University of Waterloo

Wetlands and Soils, Peat and Peatland Development

Excavating peat by hand, St. Ulric, QC, 1940s

EARTH 444

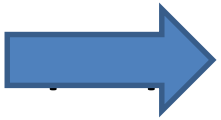
BIOLOGY 462

B.G. Warner

Properties of Wetland Soils

- Those areas/zones of biogeochemical activity where plants, animals, & microorganisms interact with water cycle
- Contain both mineral and organic matter
- Water-filled and air-filled pore spaces

Soils:
Properties of Hydric Soils

- Represent the zone of biogeochemical activity where plants, animals, & microorganisms interact with water cycle
- Contain both mineral and organic matter
- Water-filled and air-filled pore space 

WETLAND FORMATION

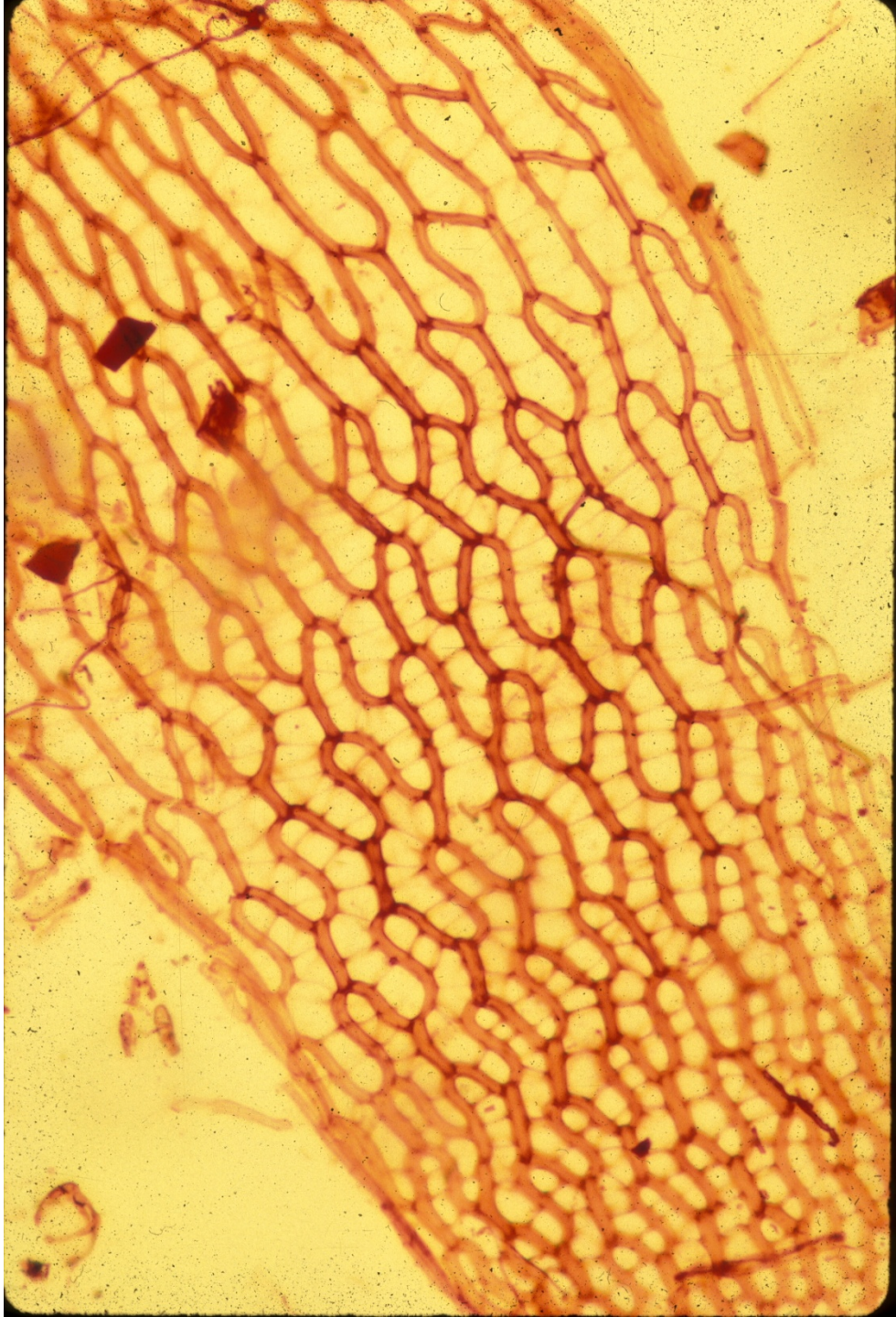
(Taken from: http://www/wetlands resources.net)

Field Indicators of Hydric Soils (from US Army Corp of Engineers 1989)

- Organic soils: more than 50% of upper 50 cm or so is organic
- Histic epipedon: surface 40 cm is saturated for at least 30 days/year
- Sulfides: rotten egg smell
- Reducing soil regime
- α-α-dipyridil indicator ferrous iron test
- Gleyed conditions: low-chroma/mottled soils
- Iron and manganese oxide concretions: black or brown

Wetland soil showing mottling

(Courtesy: Ministry of Natural Resour



Peat properties

- Botanical composition
  - moss
  - herbaceous
  - wood
  - detrital/humified peat
- State of decomposition
  - Von Post H-scale
  - Colour of squeezed water
- Organic matter content
  - Estimate organic versus inorganic content by ignition (% fresh wt)
  - C content: for Cdn peat: 45-50% of organics is carbon
- Bulk density = mass/vol.; inverse to porosity = vol. of pores/vol.
  - High BD = high mineral content, high decomposition
  - Low BD = low mineral content, low decomposition

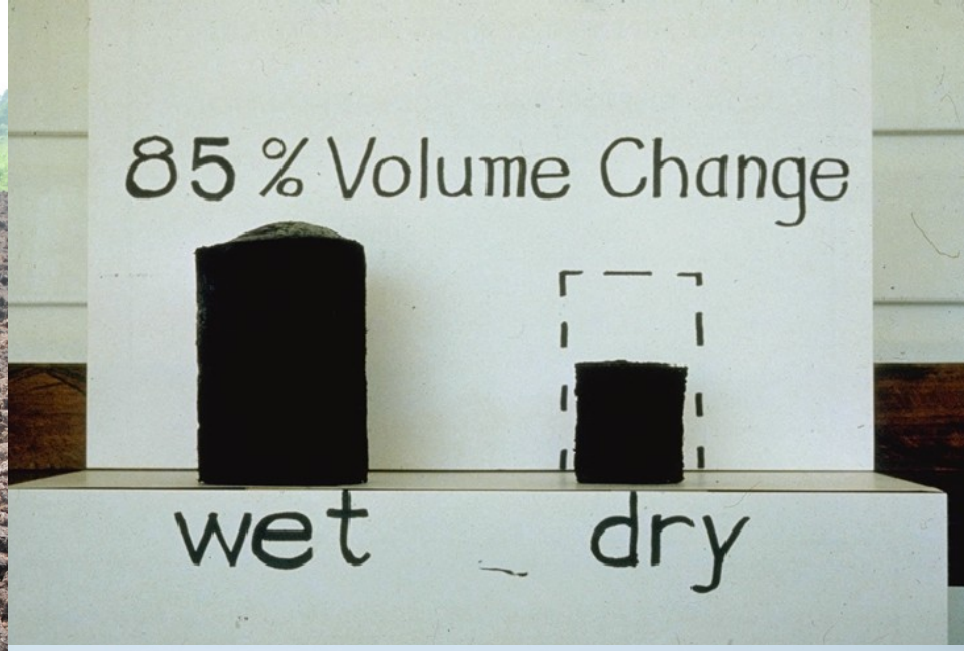
What is peat?

- partially-decomposed remains of plants (mostly) and animals that forms and accumulates *in situ* under water-logged oxygen-poor conditions
- as a material from peatlands: $\sim >$ 65% organic matter and $<$ 20-35% inorganic matter (dry wt)
- as a soil from intact peatlands: 88-97% water, 2-10% dry matter, and 1-7% gas

von Post scale

(Taken from Quinty & Rochefort 2004)

Degree of decomposition	Nature of water expressed on pressing	Squeeze test	Nature of plant residues	Description
H1	Clear, colourless	Very spongy Springs back after pressure Holds no shape No peat extruded between fingers	Living layer	Undecomposed
H2	Almost clear, brown-yellow	Spongy Springs back after pressure Holds almost no shape No peat extruded between fingers	Almost unaltered Entire structure	Almost undecomposed
H3	Slightly turbid, yellow-brown	Slightly spongy Holds a fairly definite form of handprint with rounded edge No peat extruded between fingers	Most remains easily identifiable but breaking into piece	Very slightly decomposed
H4	Turbid, brown	Not spongy Forms a distinct replica of handprint No peat extruded between fingers Very slightly soapy	Most remains identifiable	Slightly decomposed
H5	Strongly turbid, contains mixture of plant debris and amorphous material	Very little peat extruded between fingers Slightly soapy	Bulk of remains difficult to identify Some amorphous material present	Moderately well decomposed
H6	Muddy, much peat in suspension	One third of sample extruded between fingers Soapy	Bulk of remains unidentifiable Nearly half sample in amorphous state	Well decomposed
H7	Very small amount, strongly muddy	Half of sample extruded between fingers Somewhat pasty	Relatively few remains identifiable	Strongly decomposed
H8	Thick mud, little or no free water	Two thirds of sample extruded between fingers Pasty	Only resistant roots, fibres and bark identifiable	Very strongly decomposed
H9	No free water	Almost all sample escapes the hand Pudding-like	Practically no identifiable remains	Almost completely decomposed
H10	No free water	All sample escapes the hand	Completely amorphous	Completely decomposed

