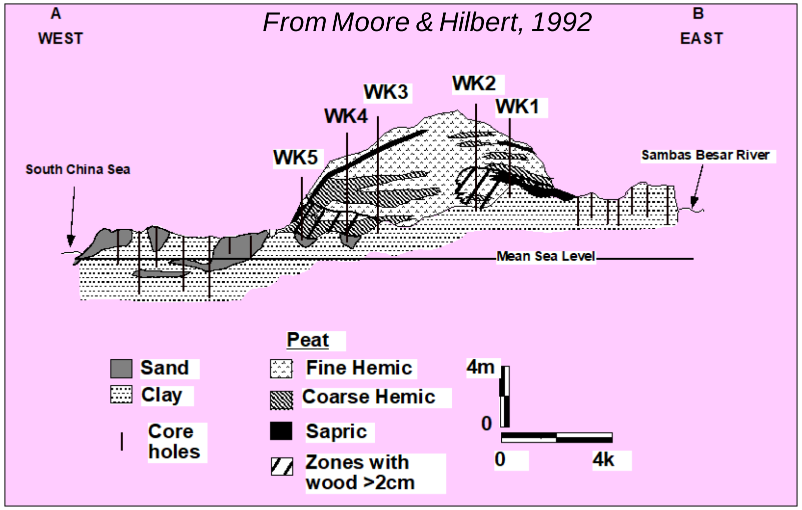
Origin of Coal

COAL forms from PEAT

PEAT forms from PLANT Material Accumulated over Thousands of Years

PEAT mires can be extensive some times covering thousands of square kilometers.

In Indonesia, the climate allows thick peat to form, and the top surfaces of these mires are often raised, or 'domed'.



Origin of Coal

Peat mires are often dissected by river channels; these channels move around over time, covering and sometimes cutting out the peat. Although it doesn't look like it, the system is ***dynamic*** *and results in coal seams which are* ***complex*** *in their three-dimensional geometries.*

photo by Joan S. Esterle, used with permission

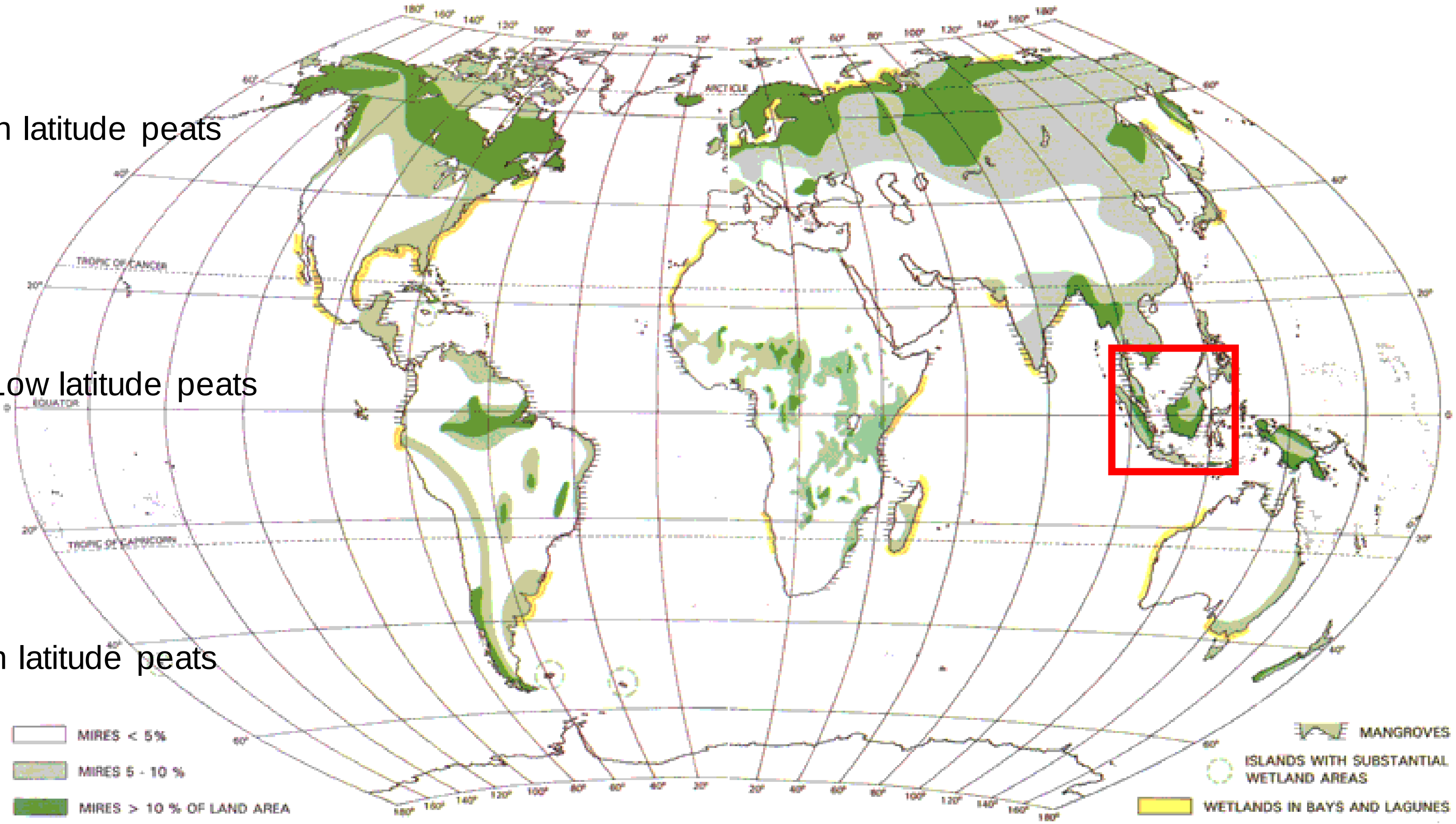
Modern analogues
Peat belts- climate influences ingredients

RESPONSE TO MOST RECENT SEA LEVEL HIGH STAND END OF THE LAST BIG ICE AGE
6000 – 10,000 Y.B.P.

High latitude peats

Low latitude peats

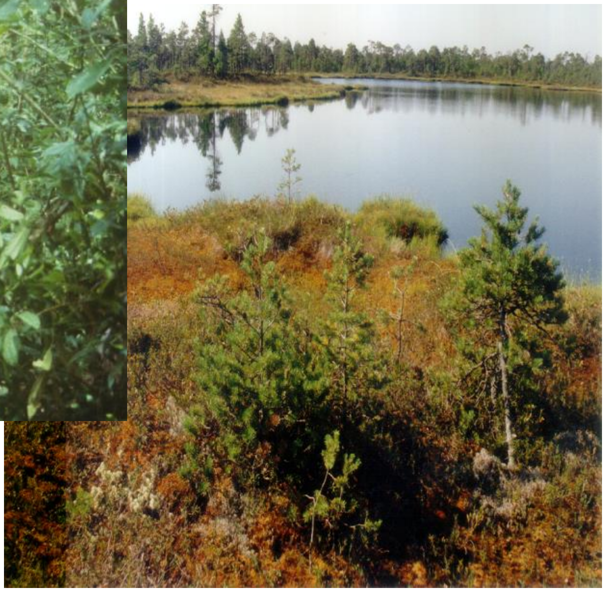
High latitude peats



Global occurrence of peat accumulating mires
(source: http://www.peatlandsni.gov.uk/formation/global.htm#globalmap)

Origin of Coal

Peat mires (and thus coal beds) can be hugely different depending on the influence of climate, depositional setting and basin subsidence rates



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WHY does peat form??

Plant growth is more rapid than decomposition

Two Controls:

- Physical
- Chemical

Controls on Peat Formation

Physical

- Protected from sediment
- Rain — lots of it!
- Not too rapid subsidence

  not to slow …

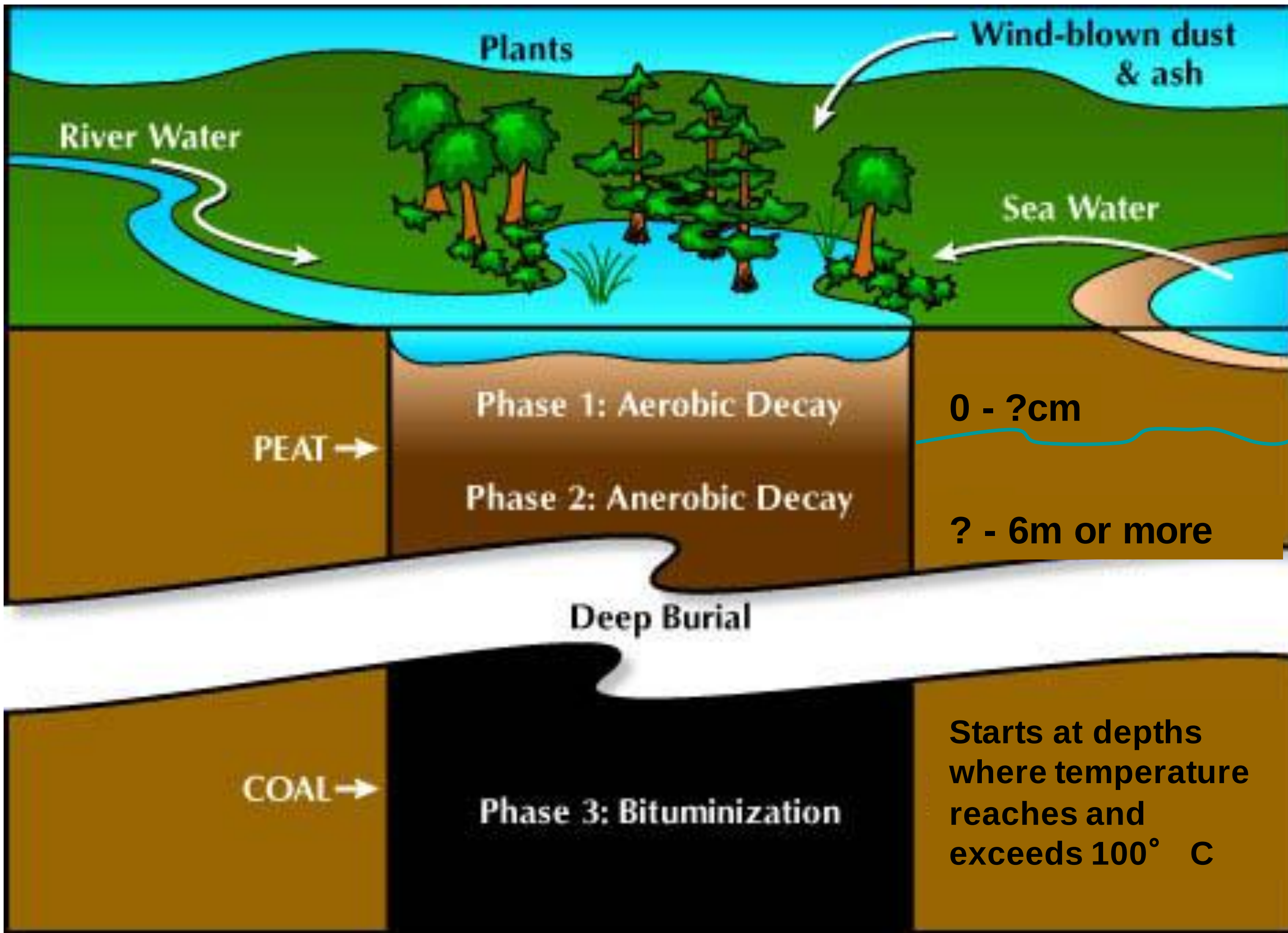
Chemical

- Low oxygen
- Low pH

3-Phase process leading to coal formation

accumulation burial

thermal maturation



Water table fluctuates seasonally and as result of long term changes

Information modified after: www.smtc.uwyo.edu/coal/swamp/how.asp AND www.quest.bris.ac.uk/workshops/0604talks/Clymo.doc

Peat Accumulation :Vegetation grows, dies and decomposes, but not all the way

**Photos of tree decomposition in modern peats, Baram River, Sarawak, Malaysia
J. Esterle, 1990**

Phases of Decay- Aerobic

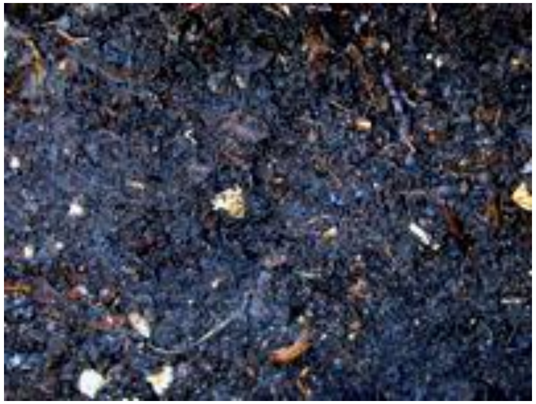
Physical decomposition – maceration or fragmentation of plant organs and tissues assisted by scavenging insects, fungi and bacteria

Chemical decomposition -

> **Humification- humic substances from lignin and decomposition products including phenolic compounds (aromatic hydroxyl derivatives)**

Compost bin

Fresh litter



Finished product

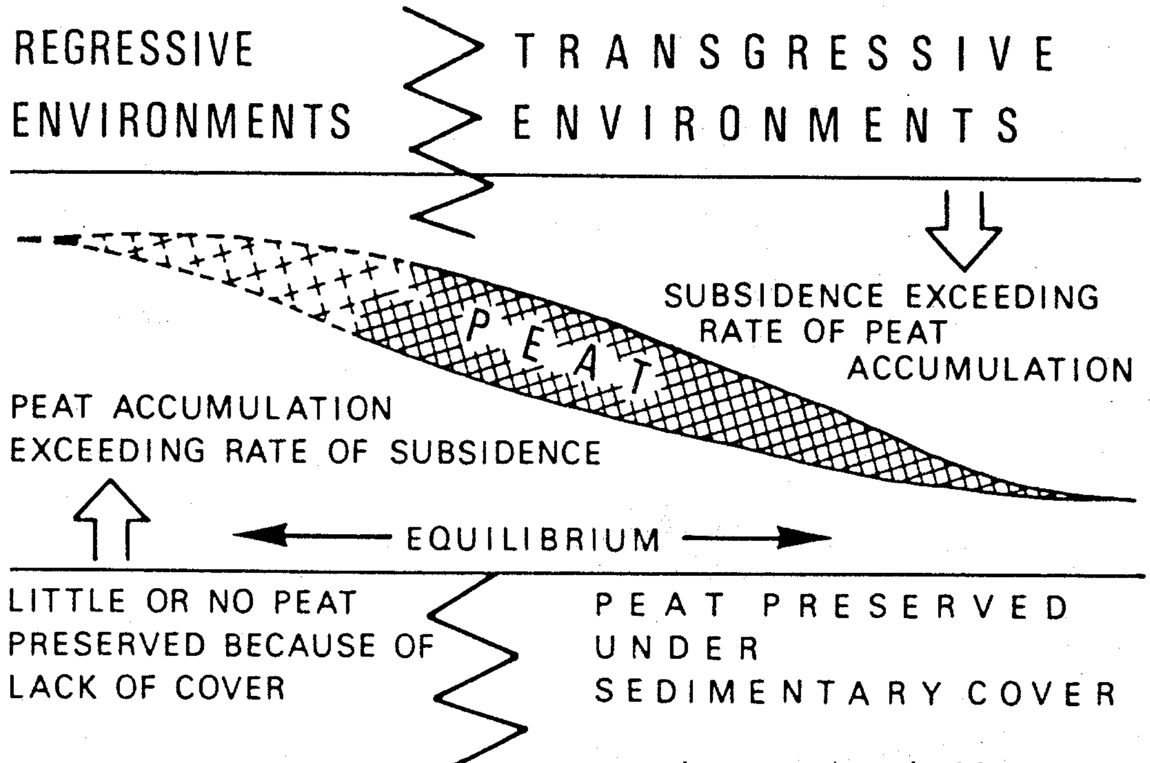
Peat Accumulation: A Balancing Act

<u>Climate</u>: need conditions of high rainfall or humidity to support <u>luxuriant plant growth</u> (can be tropical, temperate or cold)

<u>Slowly subsiding basin</u>: to allow thick accumulation of peat and burial under continuous shallow water

<u>No clastic sediment</u>: little or no influx of normal clastic sediment into peat mires from surrounding water courses

