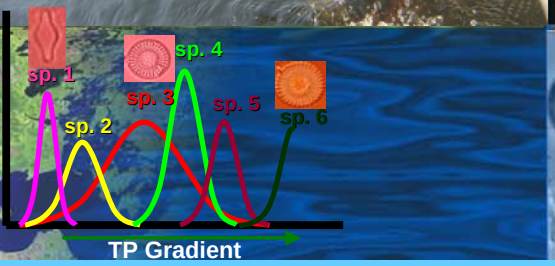
An introduction to

Paleolimnology



Focus on the Lake of the Woods

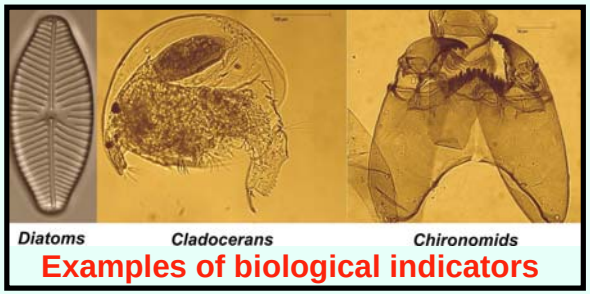
The following slides include text annotations: place cursor over comment bubble to toggle on or off

Paleolimnology: a multi-disciplinary science

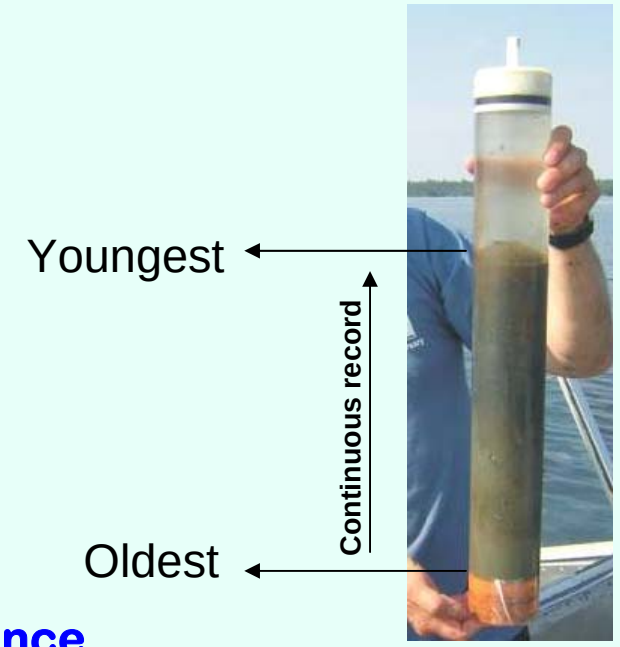
- Long-term data are essential for understanding environmental & ecological problems
  - these data are rarely available
  - indirect proxy methods must be used instead

Paleolimnology: a multi-disciplinary science

What is paleolimnology?