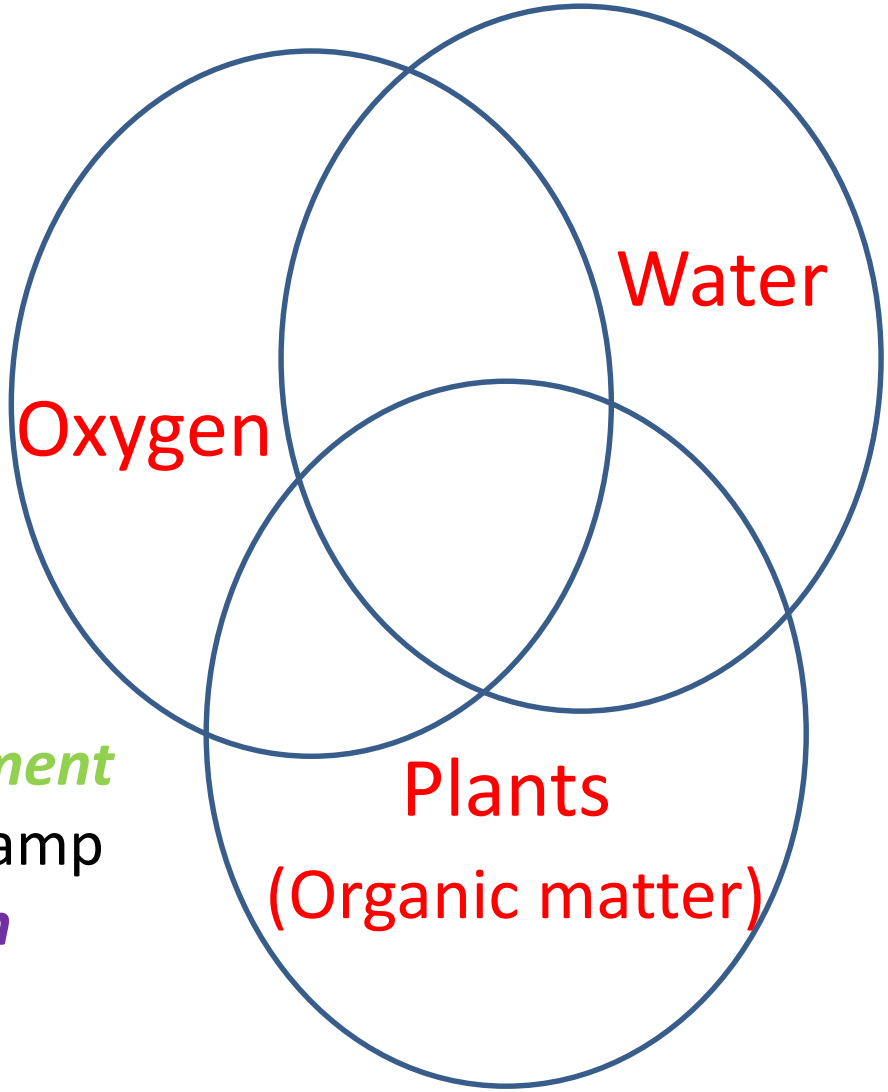

85 % Volume Change
wet
dry

Peatland formation: Soil to Landform

marsh, fen, open water

- Gradual build up of organic matter → ***plants***
- More plant matter is produced than what is decomposed → ***peat***
- peat build-up → ***peat accumulation***
- peat accumulation → ***peat landform (peatland) development***
- peat landform → bog, fen, swamp
- process is called ***paludification***

fen, swamp, bog



Processes of Peatland Formation

- Paludification: peatland formation on less wet mineral land
  - **pedogenic processes**: decreasing soil permeability
    - Pan formation: often iron oxides and org
    - Thick organic mat
    - Self-sealing: fine organic material fill in v
    - Permafrost: organic mats insulate → ice
    - nutrient depletion: (ie. N depletion, redu increase throughflow, reduce evapotran moisture on forest floor, *Sphagnum* grov

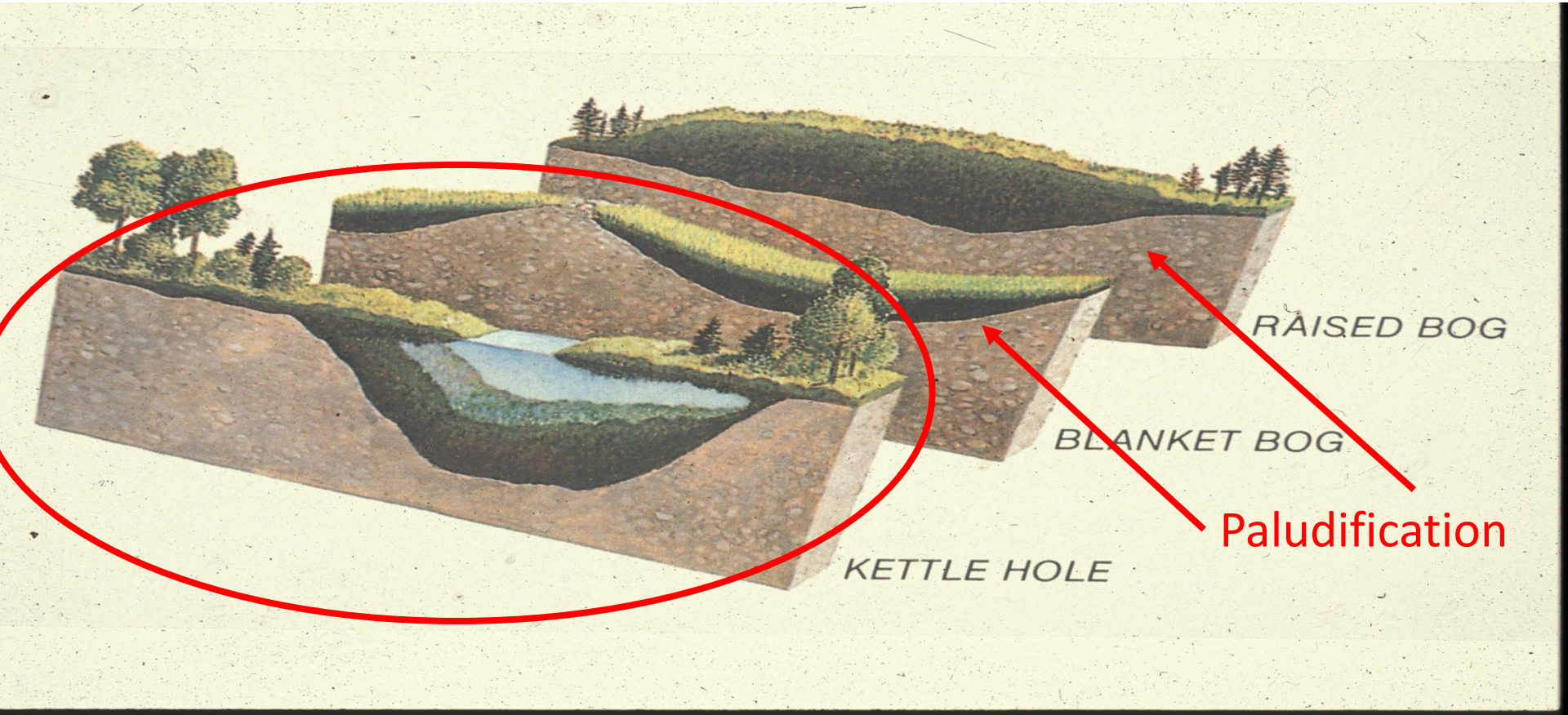
Processes of Peatland Formation

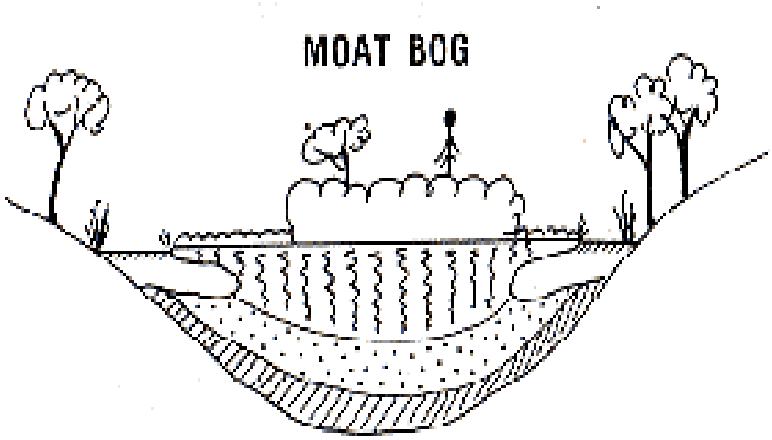
- Paludification:
  - **Peatland growth and water level rise**: usually at edges of peatlands; climate changes, fire; can be accelerated by anthropogenic causes
  - **Anthropogenic causes**: clear cutting, fire, grazing

    (e.g.: floating peatlands in kettles in SW Ontario)

Processes of Peatland Formation

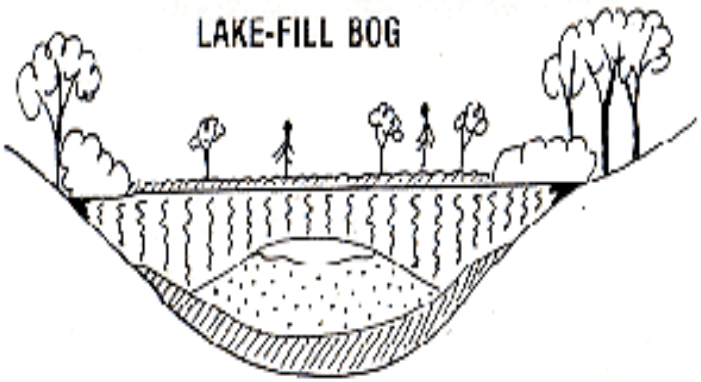
- Terrestrialization: through in-filling at the margins and in shallow waters of open water