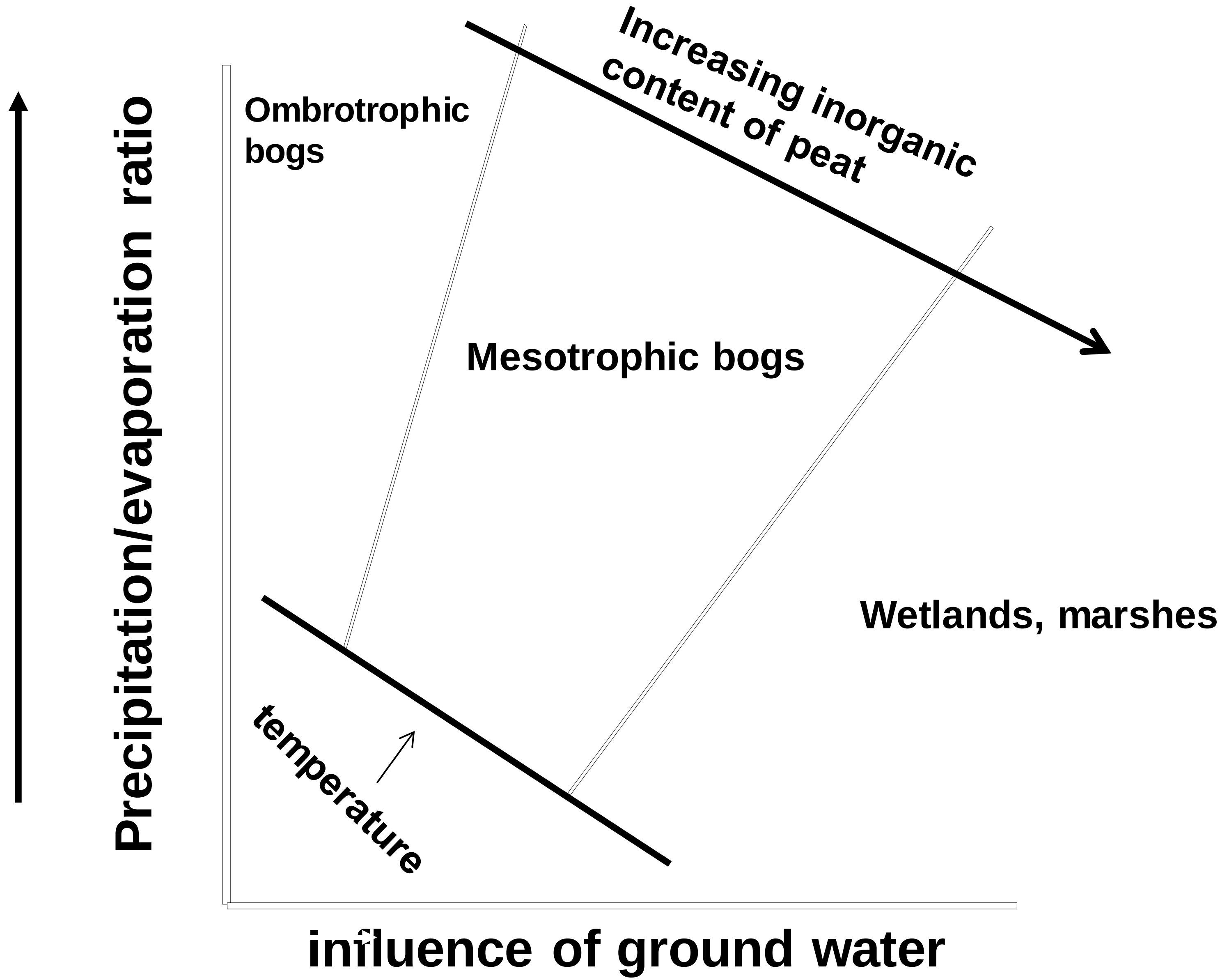
<u>Reducing conditions</u>: Stagnant or nearly stagnant water so that available oxygen is used up and plant material is not oxidised



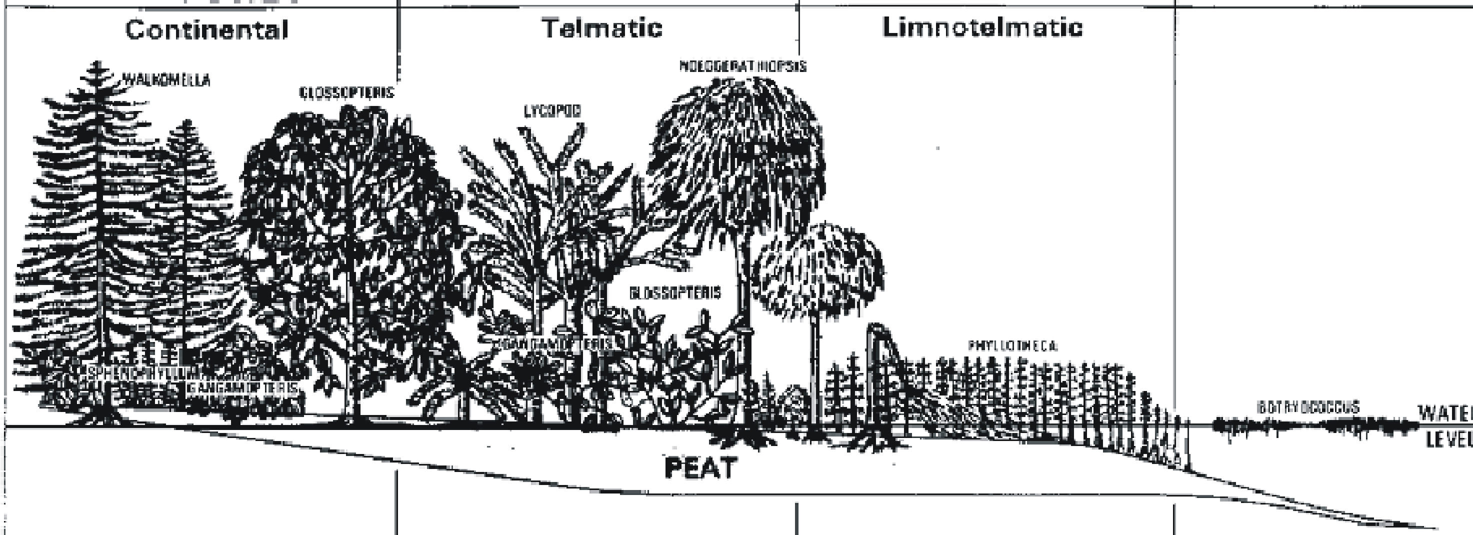
Bless MJM et al 1981

THICK PEATS WHERE ACCUMULATION KEEPS PACE WITH OR OUTSTRIPS SUBSIDENCE JUST LIKE CORAL REEFS

Classification of mires



Vegetational Succession-local to regional and global scales



	DRY FOREST	WET FOREST	REED MOOR	MOOR LAKE
WATER COVER:	NONE	OSCILLATING	ALMOST COMPLETE (~ 2m)	COMPLETE
ACIDITY:	HIGH	MEDIUM	LOW	LOW
ATMOSPHERIC O_2:	PRESENT	PARTLY PRESENT	LARGELY ABSENT	ABSENT
CHEMICAL REACTIONS:	OXIDATION	OXIDATION AND REDUCTION	MAINLY REDUCTION	REDUCTION
ORGANIC ACTIVITY:	FUNGI, INSECTS, AEROBIC BACTERIA	ACTINOMYCES, AEROBIC AND ANAEROBIC BACTERIA	MAINLY ANAEROBIC BACTERIA	ANAEROBIC BACTERIA
MODE OF PLANT DECOMPOSITION:	ROTTING	MAIN ZONE OF PEATIFICATION		PUTREFACTION
PEAT TYPES:	WOODY WITH RESIN BODIES	WOODY WITH INCREASING HUMIC COLLOIDS →	FIBROUS TO EARTHY →	ORGANIC MUD
COAL TYPES (LITHOTYPES):	FUSAIN (fibrous coal) SOME DURAIN (dull coal)	VITRAIN (bright coal), CLARAIN (banded bright coal), DURO-CLARAIN (banded coal)	CLARO-DURAIN (banded dull coal), SOME DURAIN (dull coal)	DURAIN (dull coal), CANNEL AND BOGHEAD COAL, OIL SHALE

Reconstruction of plant communities and conditions affecting peat accumulation and subsequent types of coal for a Permian age deposit (source: Diessel, 1980).

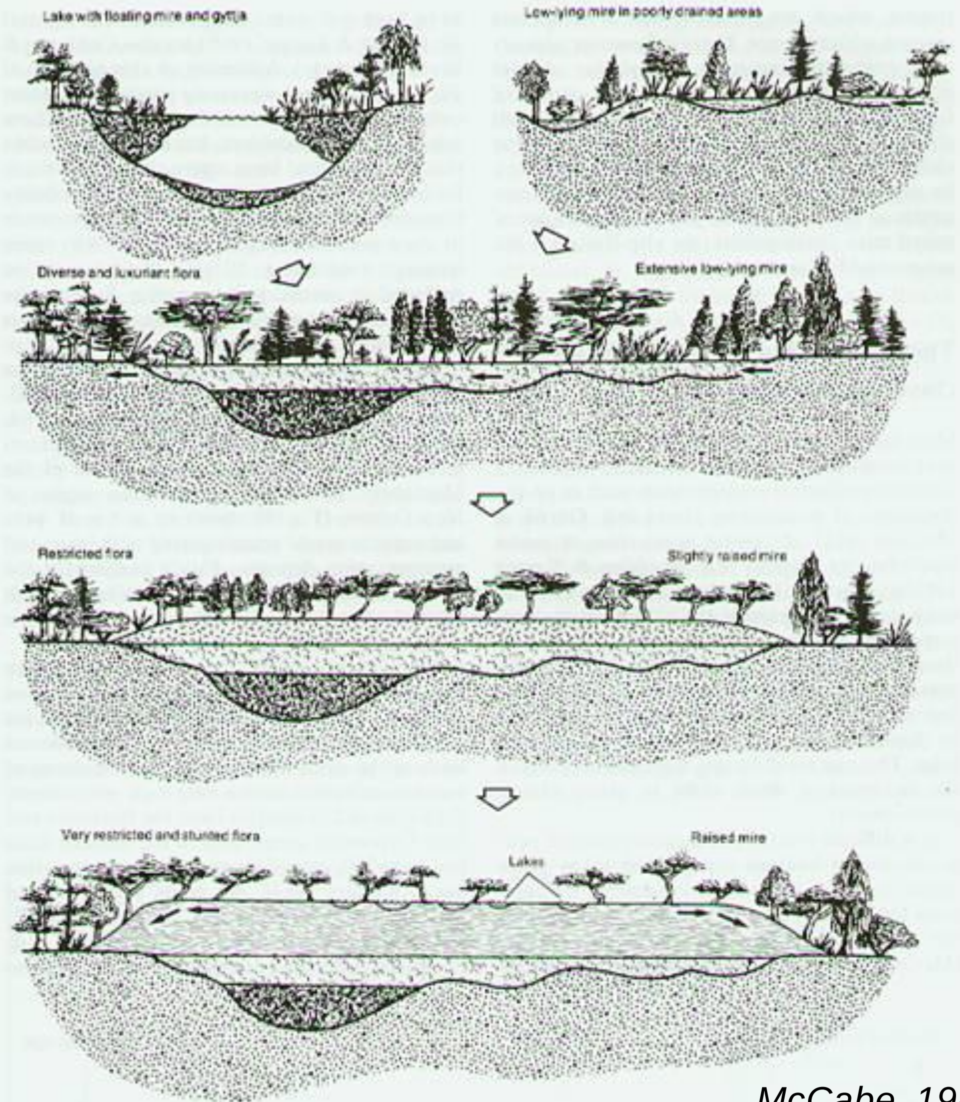
Generalised model for mire development

- **Evolutionary sequence of mire development and peat accumulation manifested in the stratigraphy of coal types (megascopic and microscopic)**

- **Lateral variability will occur due to variations in the substrate topography which is often "swamped" by mire development**

- **Paludification (to make a "lake")**

- **Terrestrialisation (to make "land")**



McCabe, 1984

FIG. 2. Evolutionary sequence of mire types showing the development of a raised mire with vertical zonation of

A peat mire is like a Soufflé

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…if conditions change, so does the soufflé/peat

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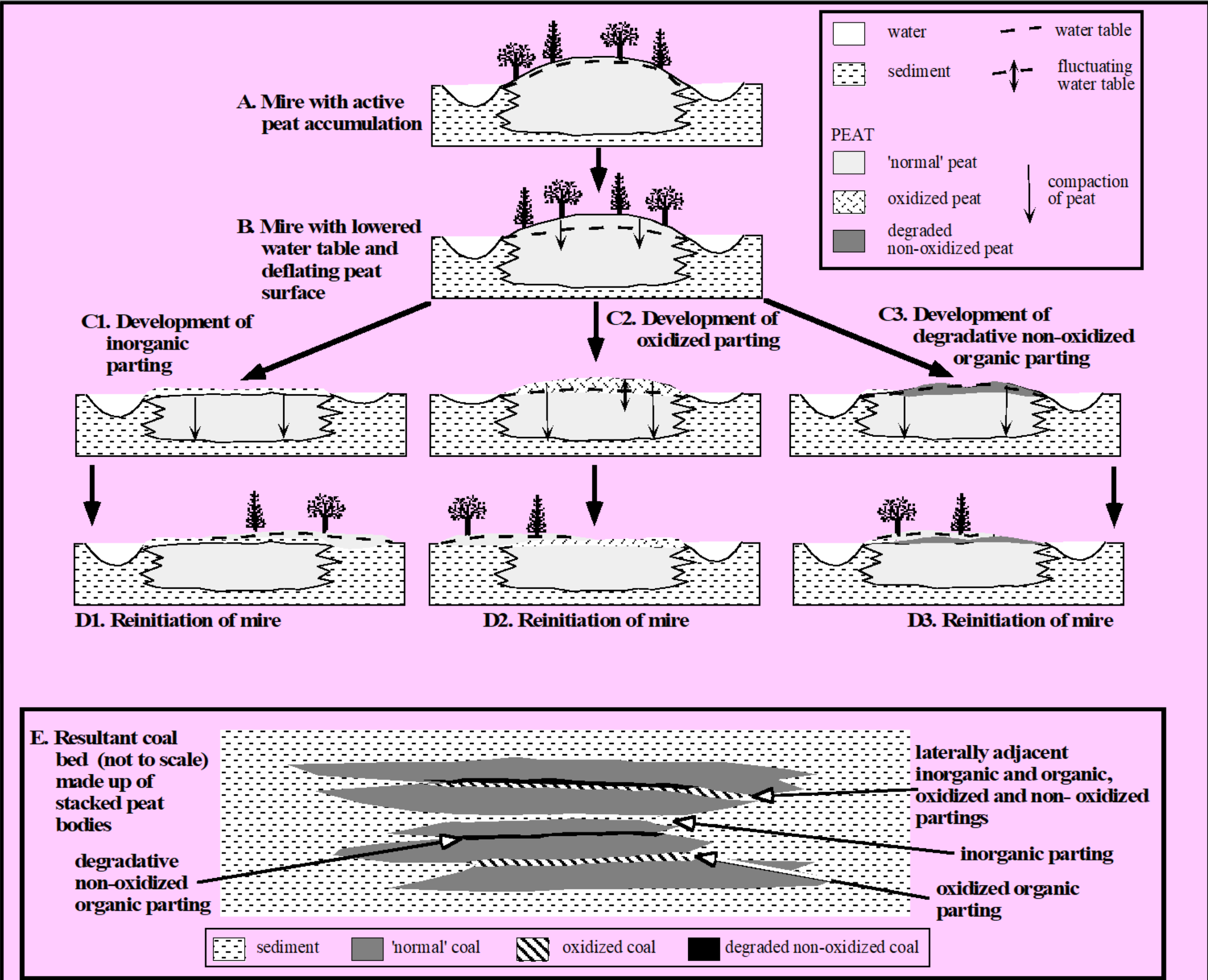
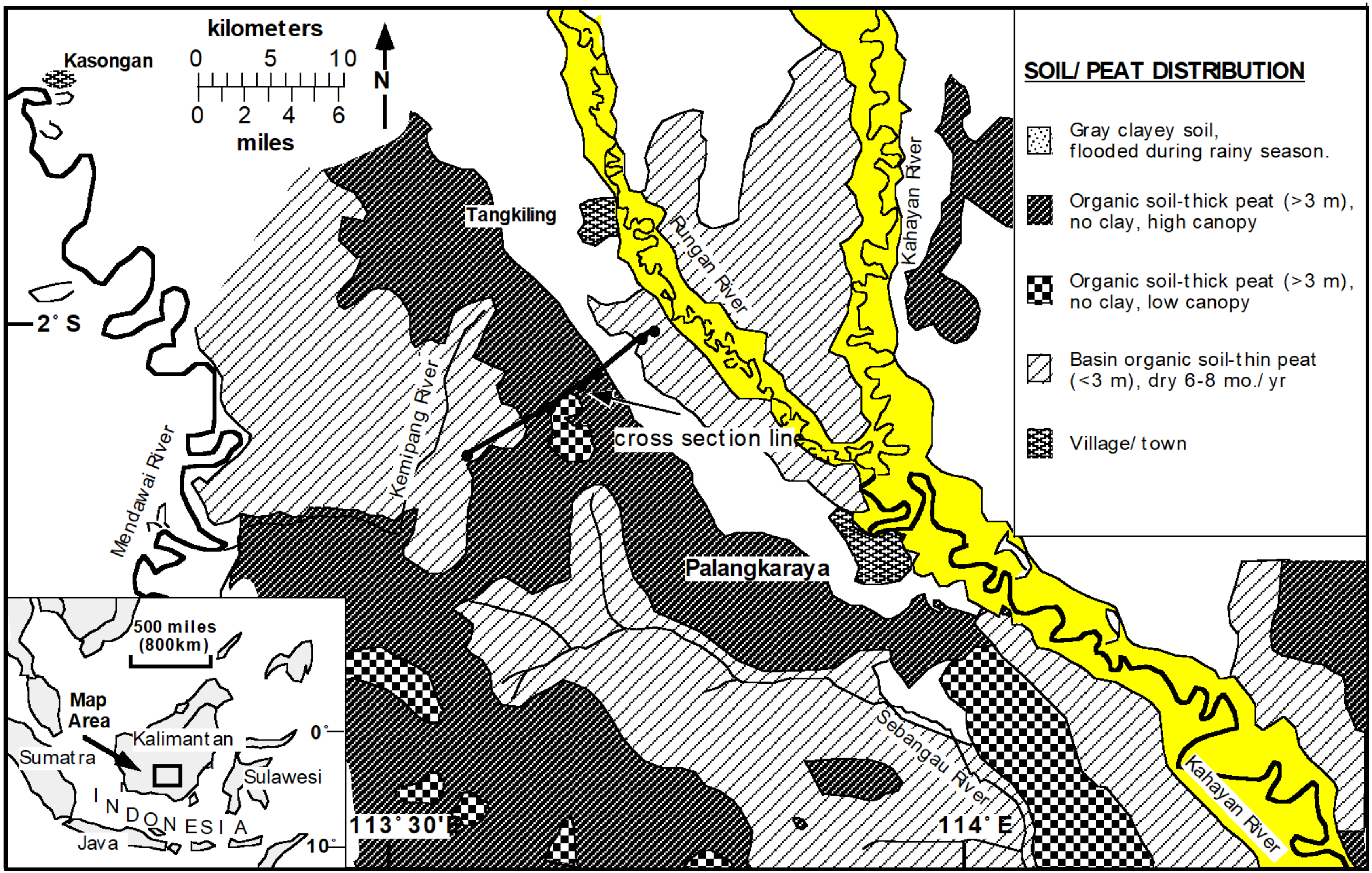
Different conditions affect the peat in different ways