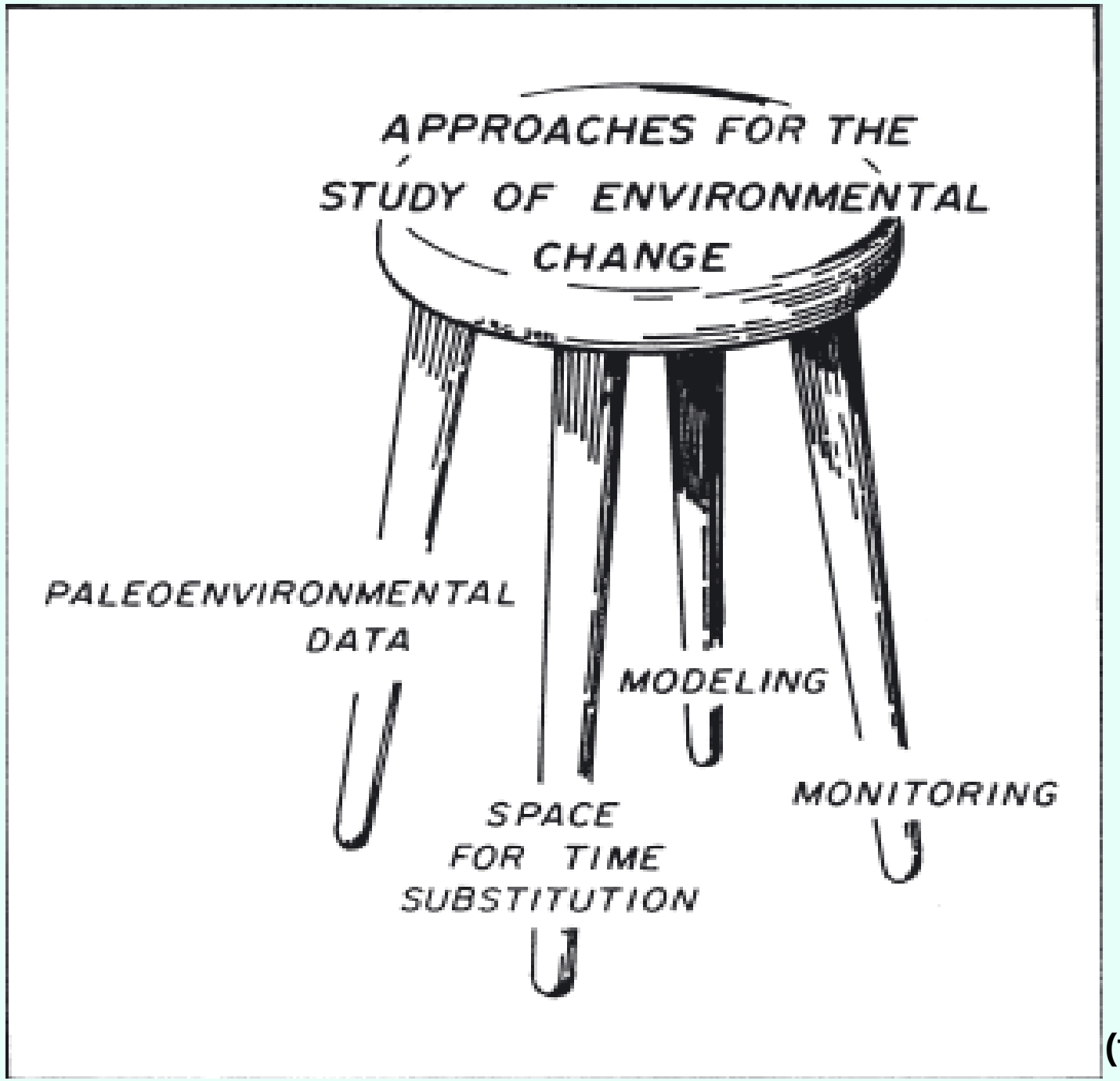


Examples of biological indicators

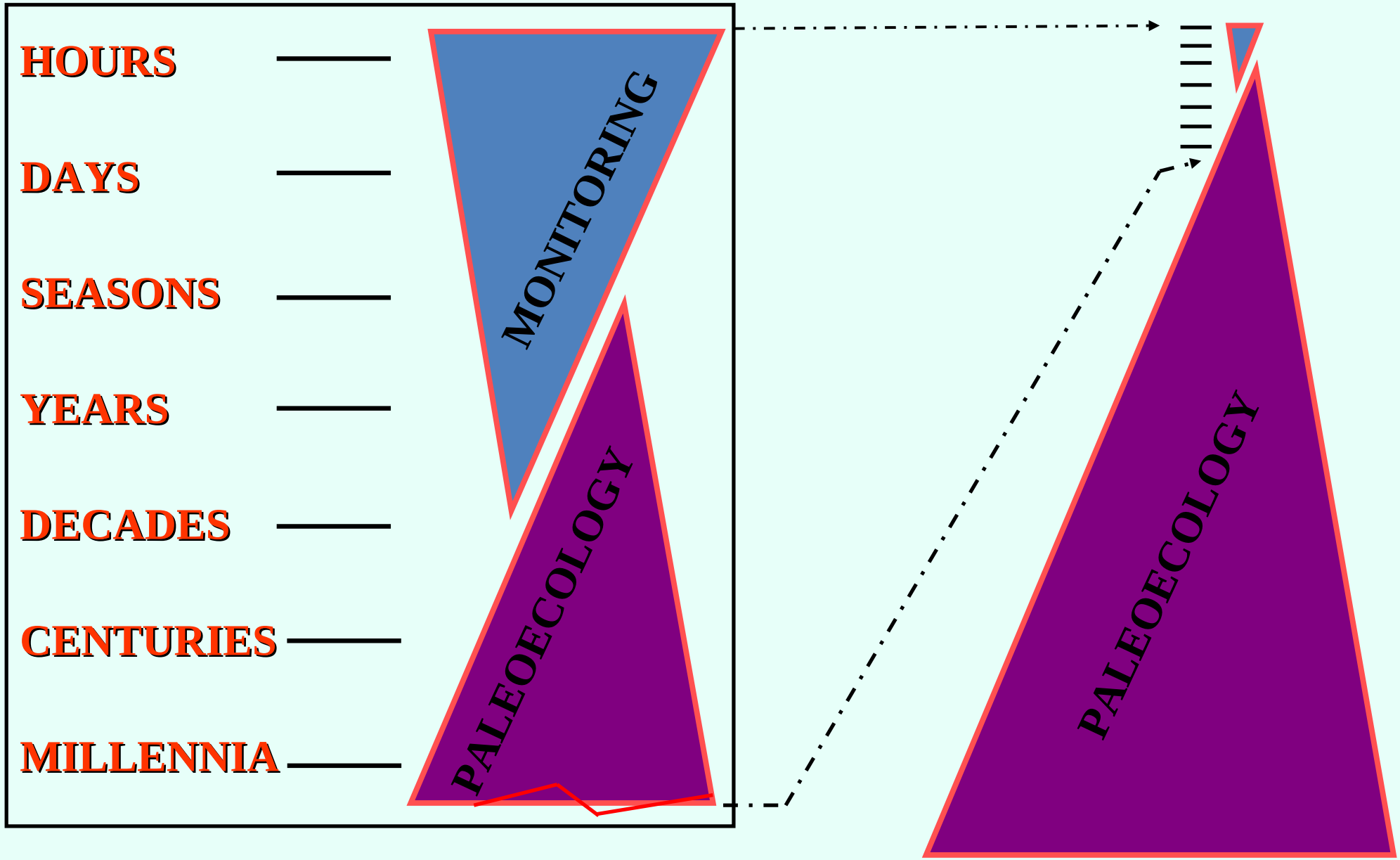


Lake Sediment Core

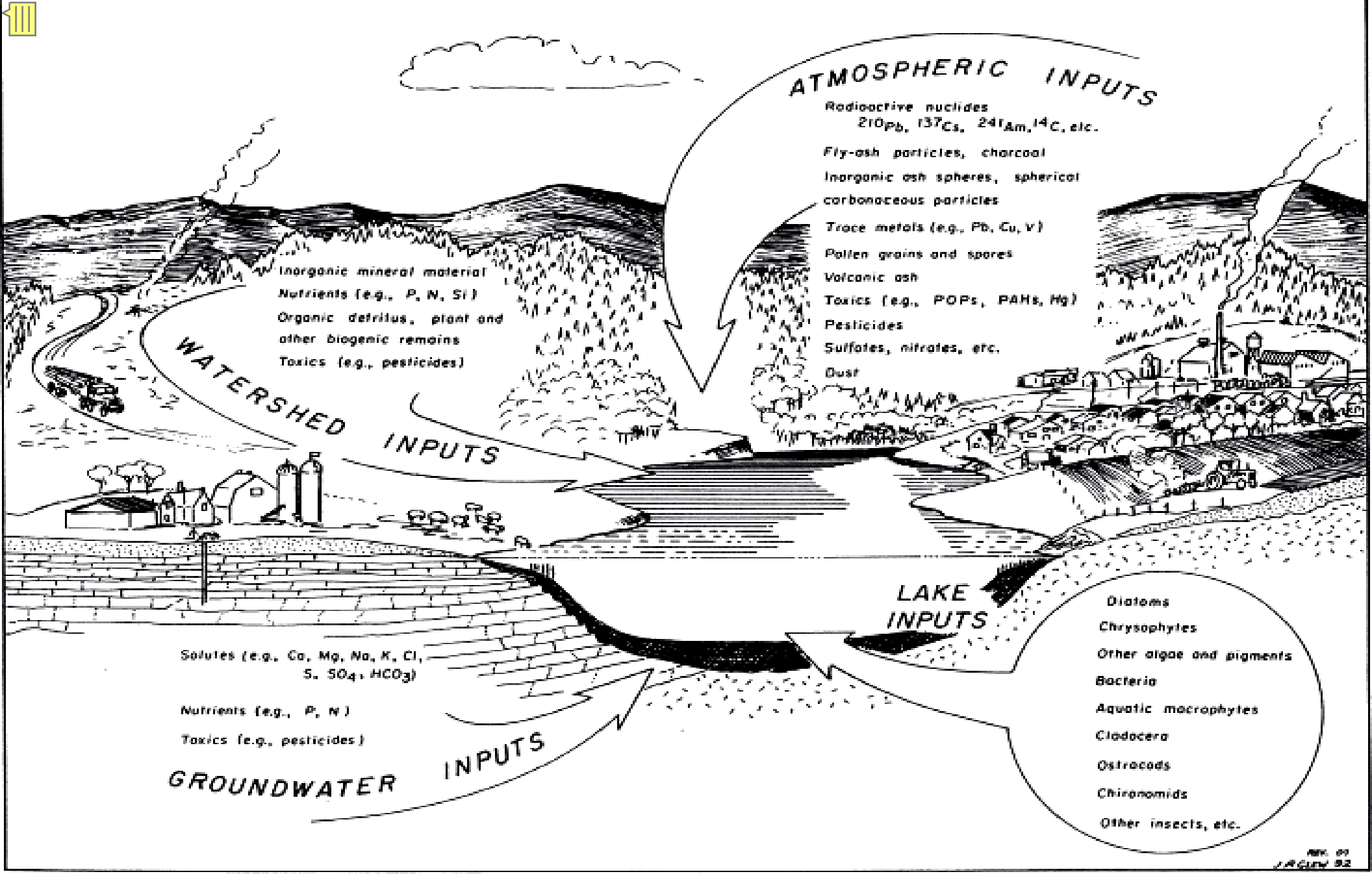
- **Paleolimnology is an inter-disciplinary science**
- **In a strict sense, "paleolimnology" is simply the study of lake histories**
- **In practice, however, it can provide valuable information on broader ecological & environmental scales (e.g. lakes, ponds, peatlands; climate, land-use changes)**
- **Uses physical, chemical, & biological information stored in lake sediments**
- **Sedimentary cores provide a continuous archive of environmental information**