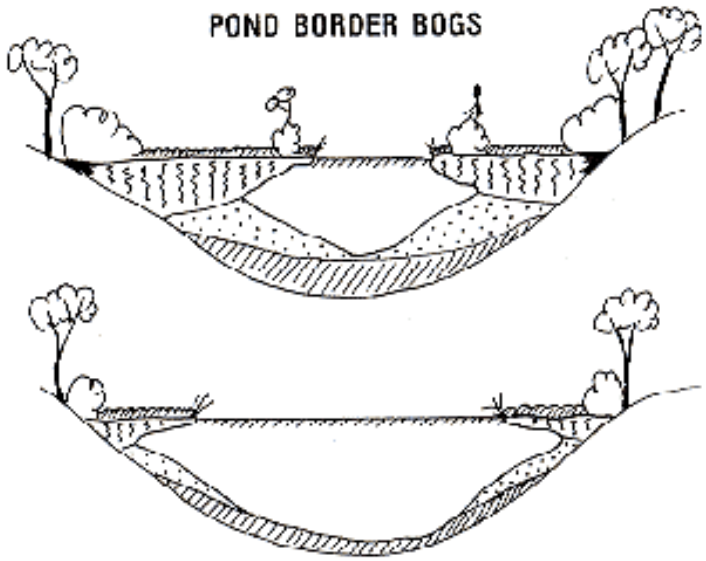


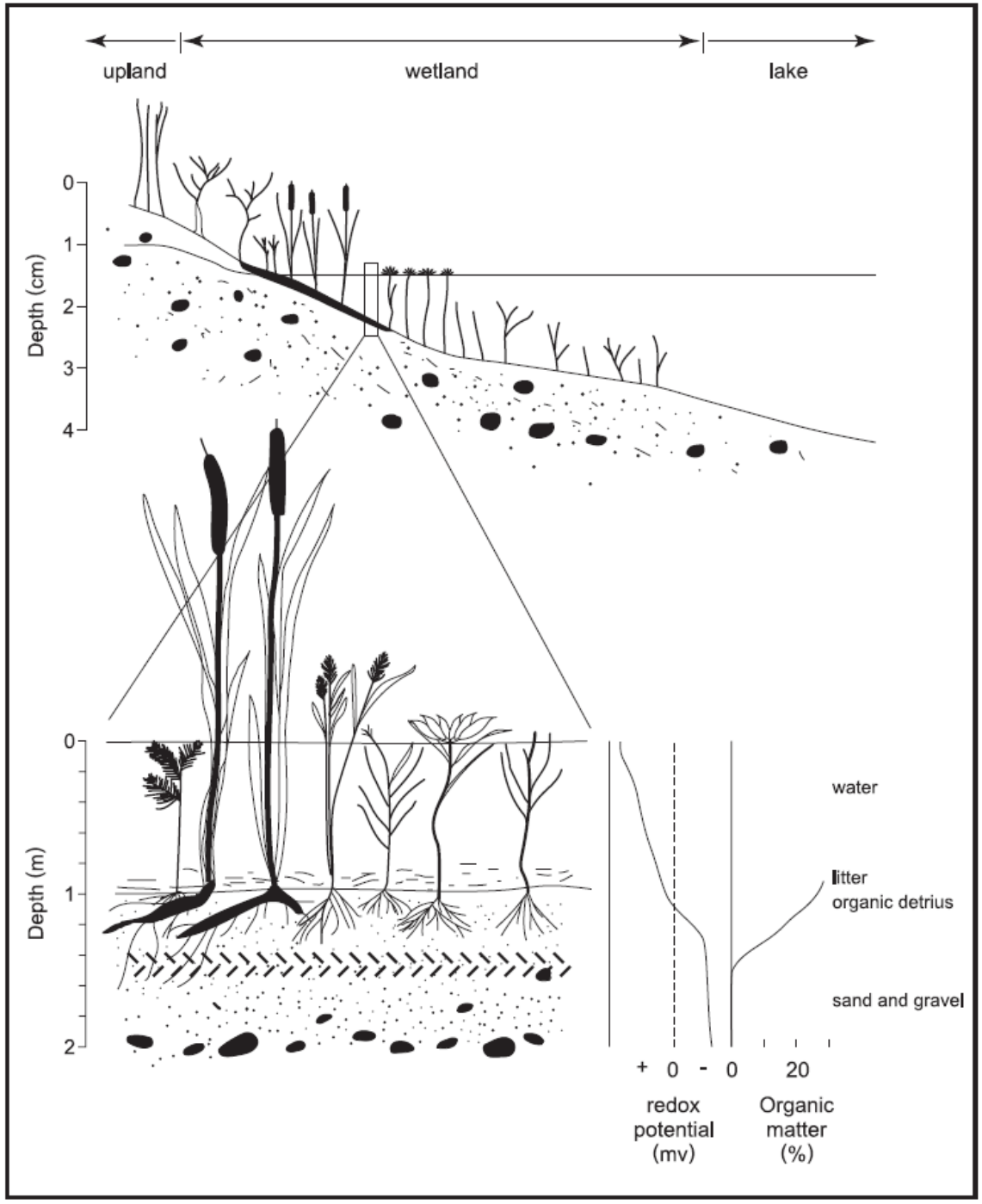

MOAT BOG

Bond Lake peatland, near Richmond Hill - Oak Ridges Moraine

(courtesy, MNR 2011)

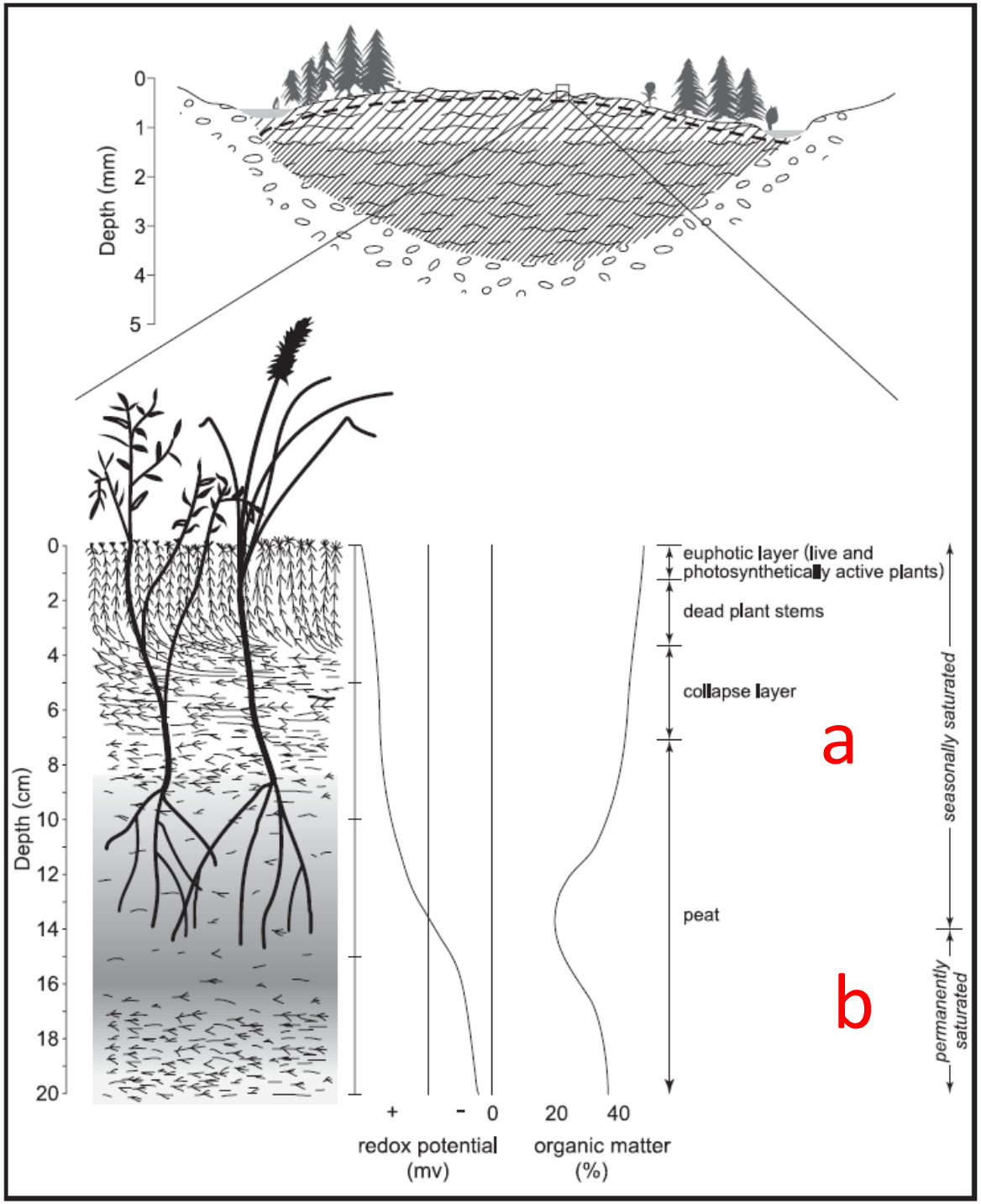

LAKE-FILL BOG


POND BORDER BOGS


upland
wetland
lake
Depth (cm)
0
1
2
3
4
Depth (m)
0
1
2
water
litter
organic detrius
sand and gravel
+ 0 - 0 20
redox potential (mv)
Organic matter (%)

Primary production and biomass formation

- Peat accumulation and growth models
- -Short-term processes
- -Long-term processes