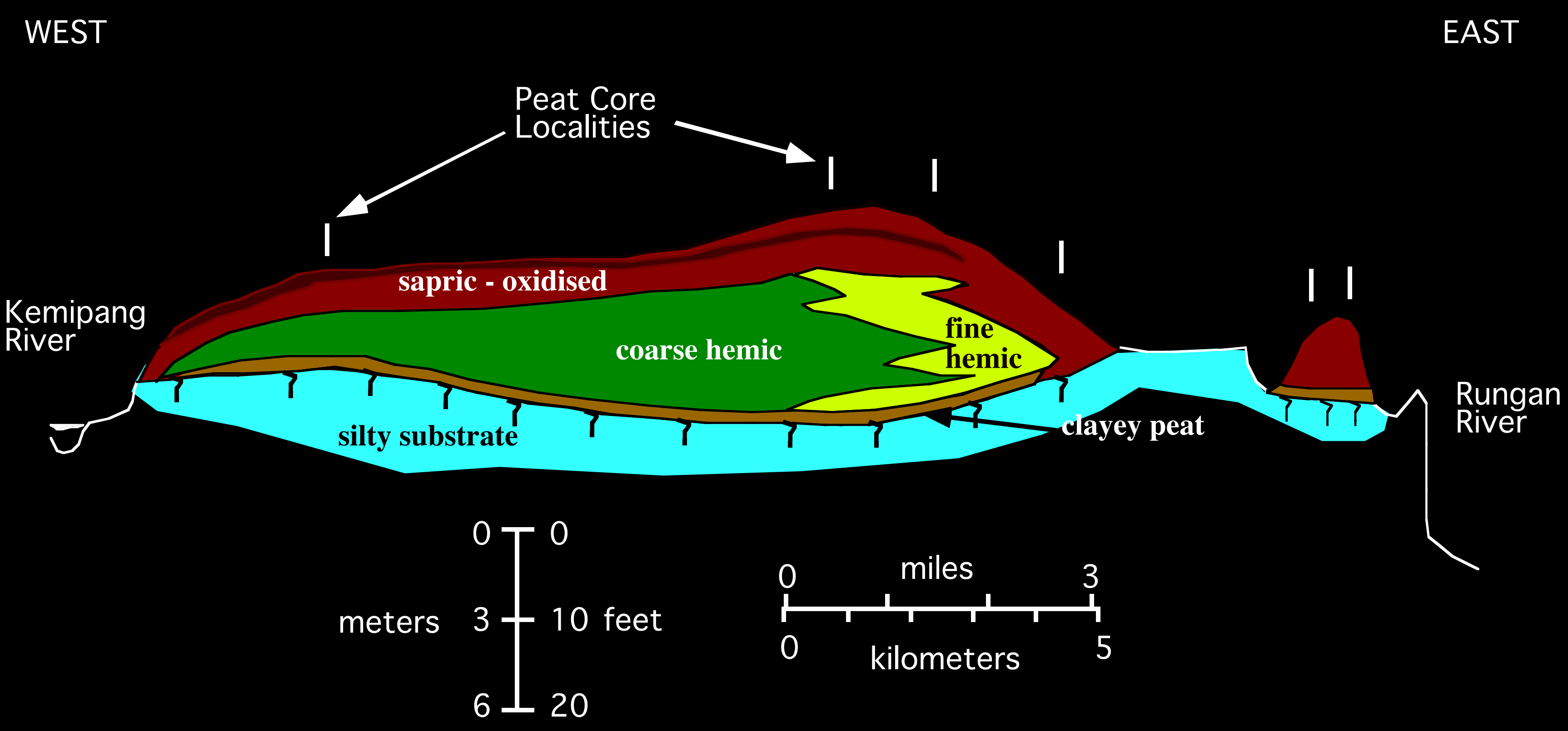
from Moore & Shearer, 1993

Palangkaraya Peat, Kalimantan Tengah



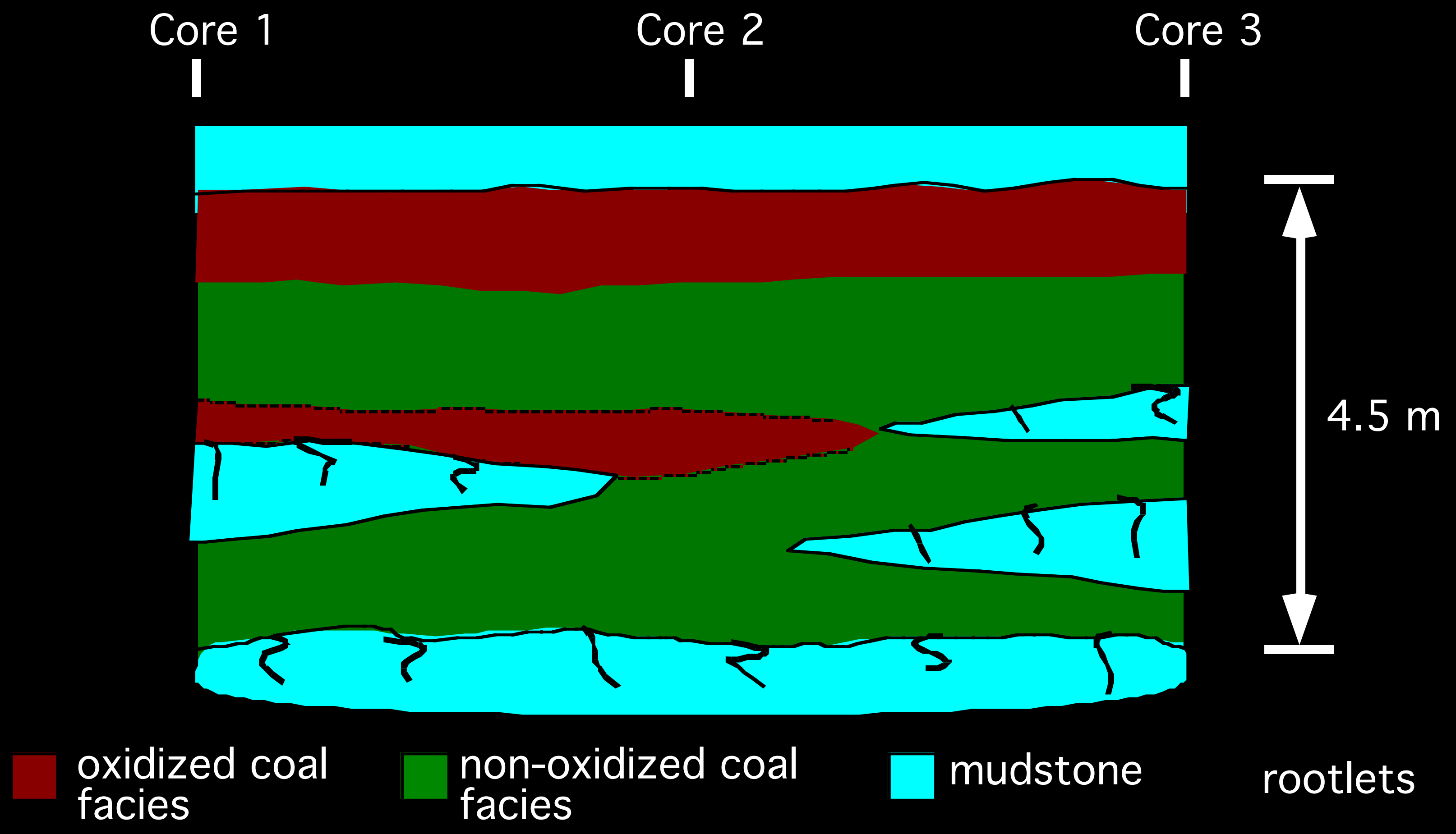
from Moore & Shearer, 1997

Palangkaraya Peat, Kalimantan Tengah



from Moore & Shearer, 1997

Anderson-Dietz coal seam, Wyoming, USA



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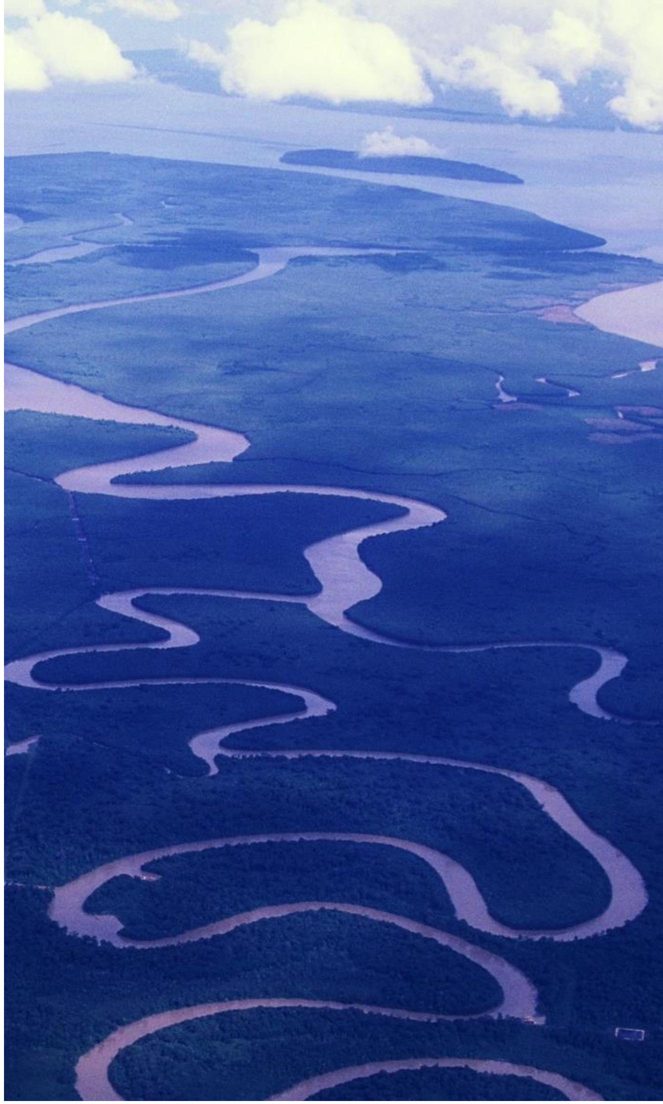