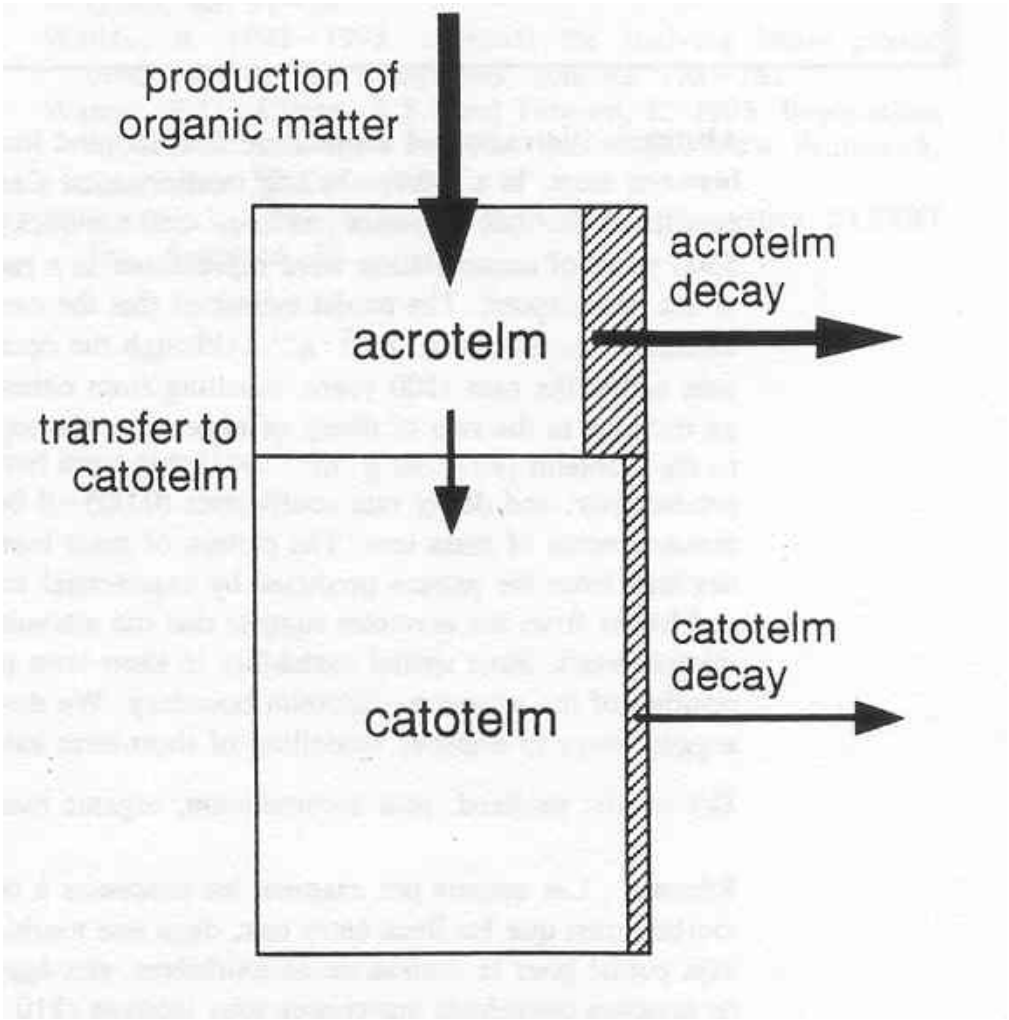


diplotelmic structure =

(a) upper oxygen-rich zone; seasonally saturated; high hydraulic conductivity

(b) lower oxygen-poor zone; permanently saturated; lower hydraulic conductivity


photosynthetic zone
brown stems zone
collapse zone
peat formation
peat
ACROTELM
CATOTELM


production of
organic matter
acrotelm
acrotelm
decay
transfer to
catotelm
catotelm
catotelm
decay

University of Waterloo

Wetland (peatland) archives

EARTH 444
BIOLOGY 462
Applied Wetland Science

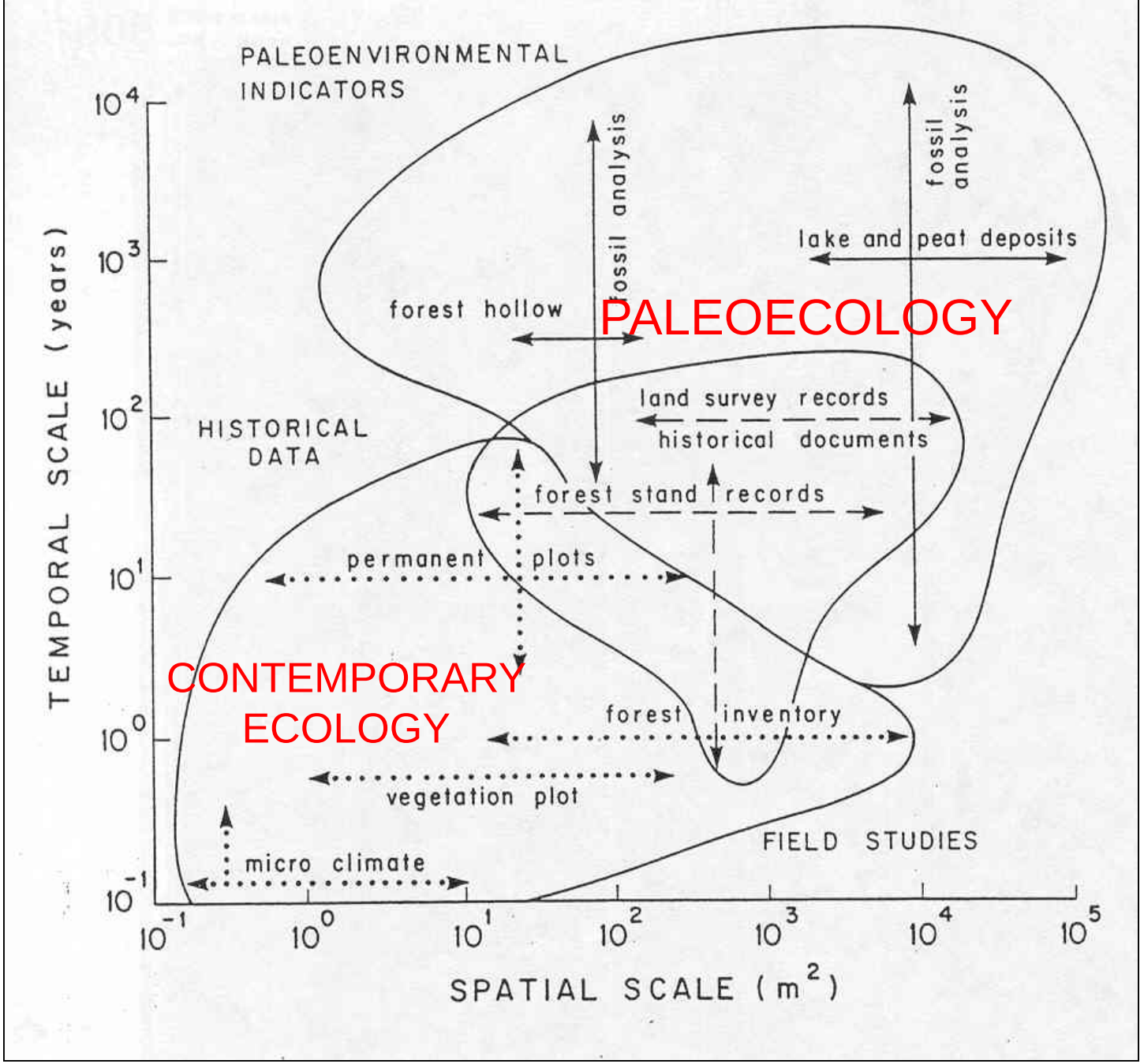
B.G. Warner

Peatland Archives

- Accumulated peat and sediment
- Contains remains of plants and animals that resided on and around peatland
- Peatlands preserve remains in peat for 100s to 1000s of years
- Contain a record of themselves in the peat archive; --paleoecology
- Peat paleoecologist = forensic scientist

Paleoecology as a Tool

- Hindcasting allows us to forecast and predict
- Understand processes and effects on processes (i.e. climate change, human impacts)

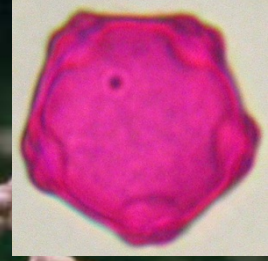


From: Foster et al. *1990*

Peat accumulation and developmental history

- Short-term history
  - Last few centuries

- Long-term history
  - Post-glacial history (1000s of years)



Common Terrestrial & Early Agricultural Pollen of the Mojave Desert

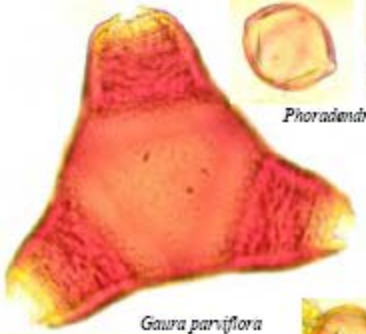
Acacia decurrens

Agave utahensis

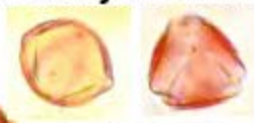
Ambrosia dumosa

Artiplex hymenolytra

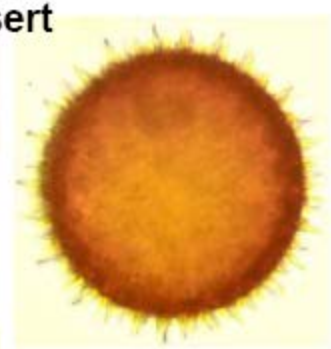
Chilopsis linearis



Gaura parviflora



Phoradendron villosum



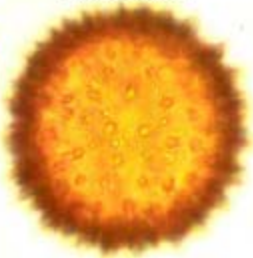
Malva parviflora

Coleogyne ramosissima

Datura meteloides

Sphaeralcea ambigua

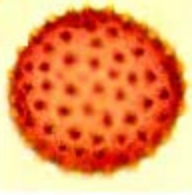
Lycium anderzonii



Echinocereus engelmannii
(Cereus-type)