Environments Associated for Peat and thus Coal

Alluvial systems, including

•floodplains,

•alluvial plains,

•alluvial fans,

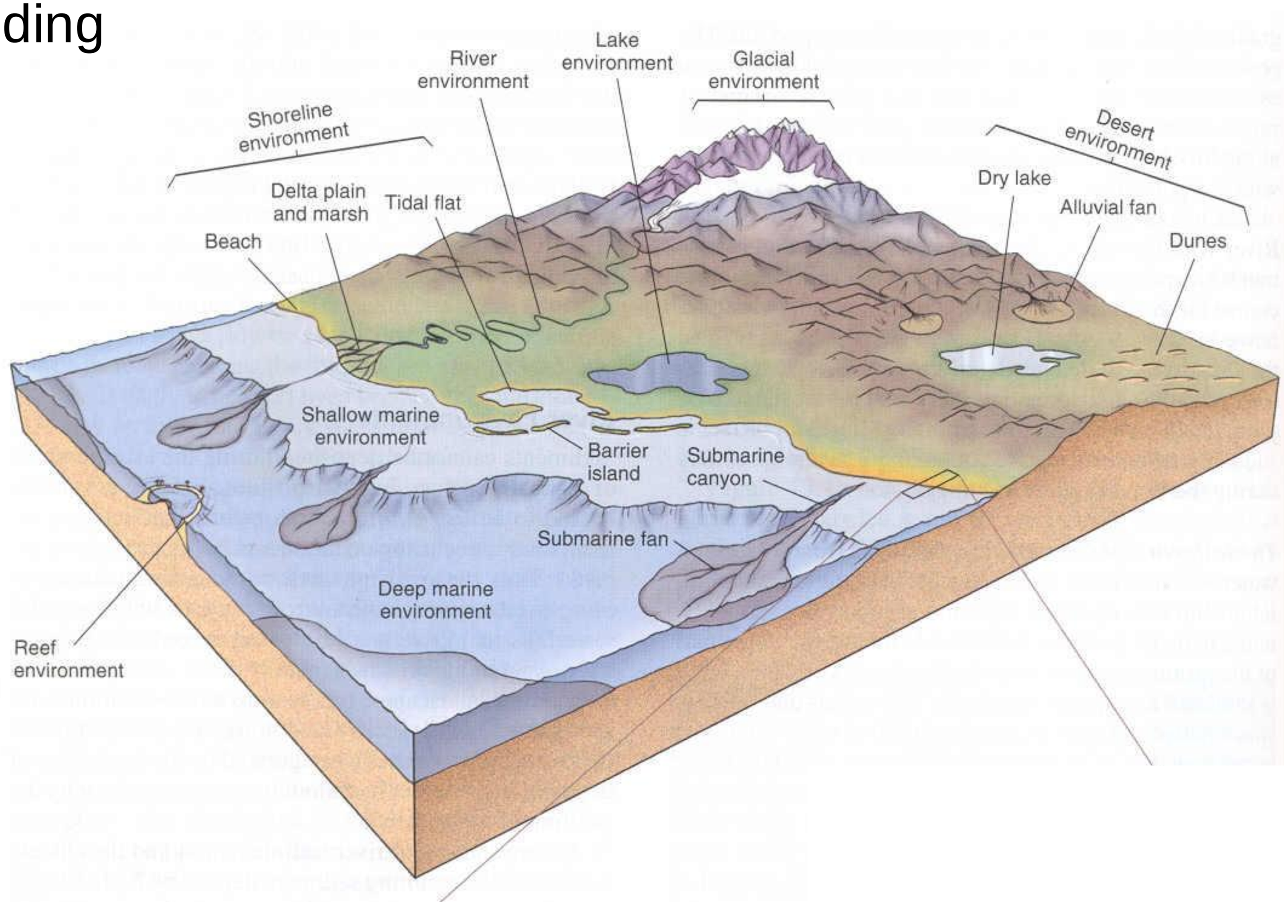
•terraces,

•levees,

•swamps,

•channels,

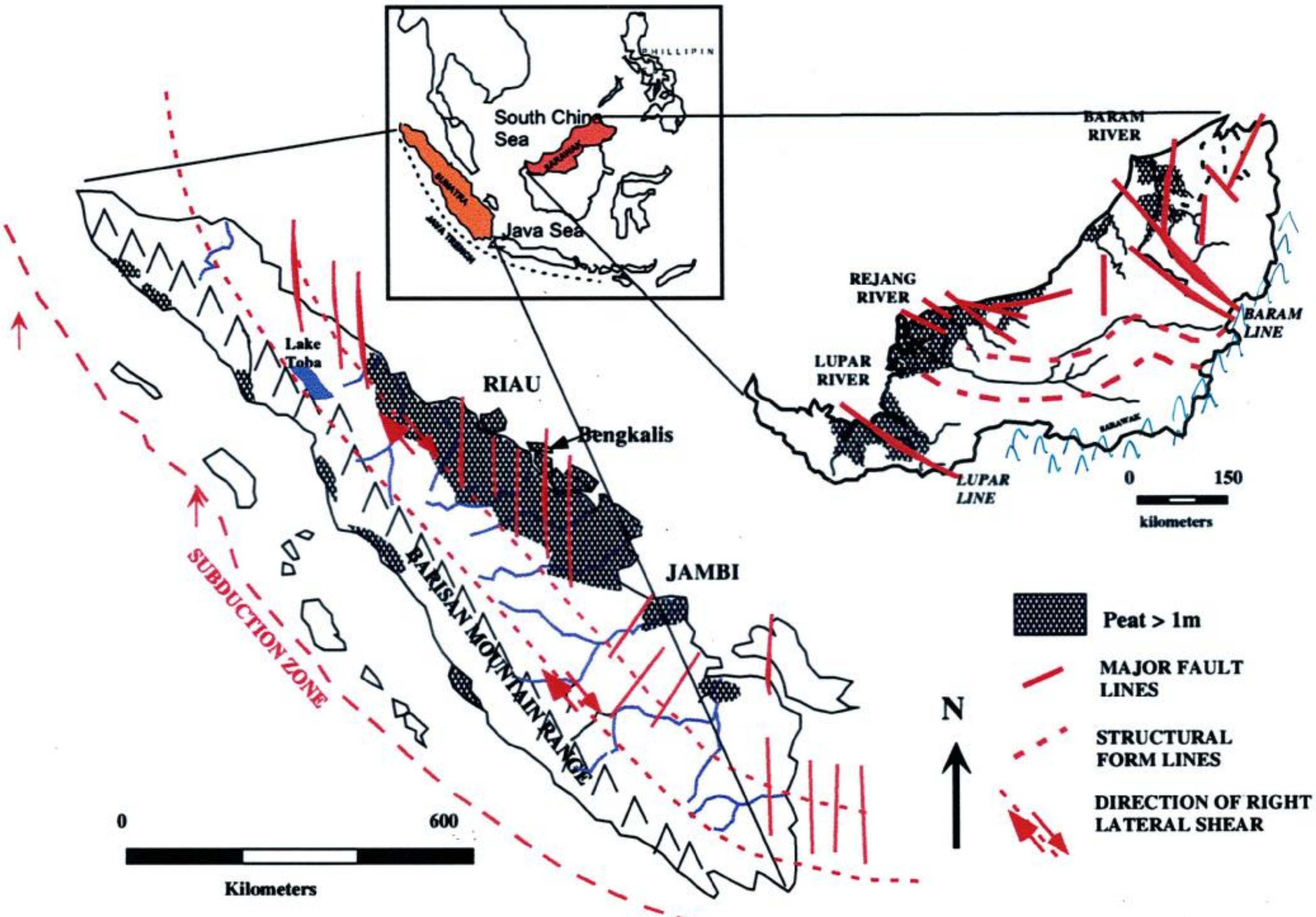
•closed depressions



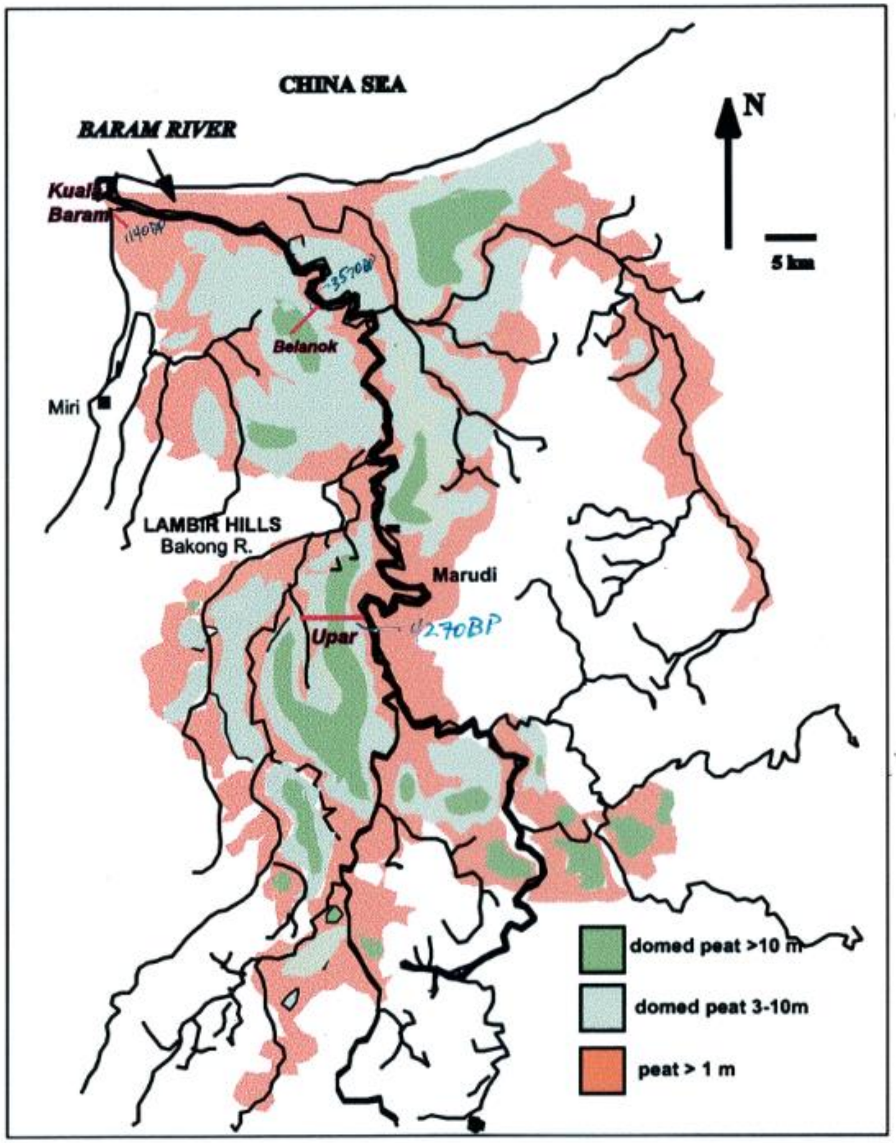
•inland lakes and associated dune systems (lunettes)

Excludes talus slopes, colluvial deposits and pediments.

Tropical Lowlands Examples
Regional variation in depositional settings



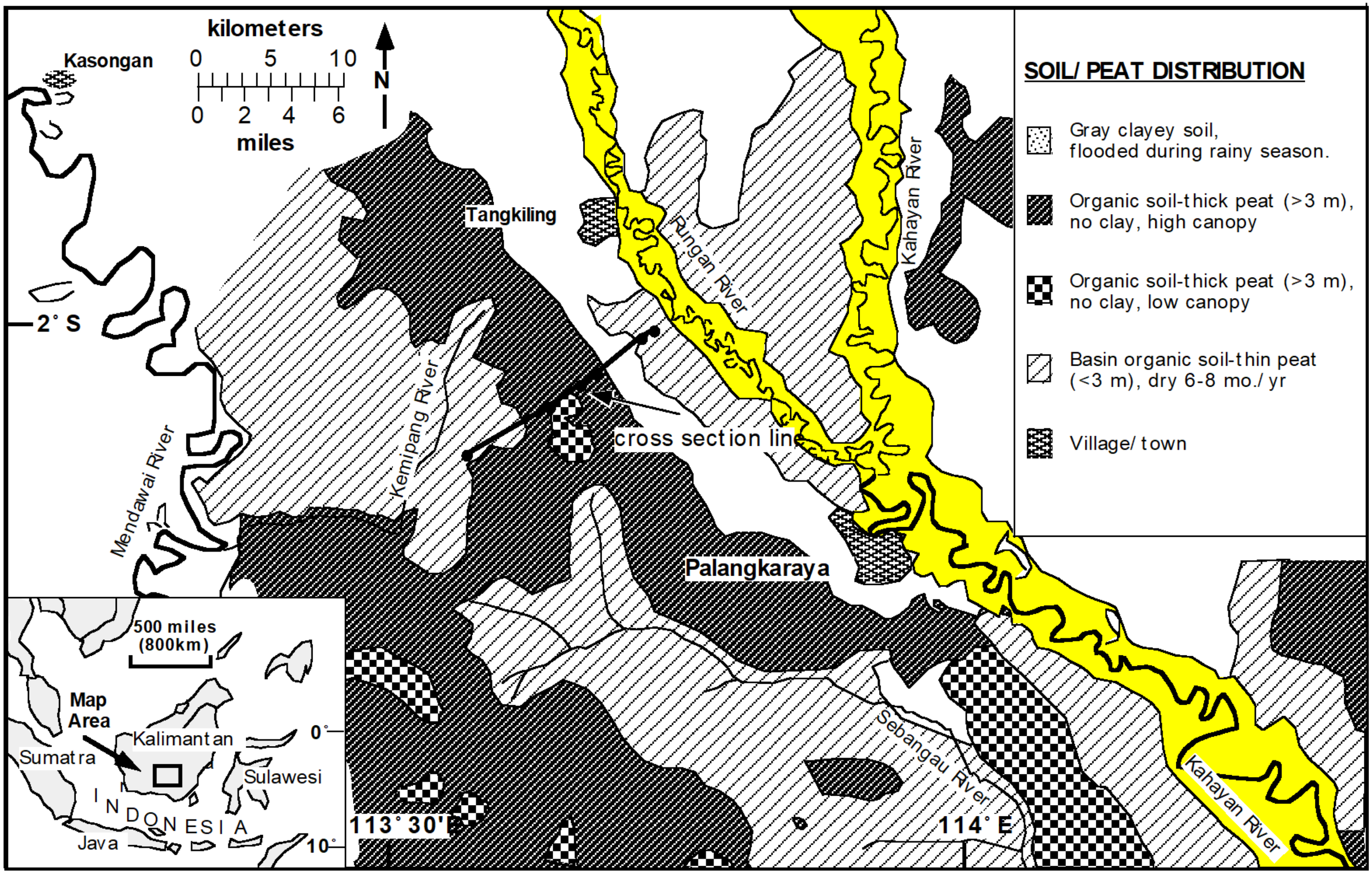
Sarawak Tropical Lowlands Example- Baram River
Local variation in peat vegetation and topography



After Anderson, 1964

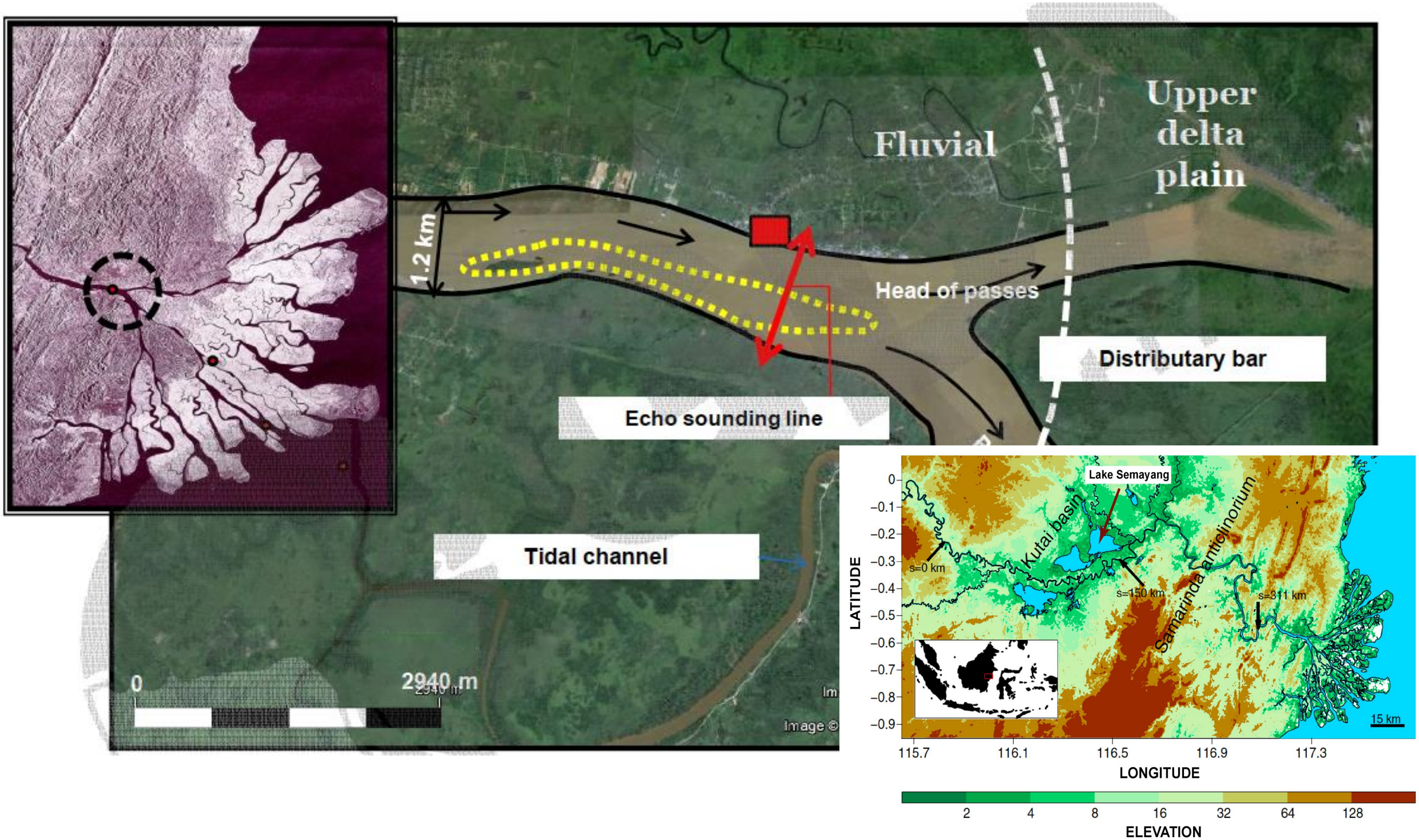
- River margins support luxuriant, high diversity forest growing on thin decomposed woody peat, and regularly flooded. *Decomposition outstrips biomass production.*
- Transitional "pole forest" of low diversity and acid tolerant ground cover on moderate to thick peat on slope of the dome. *Decomposition slows with increased acidity.*
- Central bog plain supports savannah like vegetation of pandanus, small shrubs and sparse thin trees, fed only by rain water. Peat is thick, acidic but nutrient deplete. *Preservation high but biomass production is low.*

Palangkaraya Peat, Kalimantan Tengah



from Moore & Shearer, 1997

MAHAKAM DELTAIC SYSTEM



NO peat accumulation here: too much sediment!

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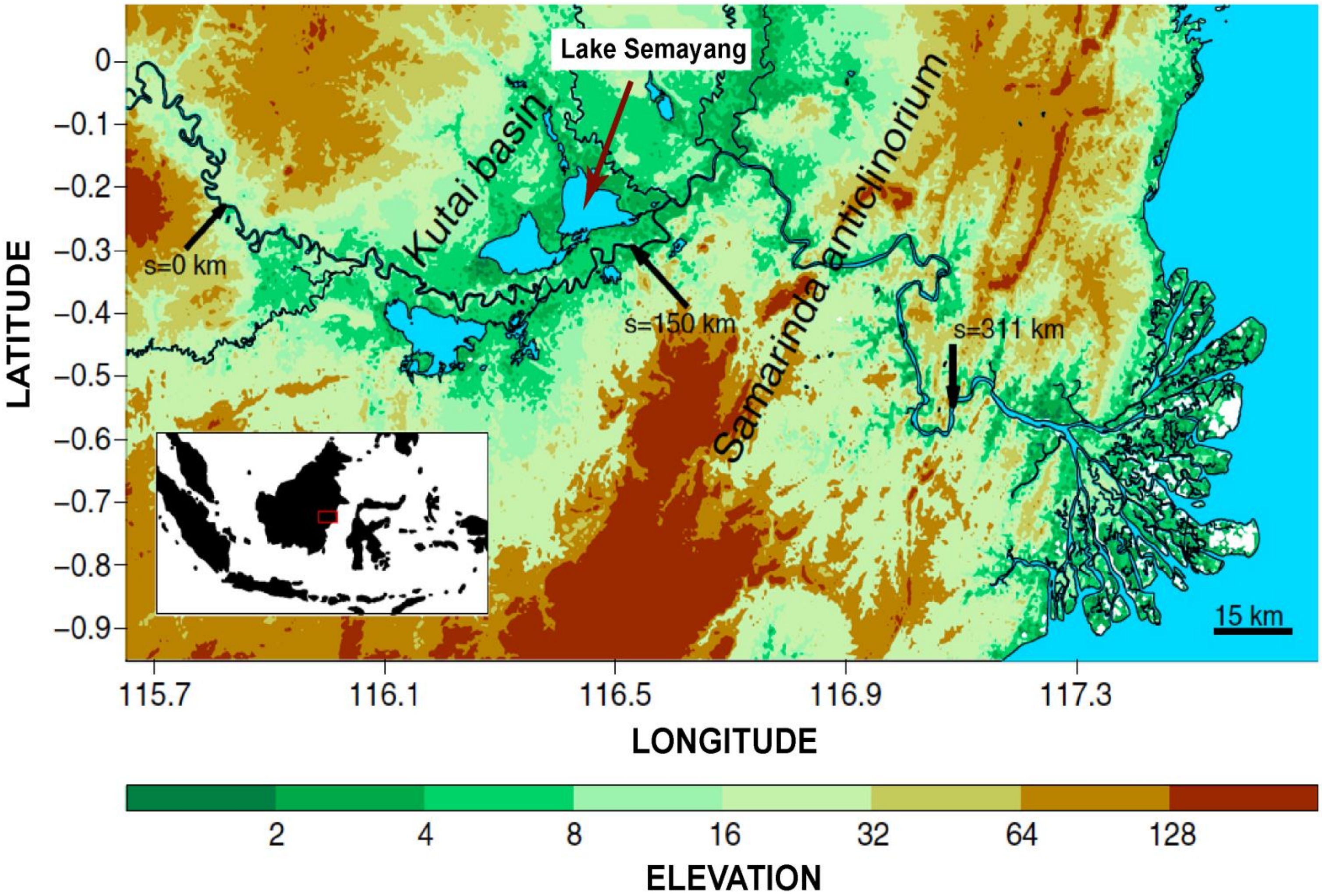
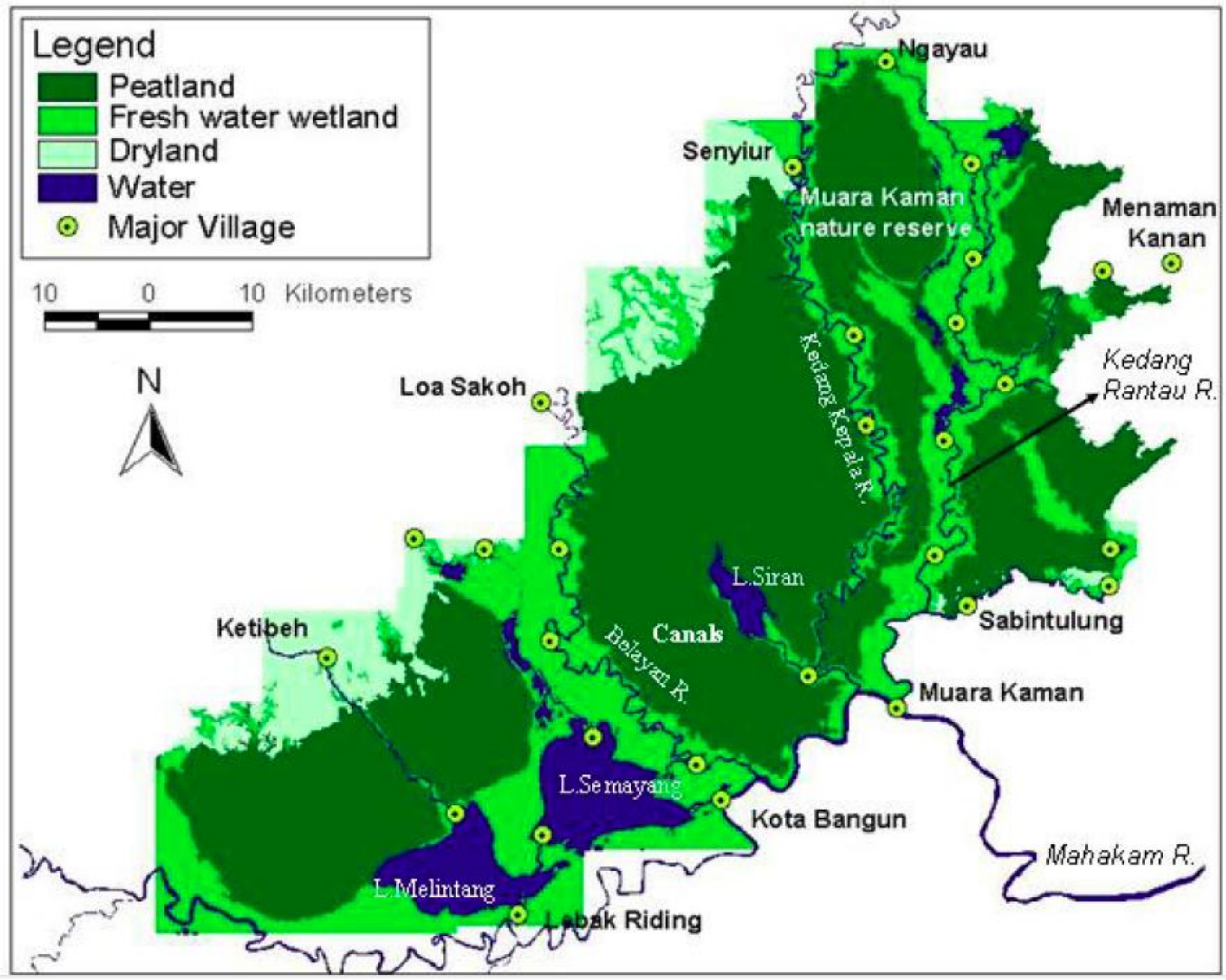
MAHAKAM LACUSTRINE-FLUVIAL-DELTAIC SYSTEM



2014

MAHAKAM LACUSTRINE SYSTEM



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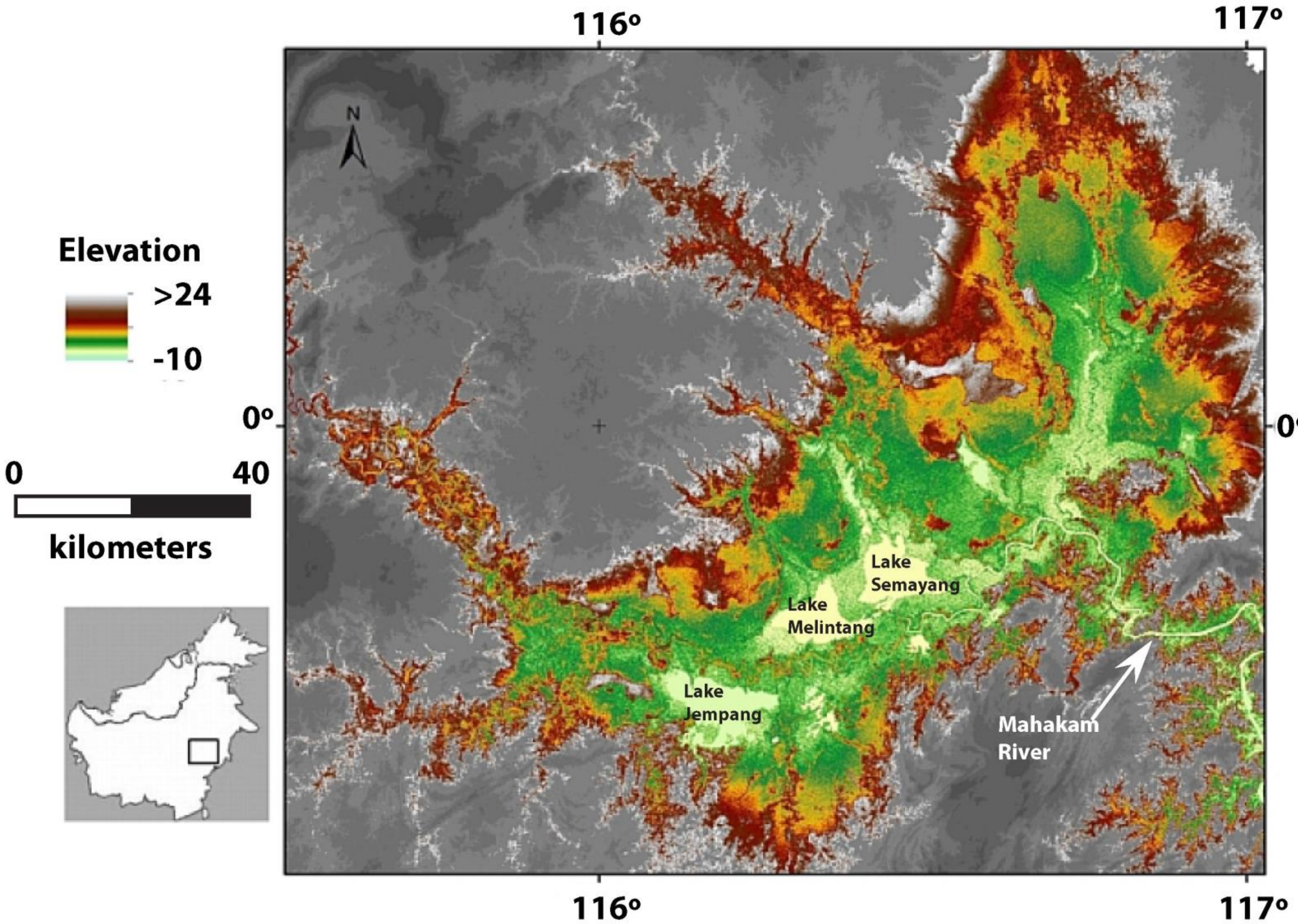
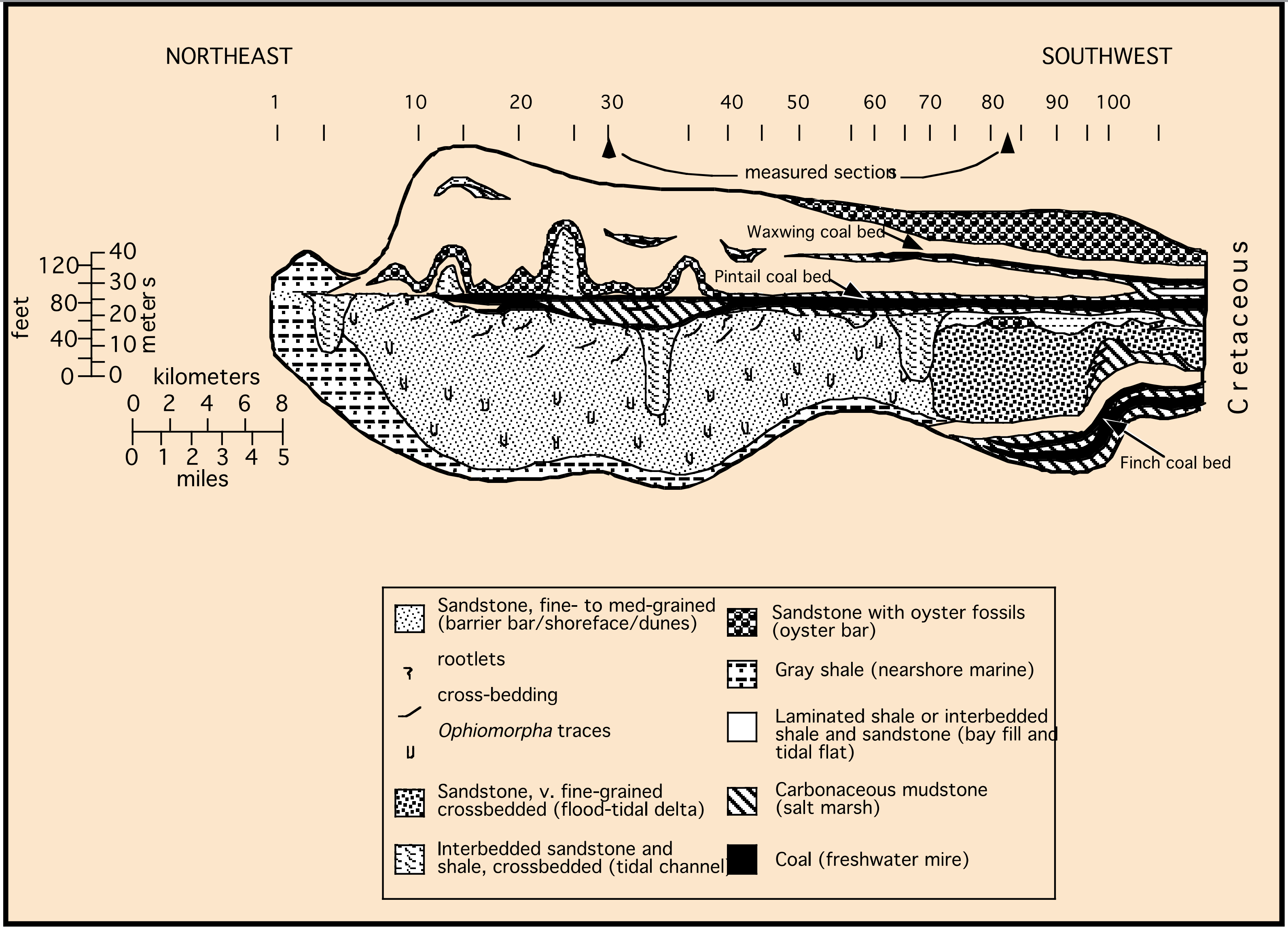
MAHAKAM LACUSTRINE SYSTEM

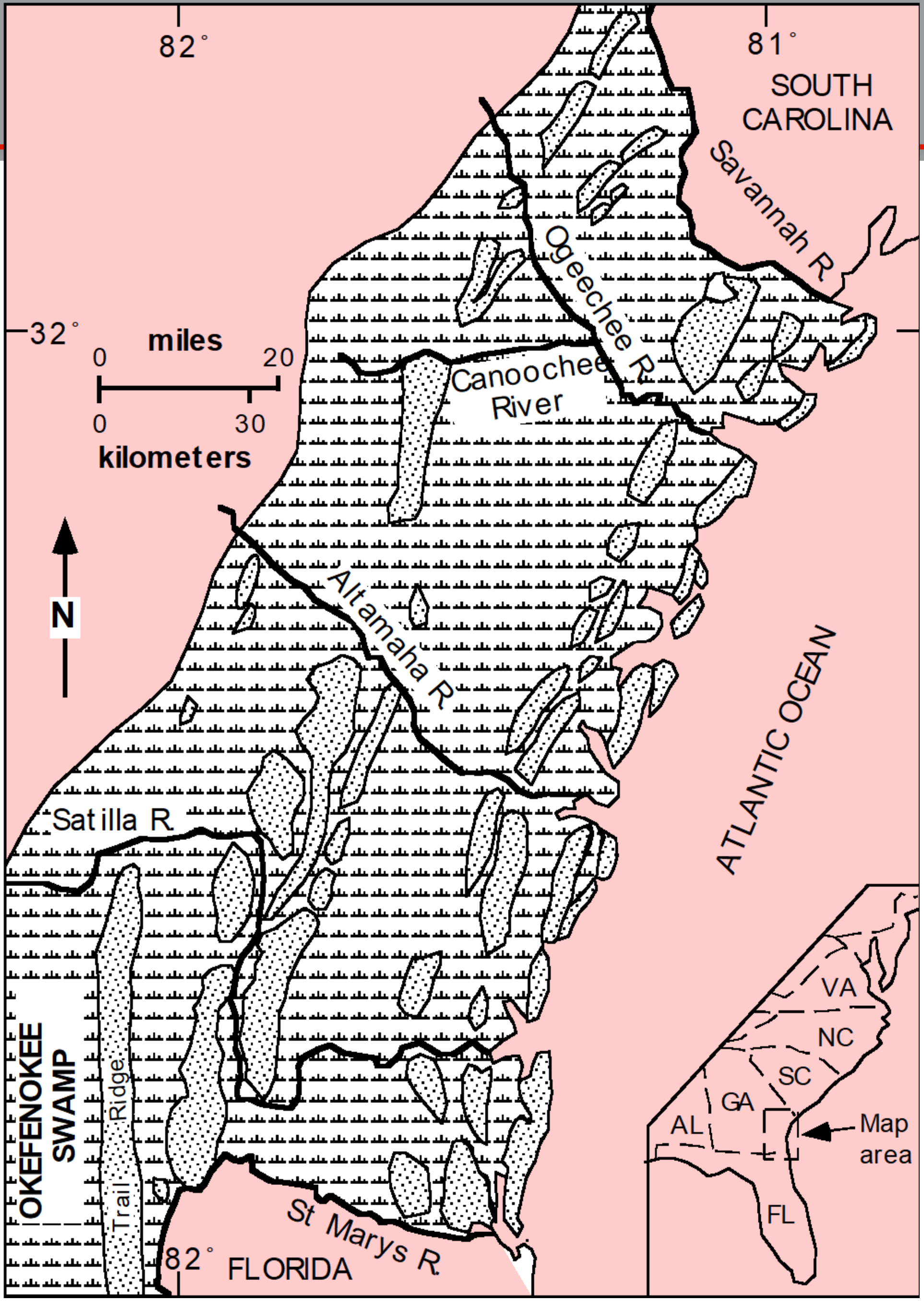


Coastal Plain, Cretaceous, Wyoming



(from Moore & Shearer, 1993)

Okefenokee peat bog, SE U.S.A.