Ephedra torreyana

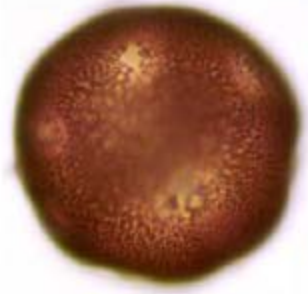
Fraxinus anomala



Forsellesia nevadensis

Stanleya pinnata

Salvia dorrii

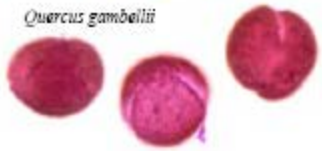


Opuntia bigelovii
(Cylindriopuntia-type)

Rhus trilobata

Ephedra funerea

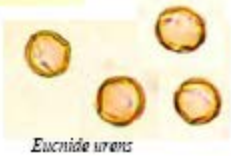
Mortonia utahensis



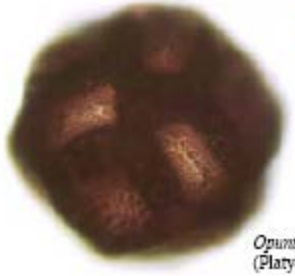
Quercus gambelii

Populus fremontii

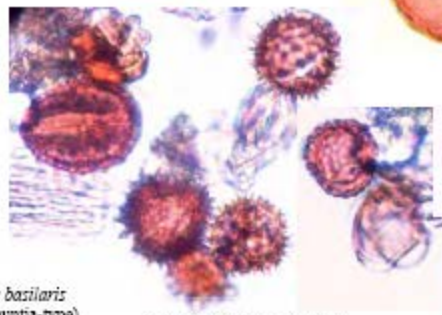
Eriastrum sparsiflorum



Eucnide urens

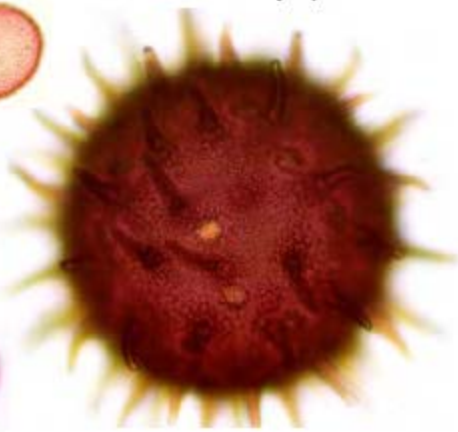


Opuntia basilaris
(Platyopuntia-type)



Mojave Desert Fossil Pollen

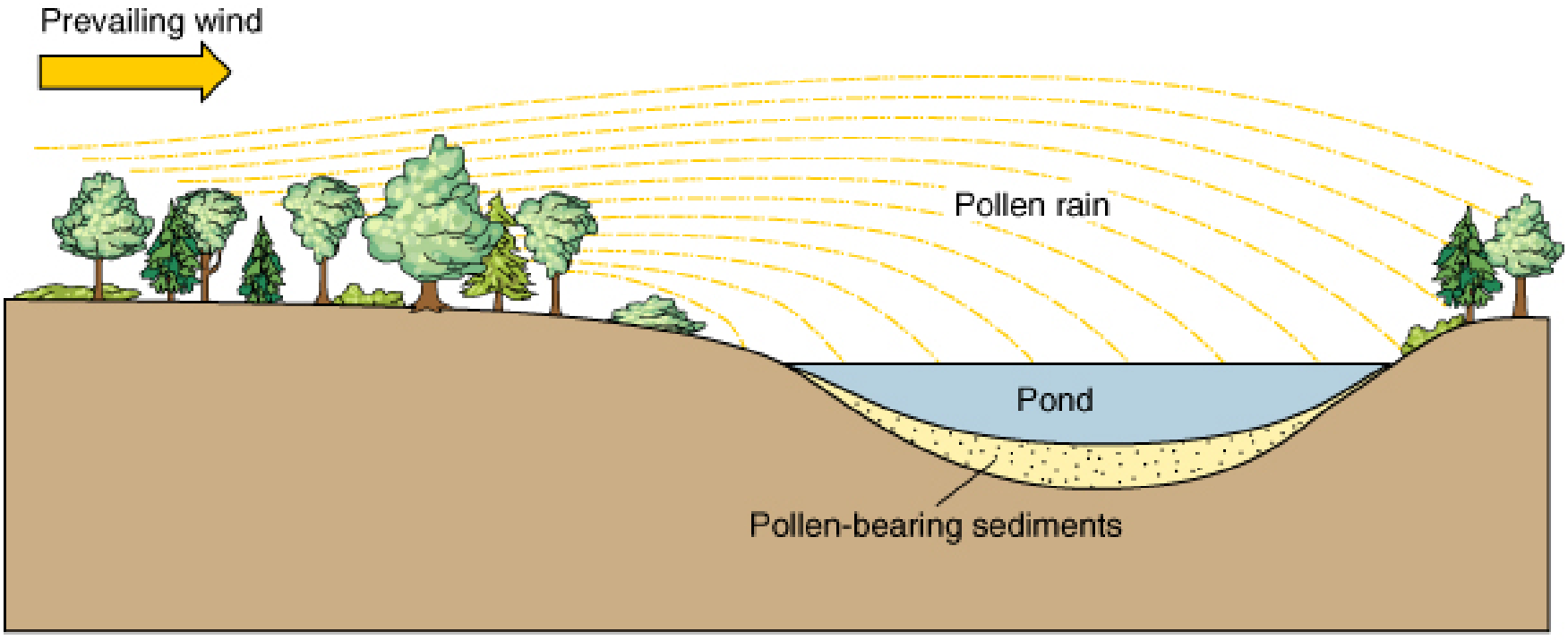
Nicotiana attenuata

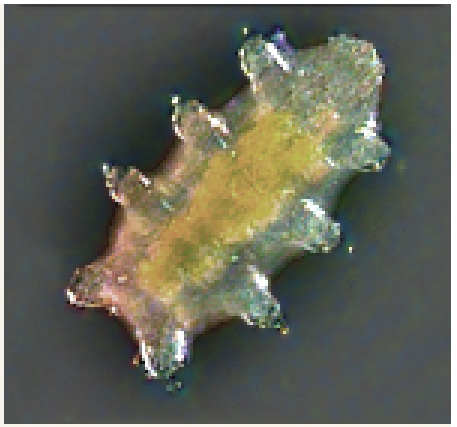


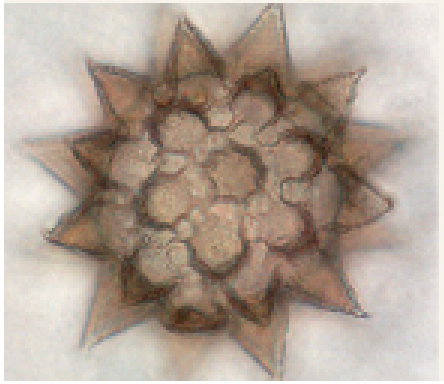
Malva parviflora

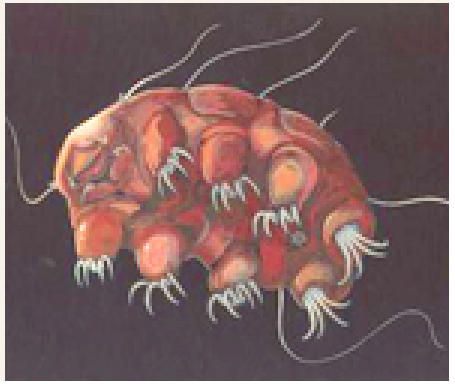
Curcurbita pepo

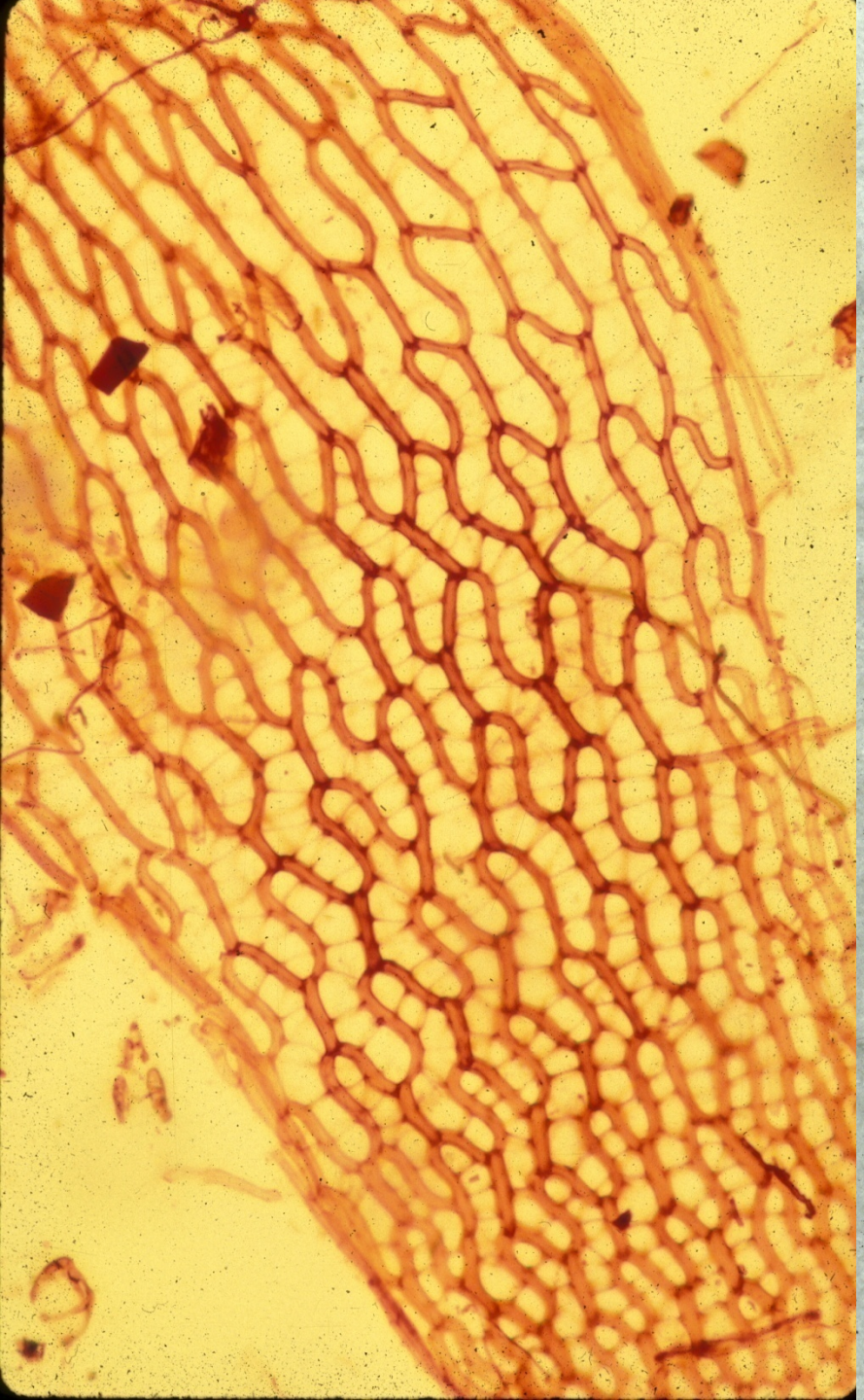
Poster made by and photos taken by Peter E. Wigand