(from Moore & Shearer, 1993)

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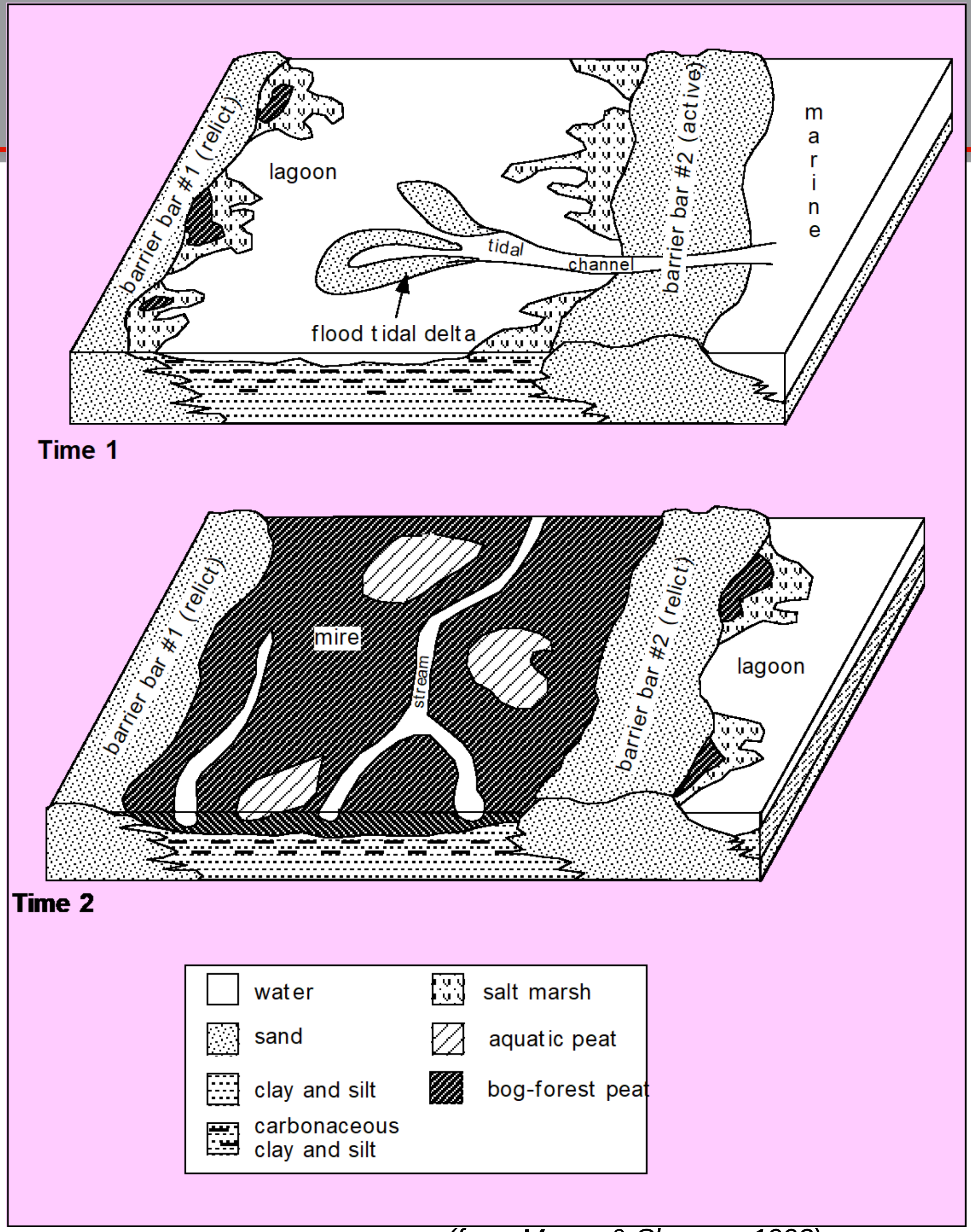
Model: Barrier Bar



(from Moore & Shearer, 1993)

“moat swamp” behind the levee

Marginal “big tree” forested peat (has been logged)

Transition to *Shorea albida* ‘pole forest’ as peat thickens and substrate becomes nutrient deplete and acidic

Pandanus, stunted trees, shrubs and mosses growing on thick, nutrient deplete and acidic peat in central bog plain

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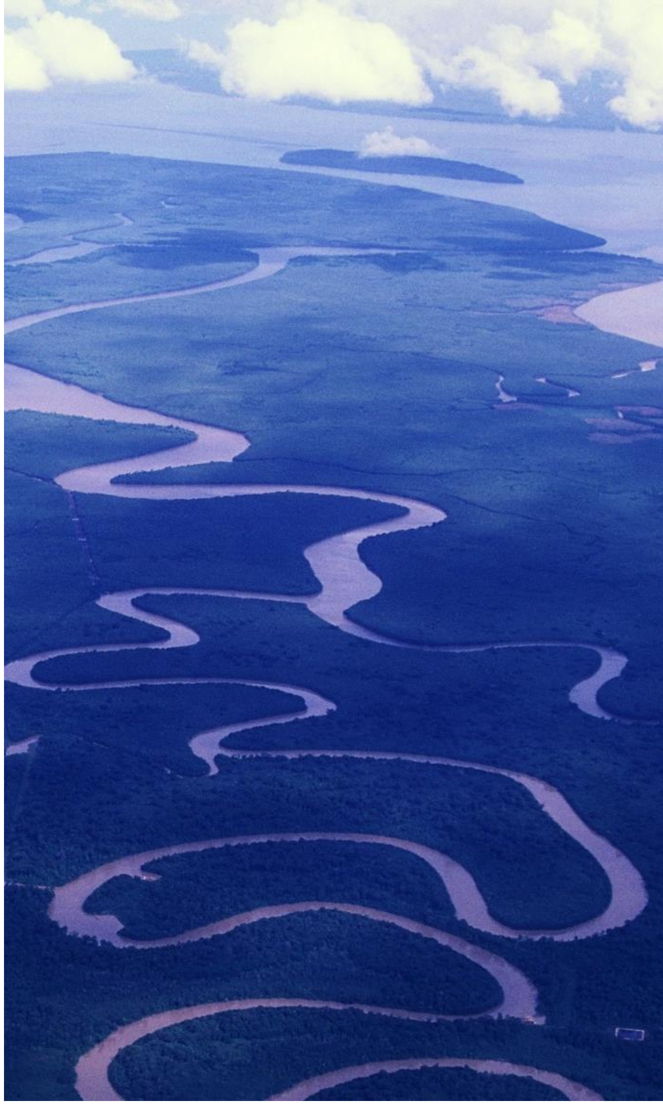
- **Relevance to Coal**



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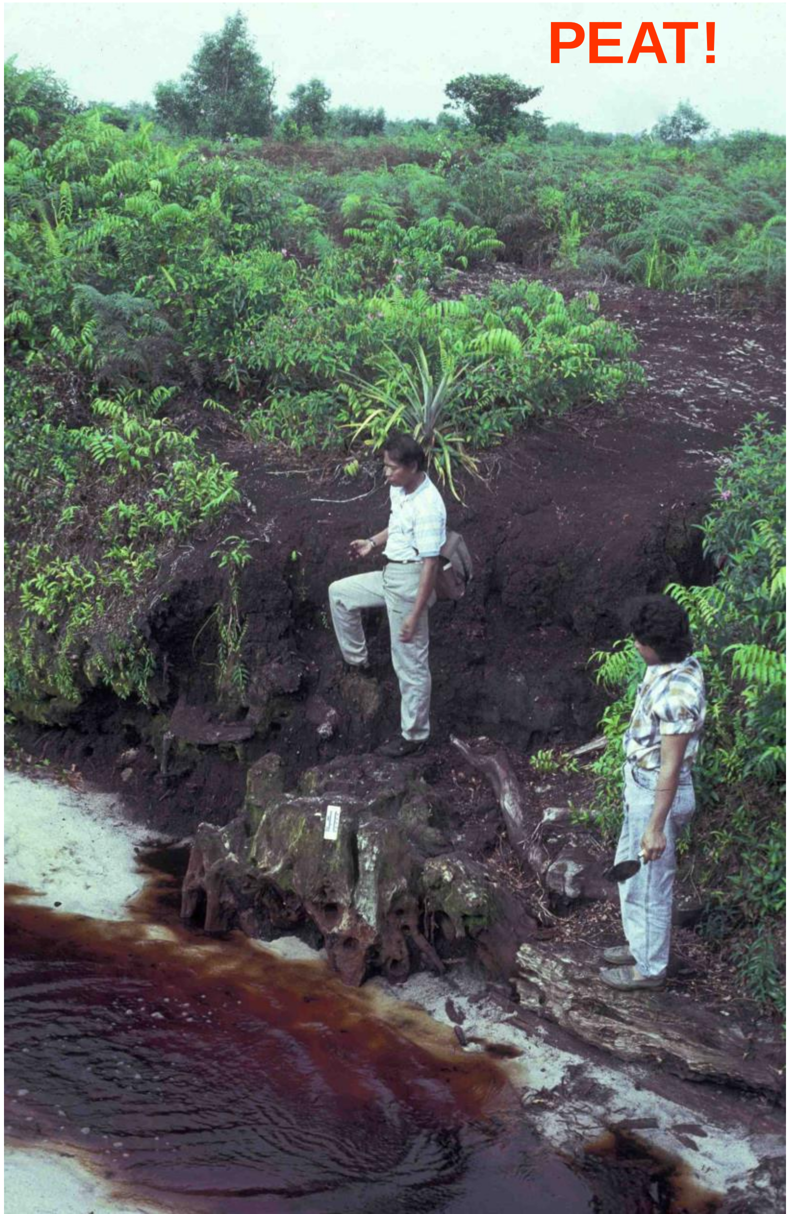
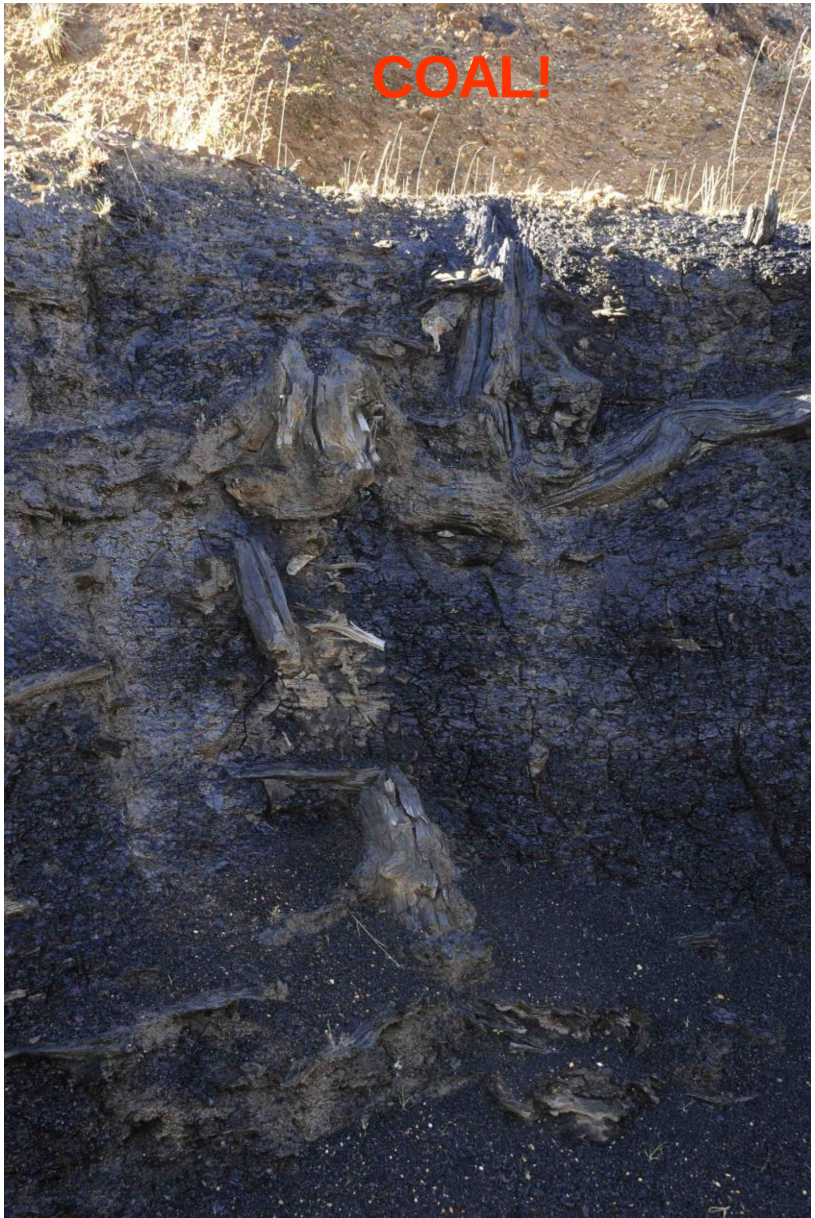
Peat types

-organic rich clay
-high ash sapric
-sapric
-hemic (woody)
-fibric

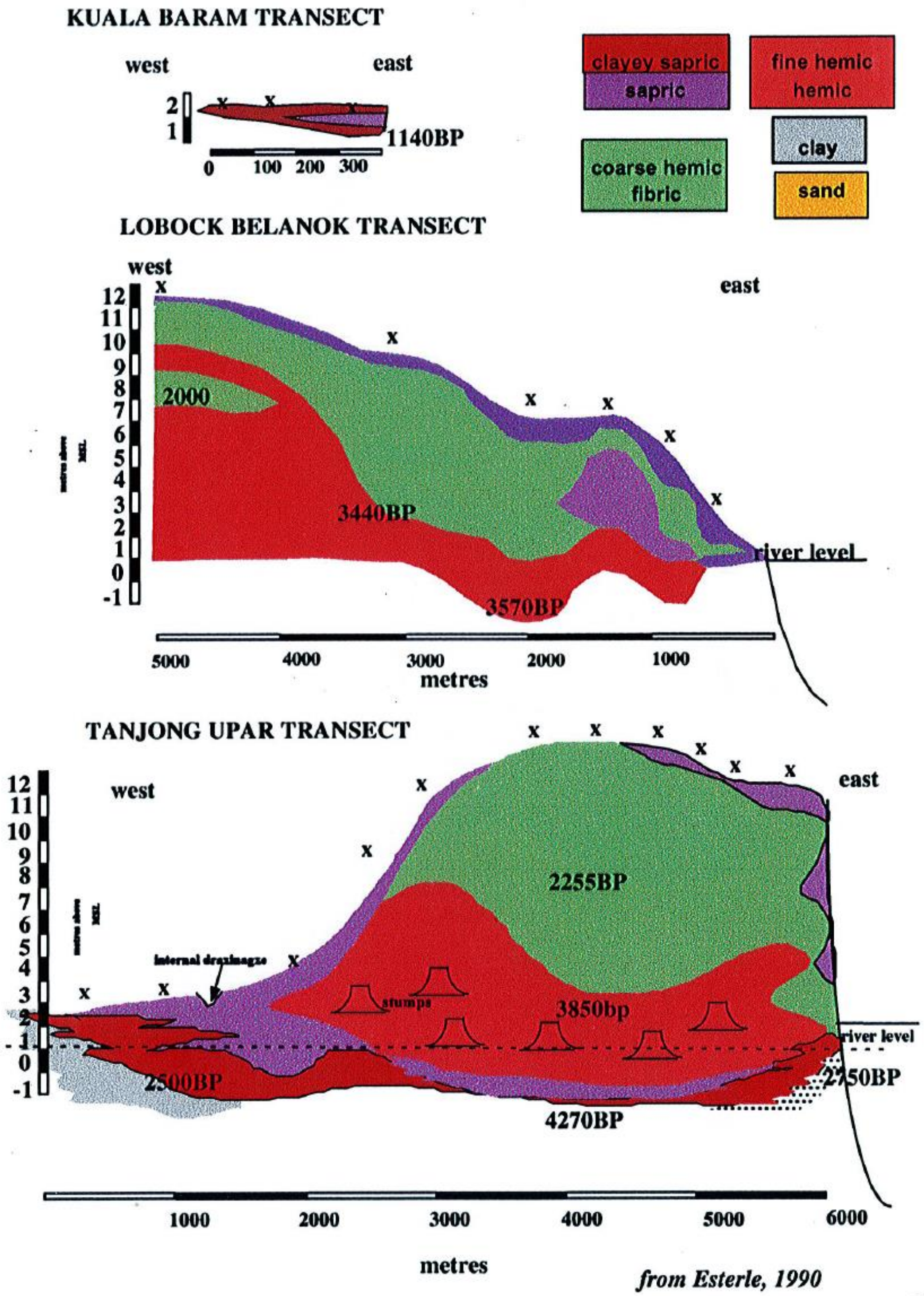
Change in degree of decomposition and grain size

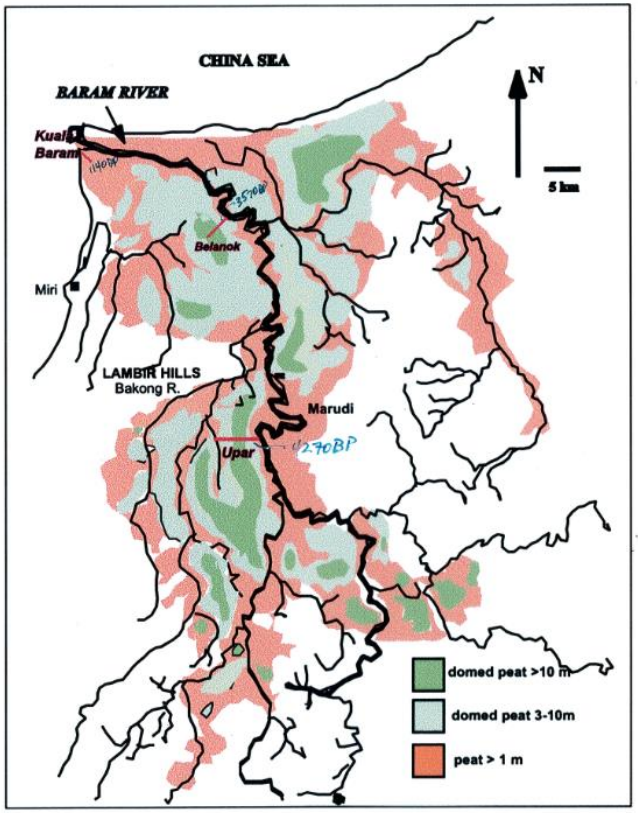
Base of Peat in Kalimantan Tengah, Indonesia,
Lignite in Southland, New Zealand – which is which??





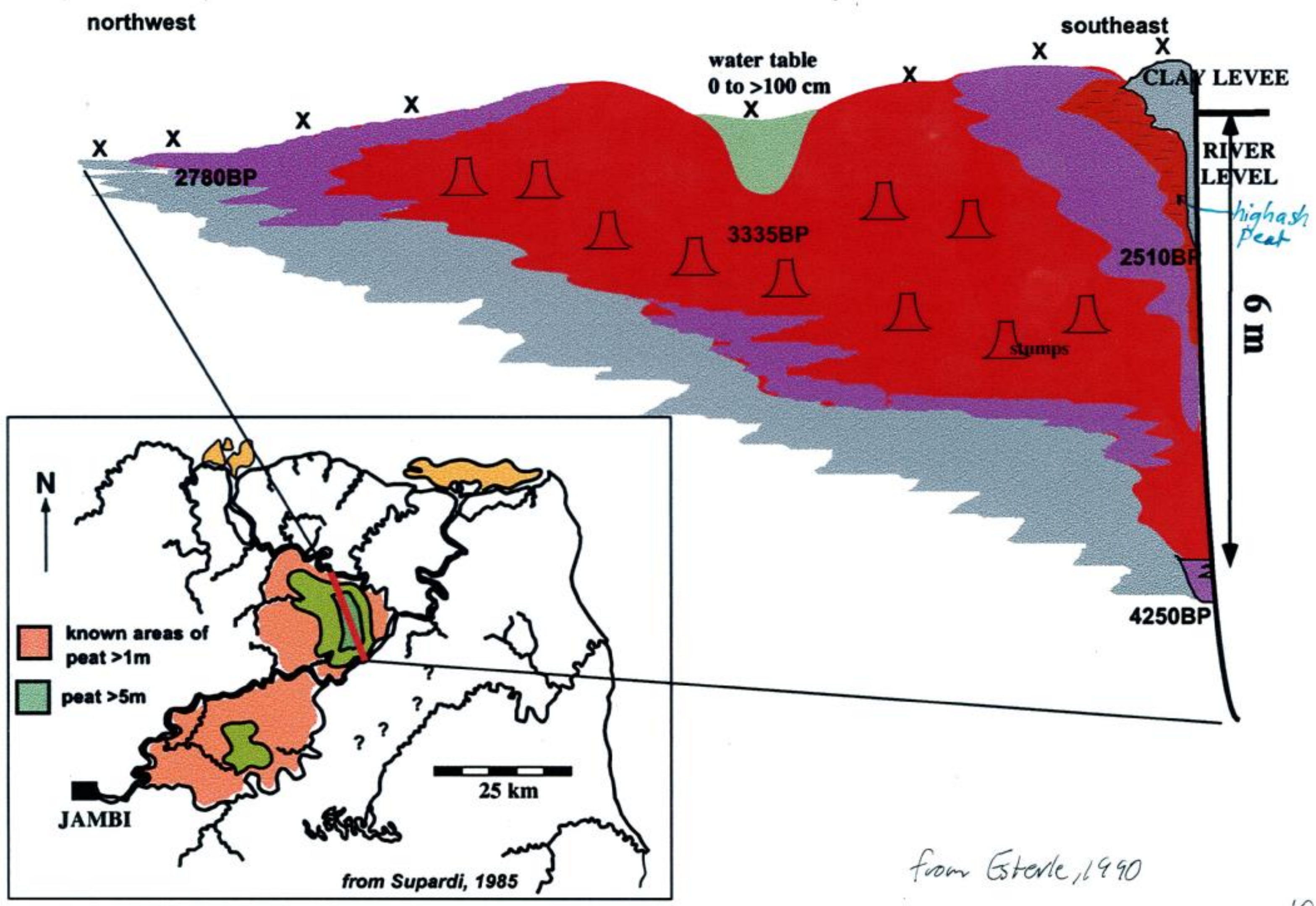
Cross sections through peat domes





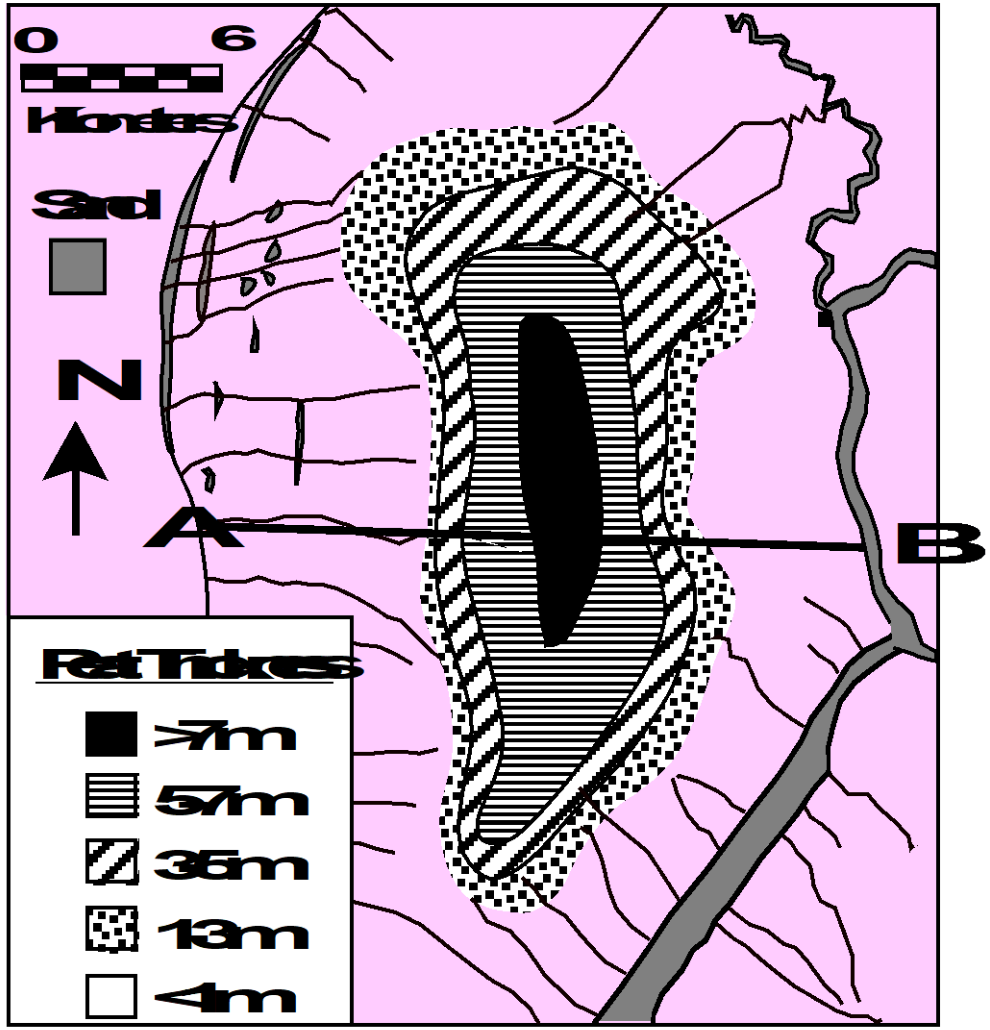
- Young towards the coast
- Young from centre to margin
- Accumulation 2mm – 4mm pA
- Ash yield varies
- Sulphur content varies

South Sumatra- Jambi Peat "dome" with topogenous character



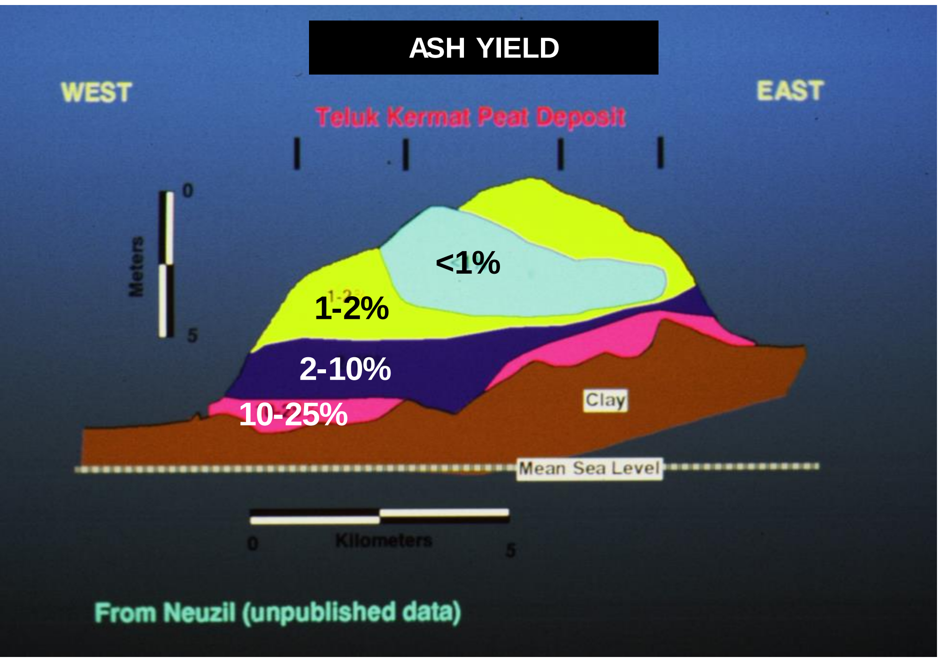
from Esterle, 1990

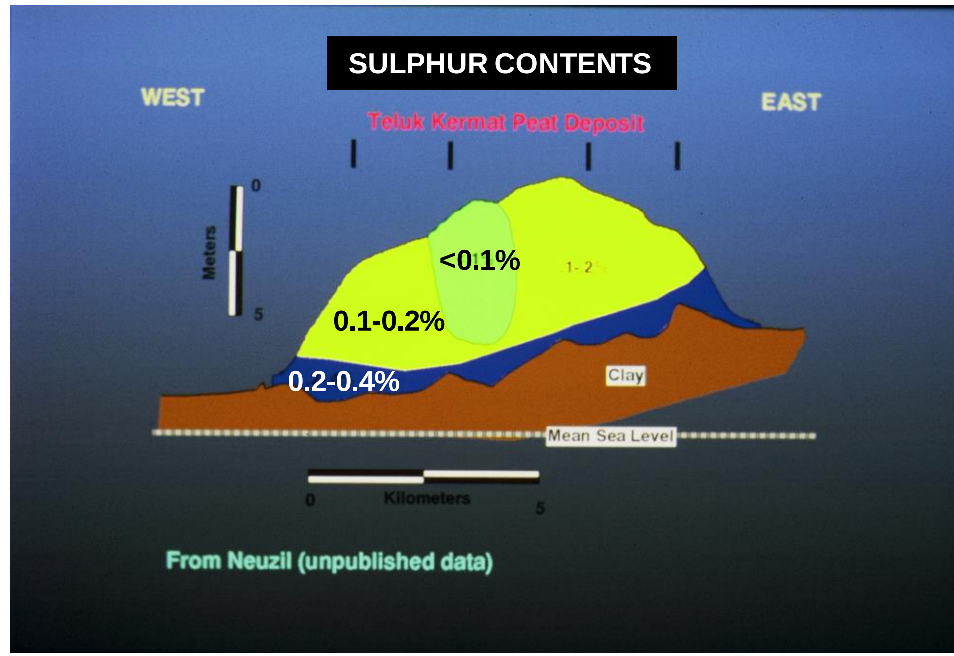
Peat Mire: Indonesia [Kalimantan Barat]



from Moore & Hilbert, 1992

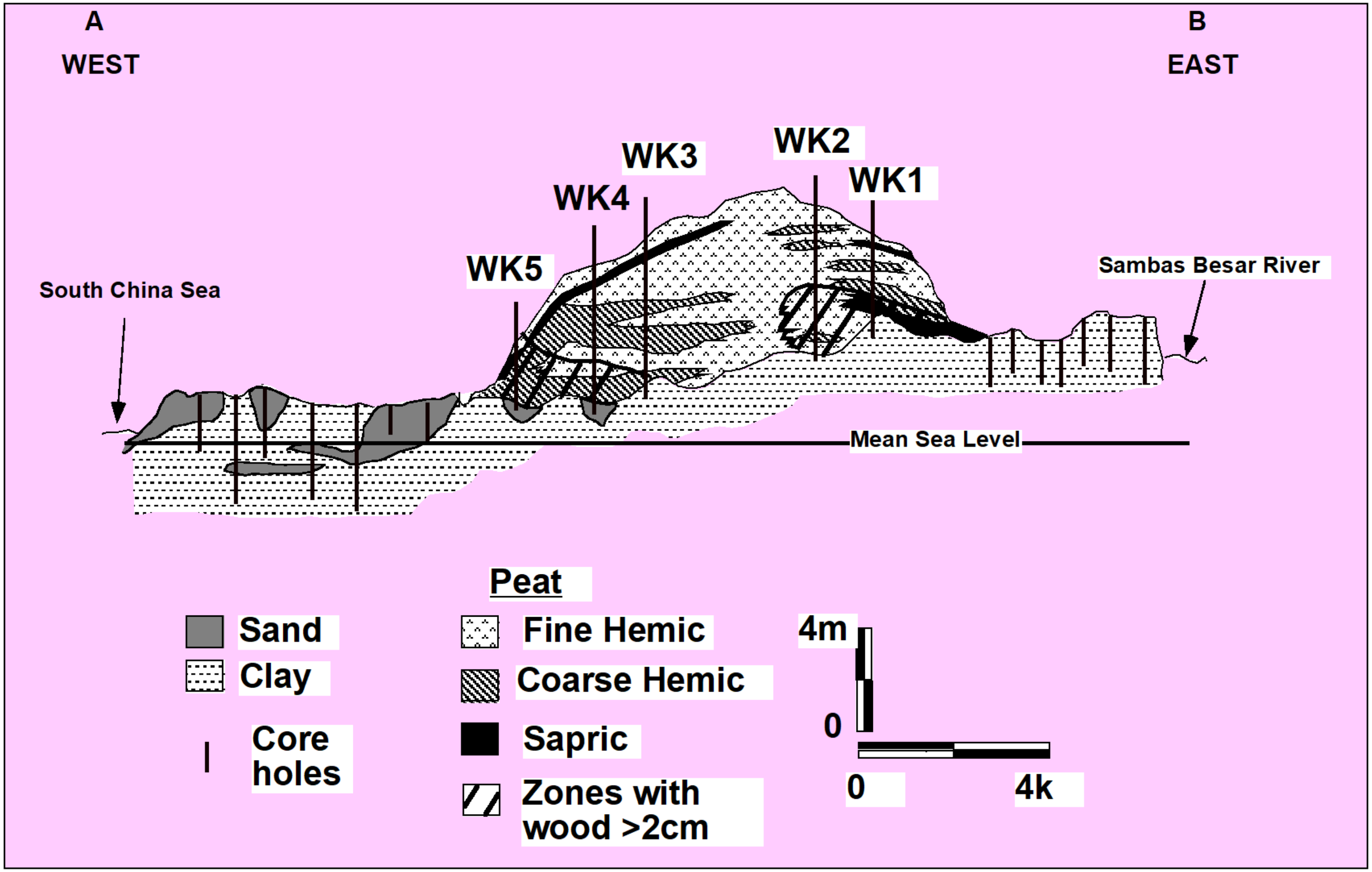
Ombrogenous peats/coals have very little mineral matter