Prevailing wind
Pollen rain
Pond
Pollen-bearing sediments







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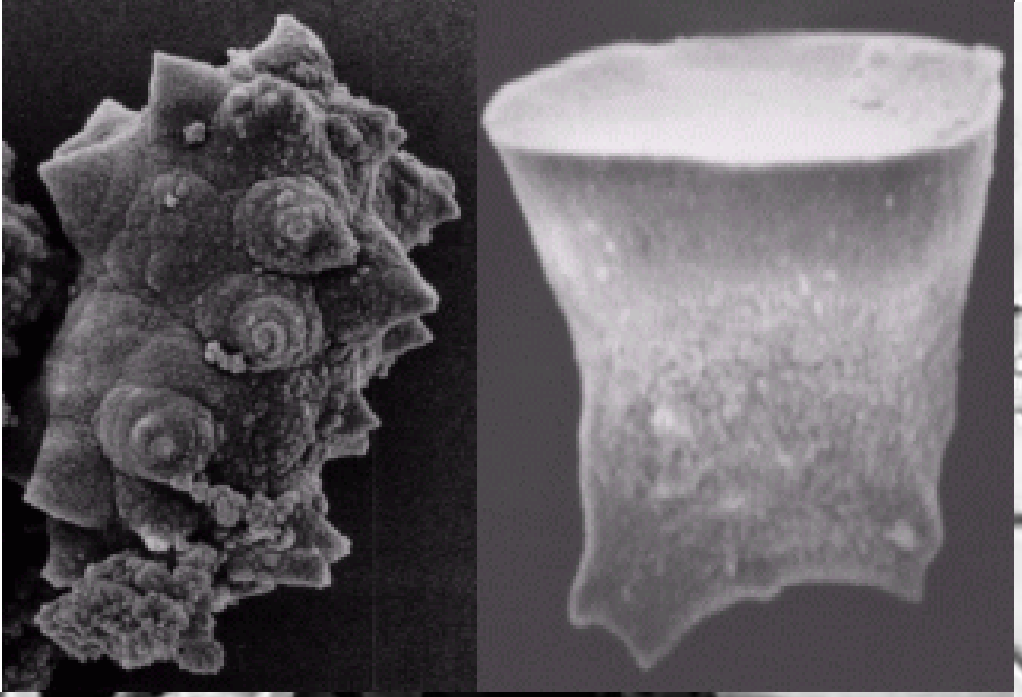
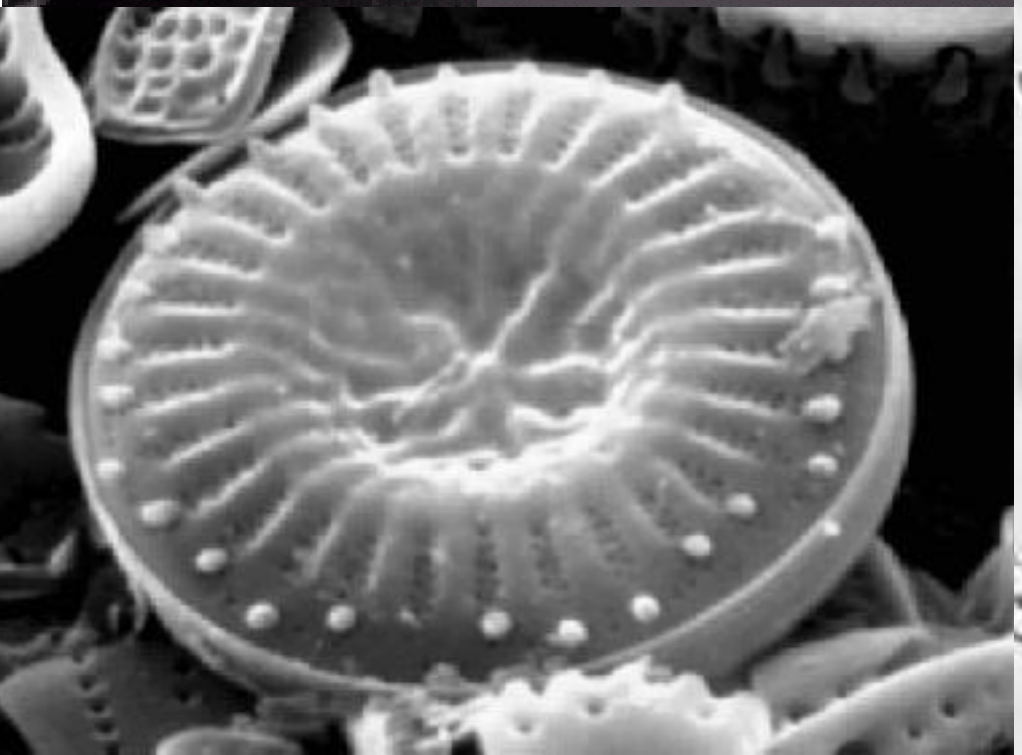
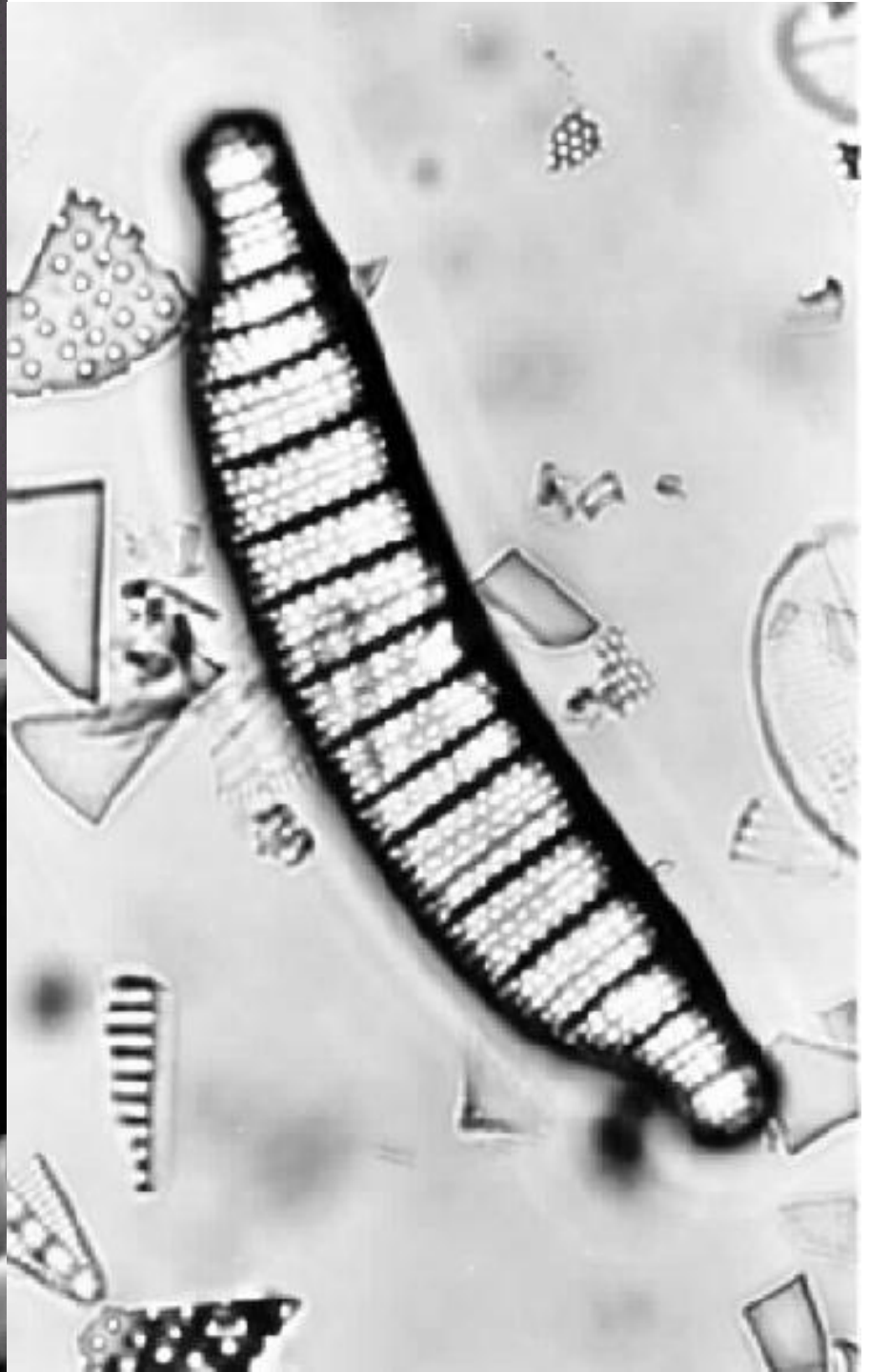




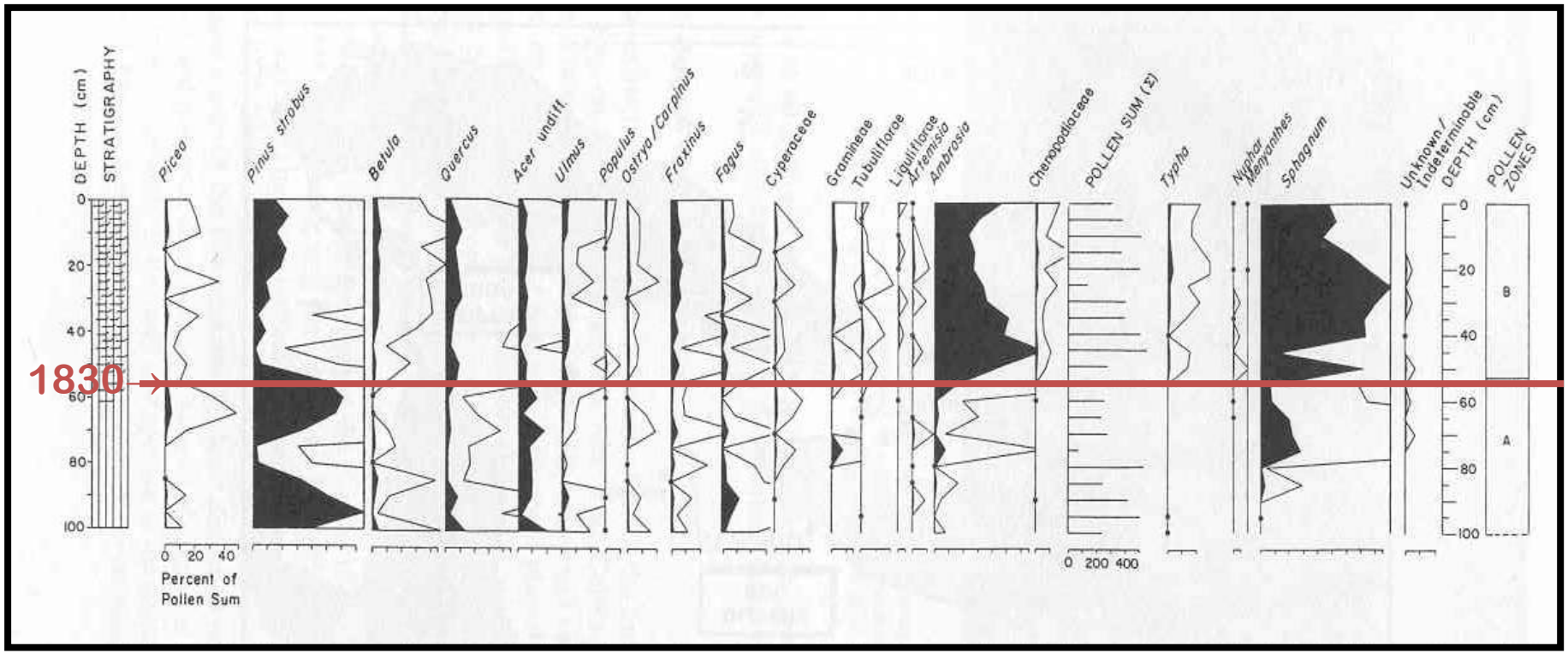


Jura Valley, Switzerland

Tollund Man, Denmark

Medieval Churn, Gallway, Ireland

Type of evidence	Indicator
Peat depth & topography	Morphology of peat deposit/land form
Stratigraphy	Detection of main changes in peat composition
Biological indicators: -Pollen and spores -Plant macrofossils -charcoal -testate amoebae -Fungal remains -Insecta -Chironomidae head capsules -beetles (Coleoptera) skeleton remains -Mollusca -Porifera -Vertebrata bones and soft tissues	 Plant community and vegetation Plant community and vegetation Fire Hydrological conditions
Mineral content	Accumulation rates, compaction estimates
Humification	Degree of decay
Isotopes of O, H, and C	Past water sources and climate
Time markers -volcanic ash -pollen and spores -fires -spheroidal carbonaceous particles (soot)	 Post-European settlement period; Hemlock d Decline Industrial period


1830
DEPTH (cm)
STRATIGRAPHY
Picea
Pinus strobus
Betula
Quercus
Acer undiff.
Ulmus
Populus
Ostrya/Carpinus
Fraxinus
Fagus
Cyperaceae
Gramineae
Tubuliflorae
Liguliflorae
Artemisia
Ambrosia
Chenopodiaceae
POLLEN SUM (Σ)
Typha
Nuphar
Menyanthes
Sphagnum
Unknown/
Indeterminable
DEPTH (cm)
POLLEN ZONES
0 20 40
Percent of
Pollen Sum
0 200 400
B
A

Implications of Results

- Ecosystems are much younger than previously thought
- Basins are sensitive to hydrological changes in watershed
- Human development must consider hydrological conditions of peatland in context of watershed

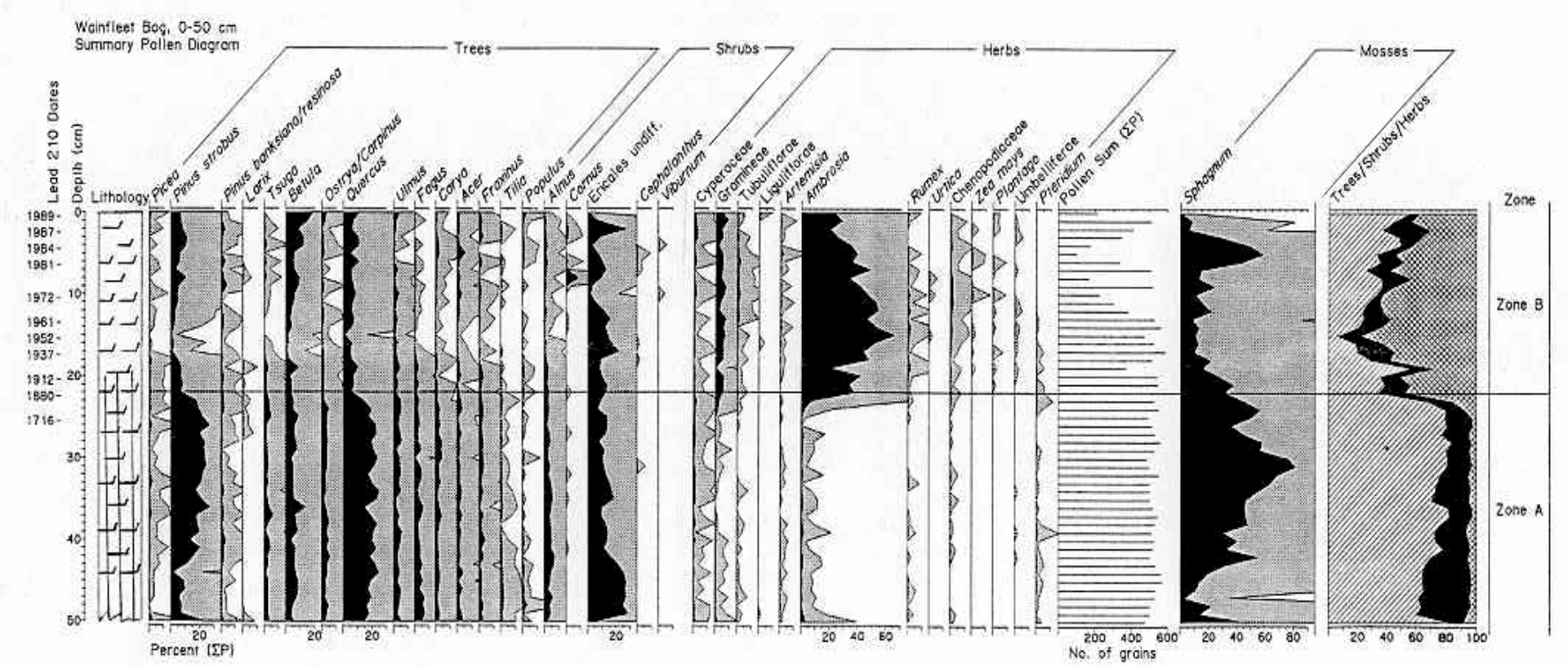
Wainfleet Bog, Port Colborne, ON-
The case of alien *Betula pendula*

- Canada's most southern raised bog
- severely degraded state
- invaded by European birch (*Betula pendula*)
- what is its status and how best to manage it to preserve the bog?