Ash yields decrease rapidly from the base to <1%

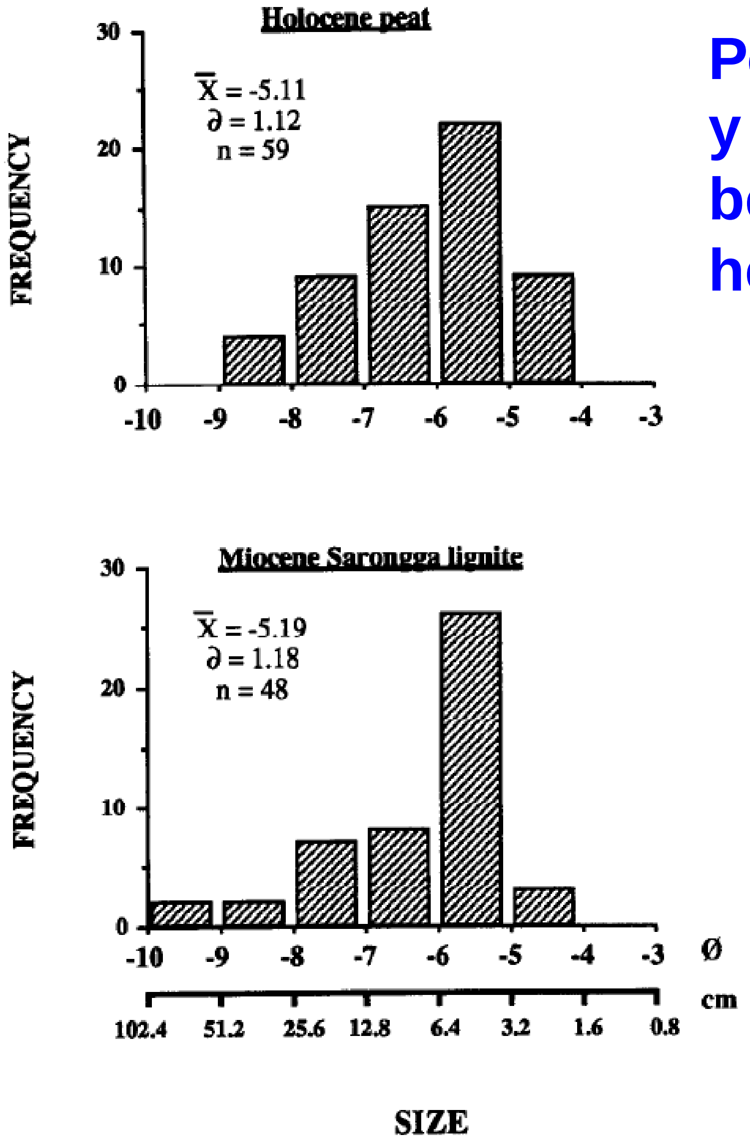
Cross section of peat mire: Kalimantan Barat



from Moore & Hilbert, 1992

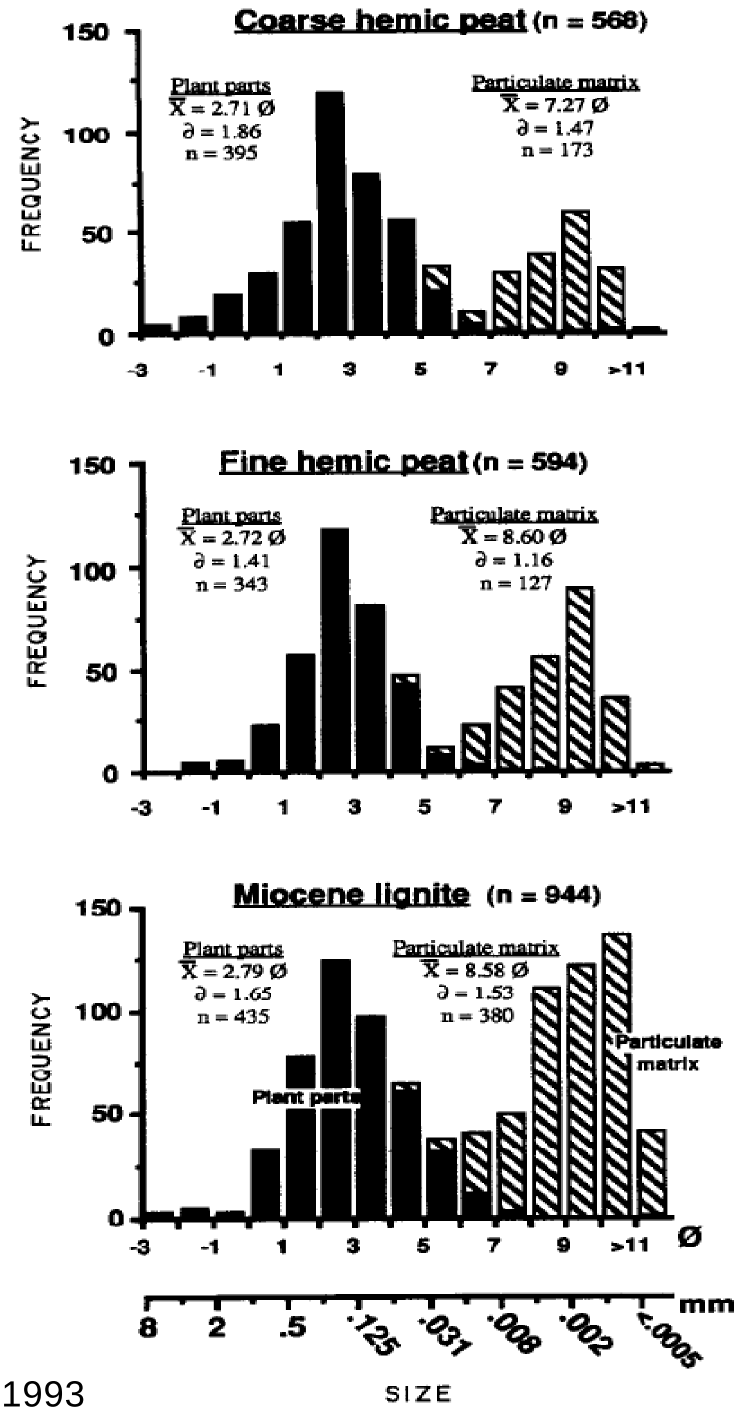
Similar texture and botanical composition between peat and coal in Indonesia

macroscopic



Porosity begins here!

microscopic



Demchuck and Moore, 1993

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Brown Coal Lithotypes

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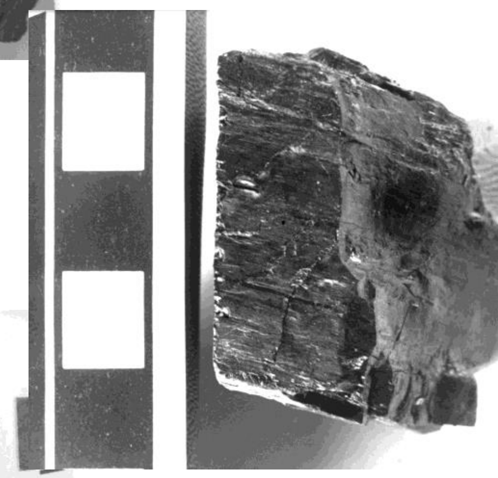
Brown Coal- the next phase

Peat Types can be followed directly into Coal Types

Bright, nonbanded

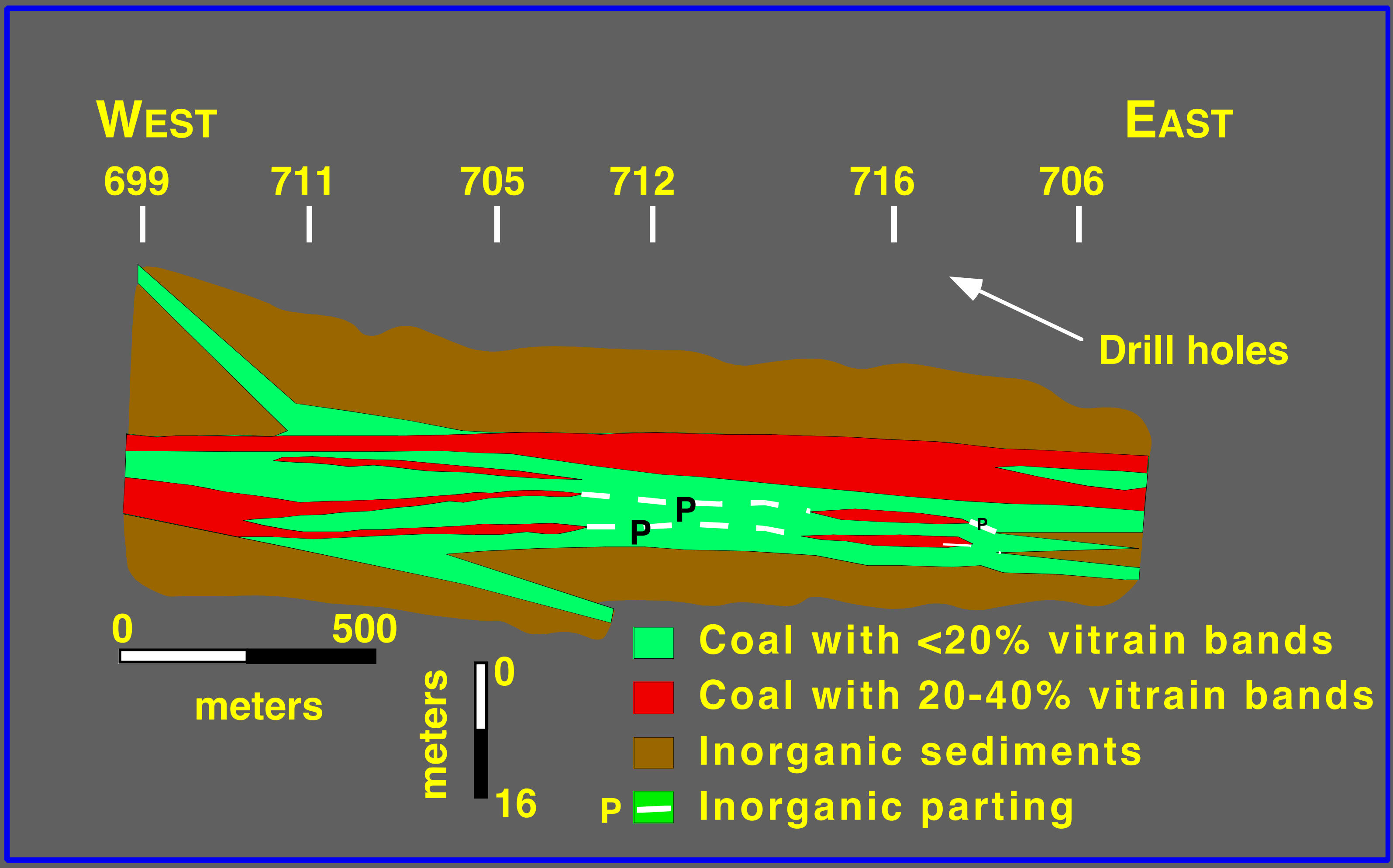
Bright, <20% banded



Bright, >20% banded

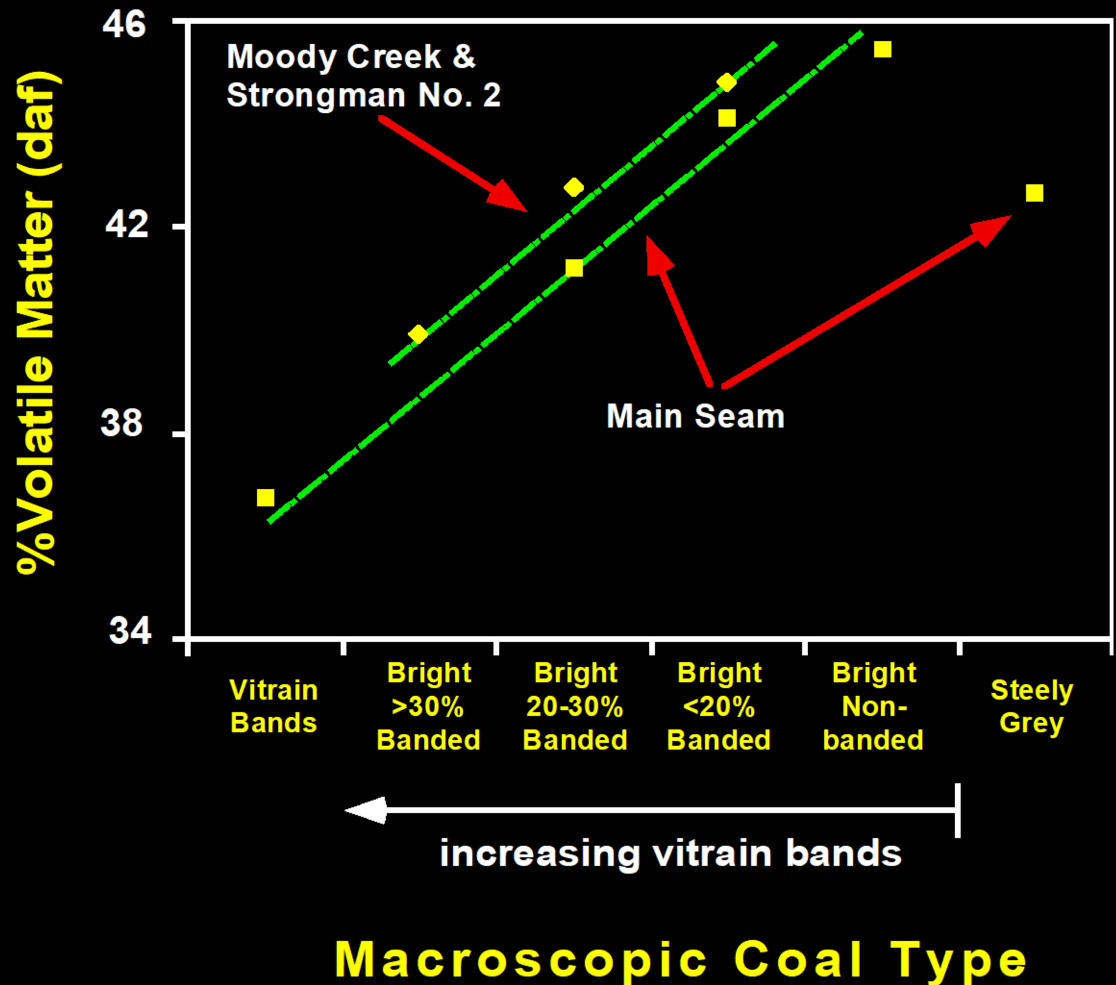
Permeability is closely related to both coal type and rank

PEAT TYPES ARE CARRIED OVER INTO COAL TYPES

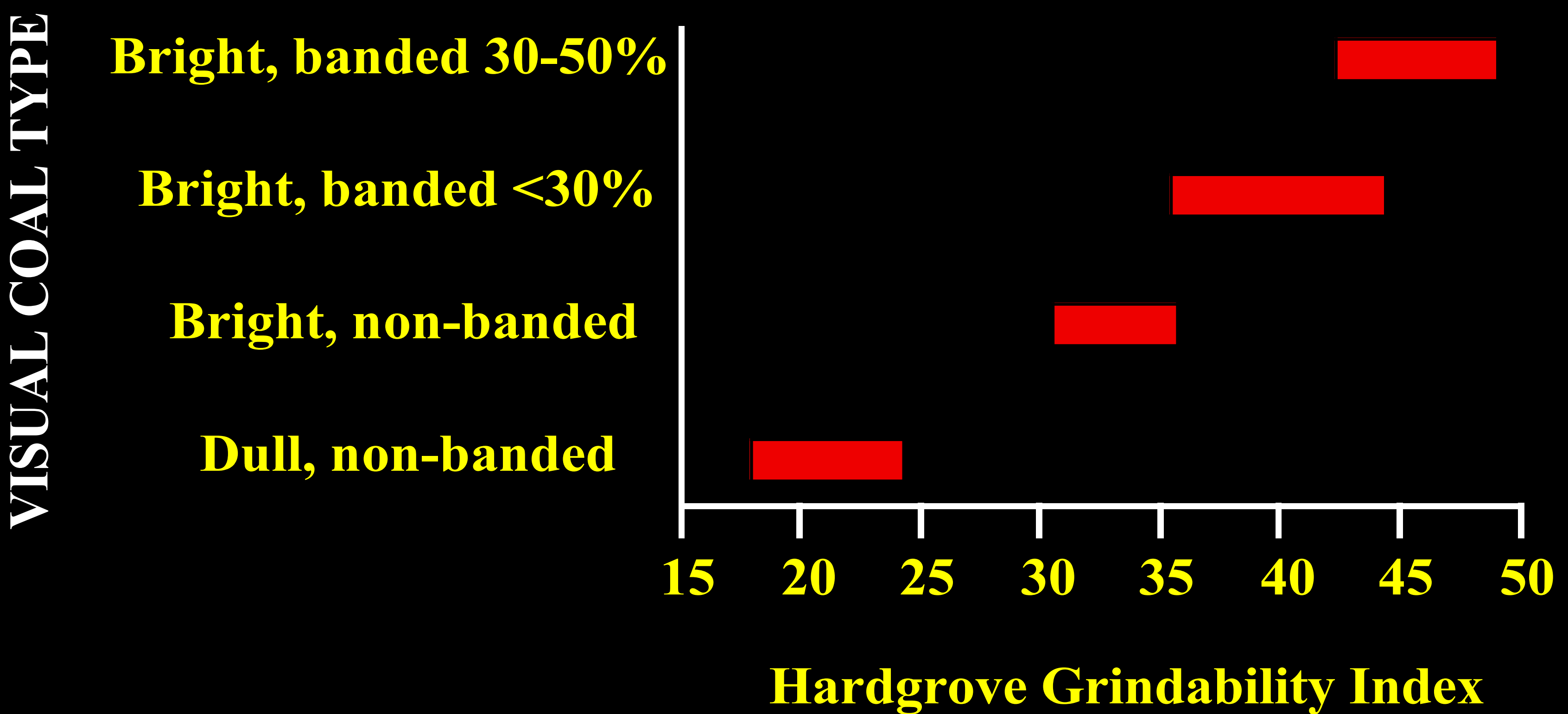


from Moore et al., 2005

COAL TYPE VS VOLATIVE MATTER



HGI vs Coal Type



SUMMARY

1. **Peat forms in very specific environments that:**
   - Are shielded from clastic sediments
   - Have moderate subsidence rates
   - Have low pH
   - Are in climates that are ‘ever wet’ (rains all year round)

2. **Thick peat forms as ombrotropic bogs**

3. **Peat forms in a variety of depositional settings (ALL non-marine: NEVER marine!)**

4. **Peat can be composed of a number of peat types**

5. **These peat types translate directly into coal types**

6. **Coal type is a major control on coal properties, such as porosity and permeability**

Selected Recommended Reading

Anggara, F., Muchitawati, G.S., Moore, T.A., Septantia, A., 2021. Spatial variability in macro- and micro-texture of a tropical intermontaine peatland: Preliminary investigation into the Kutai Lakes peat system, East Kalimantan (Borneo), Indonesia. Indonesian Journal on Geoscience, 8, 275-296.

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