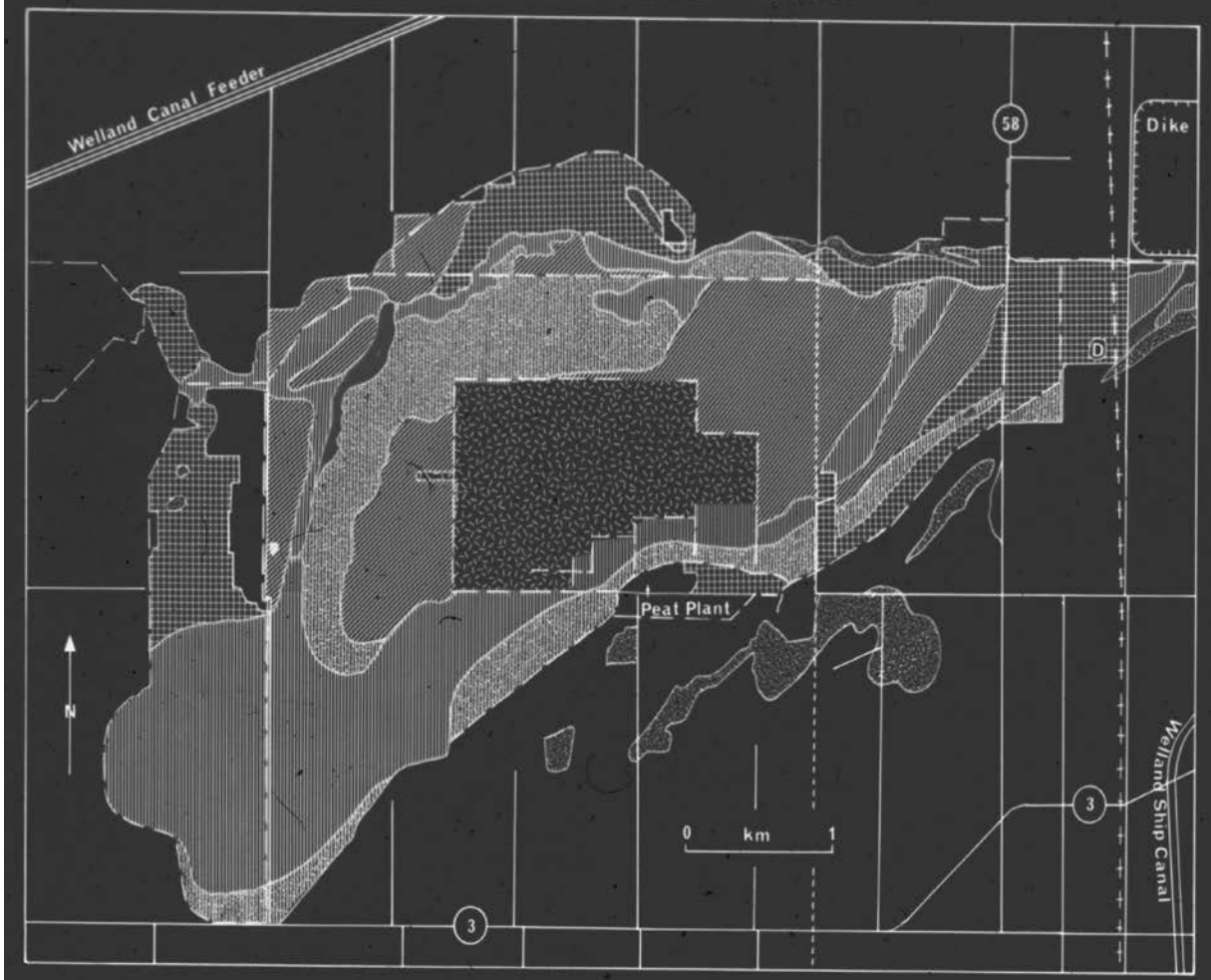

Lake Ontario


Port
Colborne
1·72·4238
1·72·4238


FIRST RIDING
THIRD RIDING
STAMFORD
CAISTOR
PELHAM
GAINSBORO'
THOROLD
WILLOUGHBY
GRAND ISLAND
CANBORO'
CROWLAND
FOURTH RIDING
WAINFLEET
BERTIE
HUMBERSTONE
Canborough
Caistor
Gainsborough
Clinton
Scale of distance in Miles

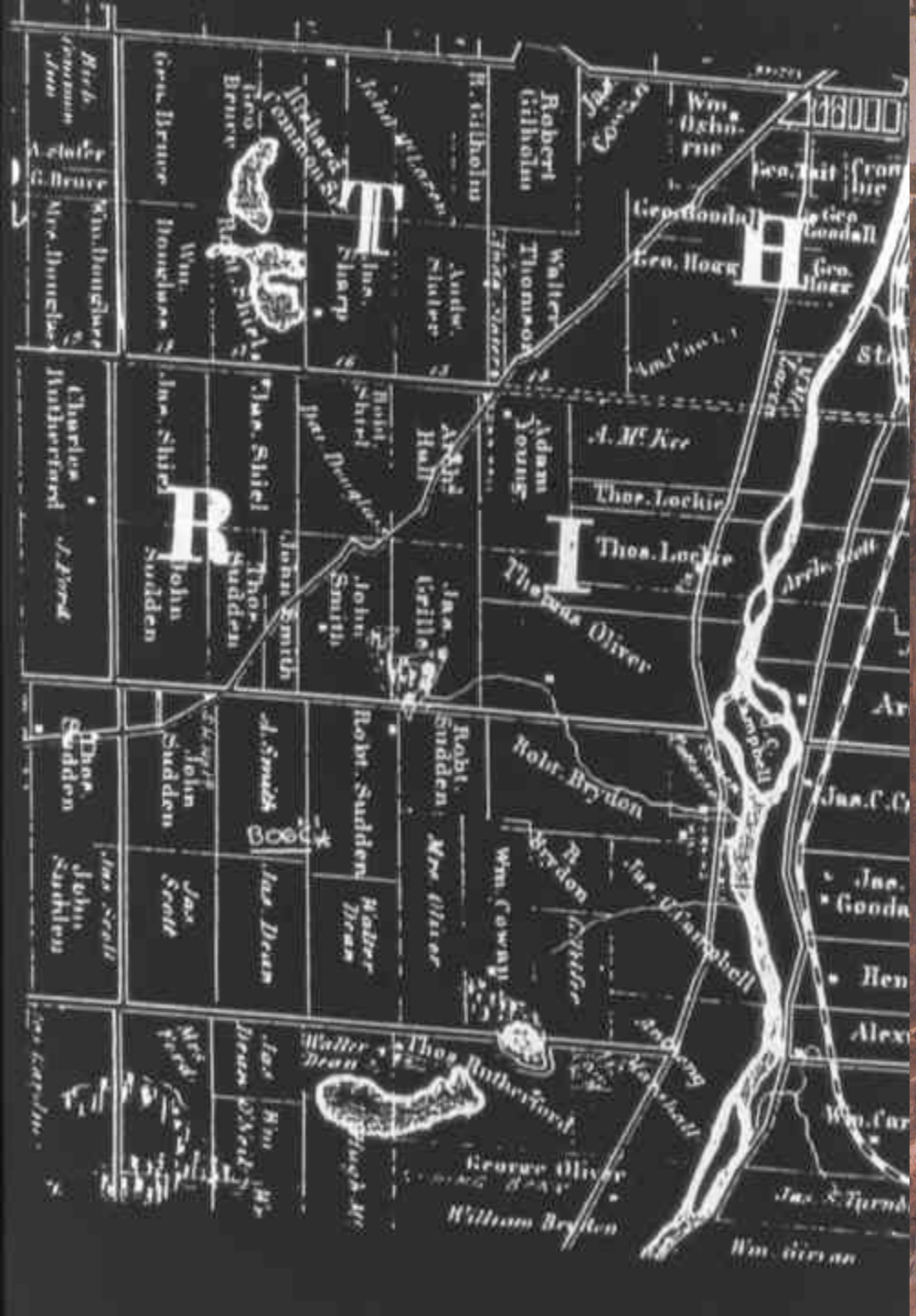

Wainfleet Bog, 0-50 cm
Summary Pollen Diagram
Trees
Shrubs
Herbs
Mosses
Lead 210 Dates
Depth (cm)
Lithology
Picea
Pinus strobus
Pinus banksiana/resinosa
Larix
Tsuga
Betula
Ostrya/Carpinus
Quercus
Ulmus
Fagus
Carya
Acer
Fraxinus
Tilia
Populus
Alnus
Cornus
Ericales undiff.
Cephalanthus
Viburnum
Cyperaceae
Gramineae
Tubuliflorae
Liguliflorae
Artemisia
Ambrosia
Rumex
Urtica
Chenopodiaceae
Zea mays
Plantago
Umbelliferae
Pteridium
Polien Sum (ΣP)
Sphagnum
Trees/Shrubs/Herbs
Zone
1989
1967
1954
1961
1972
1961
1952
1937
1912
1850
1716
0
10
20
30
40
50
Zone B
Zone A
20
Percent (ΣP)
200 400 600
No. of grains
20 40 60 80
20 40 60 80 100

WAINFLEET BOG
VEGETATION MAP 1955



LEGEND

- Trees
- Shrubs
- Trees and Shrubs
- Shrubs and Trees
- Mined
- Open
- Open and Shrubs
- Agriculture
- D Disturbed


T
H
R
I
Robert Gilholm
Wm. Oshurne
Geo. Hogg
A. McKee
Thor. Lockie
Thos. Lockie
Thomas Oliver
Adam Young
Robt. Brydon
Robt. Sudden
John Sudden
Thor. Sudden
Thos. Shiel
John Smith
Thos. Rutherford
Walter Dean
George Oliver
William Brydon

Change in areal extent

1798	*ca.* 21,119 ha
1817	*ca.* 5,698
1854	*ca.* 5,621
1909	1,983
1941	1,416
1980	1,324
1987	1,030

Historical Highlights

- 1876 – "…a large swamp consisting of tamarack bush in the centre of the township but this is rapidly being drained into good land"
- 1880 – *Pinus strobus* nearly logged out
- 1882 – parts of the bog sold to private owners
- 1905 – peat mining nearly ceased on the bog due to declining demand

Historical Highlights

- 1909 – only a few trees growing on the bog and around the edges
- 1936 – peat mining resumed
- 1941 – establishment of prison on bog – over 200 people employed
- 1950-1955 – drainage program consisted of 91 km of ditches through bog
- 1971 – last *Picea mariana* on bog

Implications of Results

- *Betula pendula* recent invasive – major spread in 1970s
- drainage ditches, poor management, spread of *B. pendula* contributing to degradation
- Restoration Plan – initiated in 1998: plug up ditches, remove *B. pendula,* restrict human traffic