(from Smol, 2008)

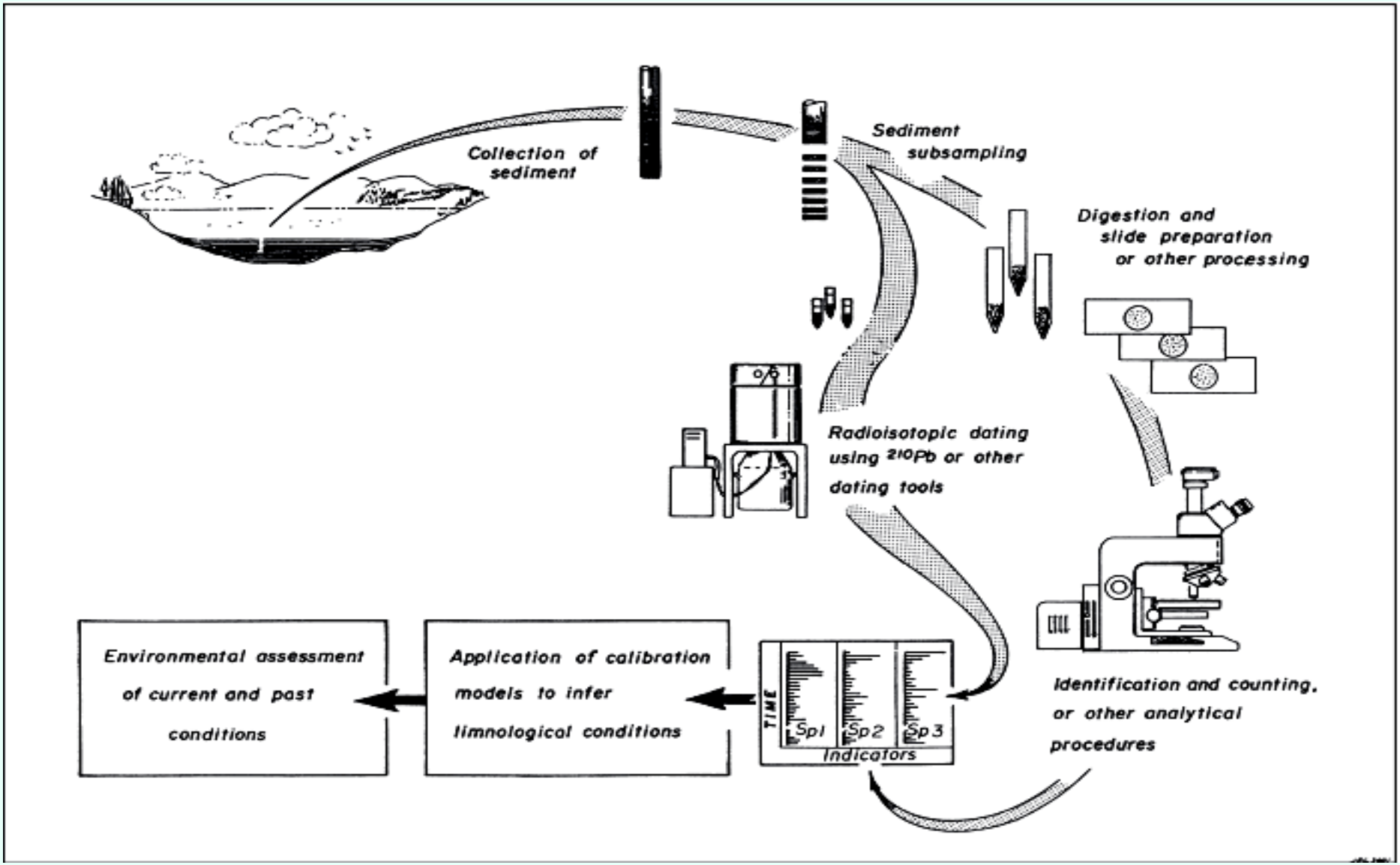


Modified from Smol 2008



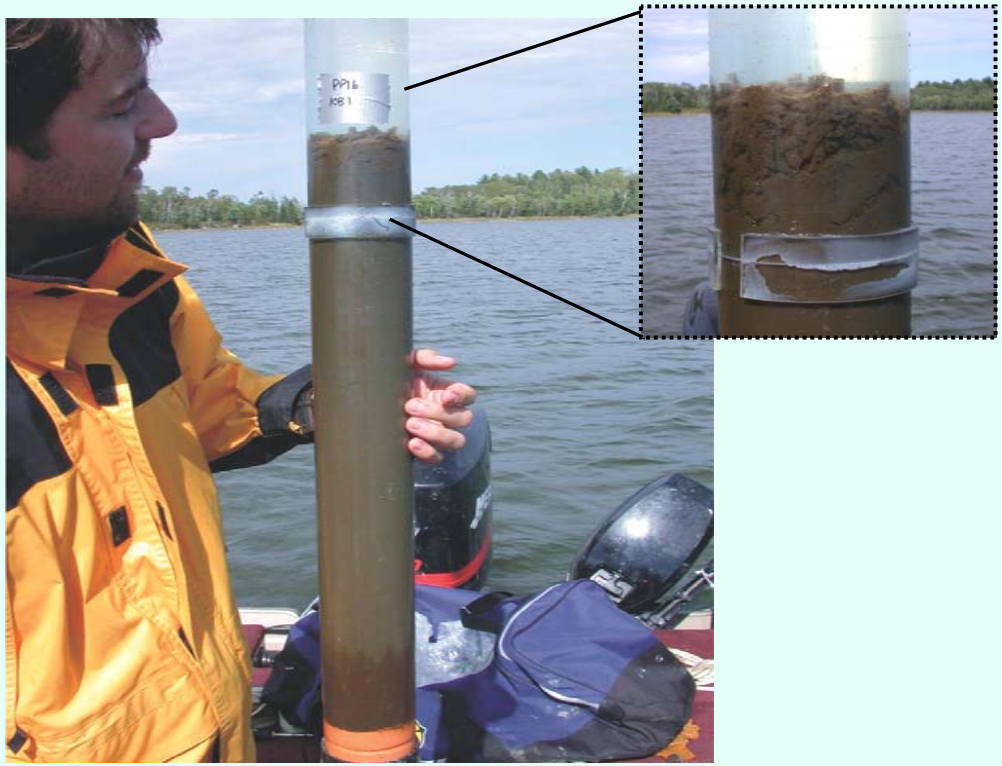
From Smol *et al.* (2001a)

The Paleolimnological Method



(*from Smol 2008*)

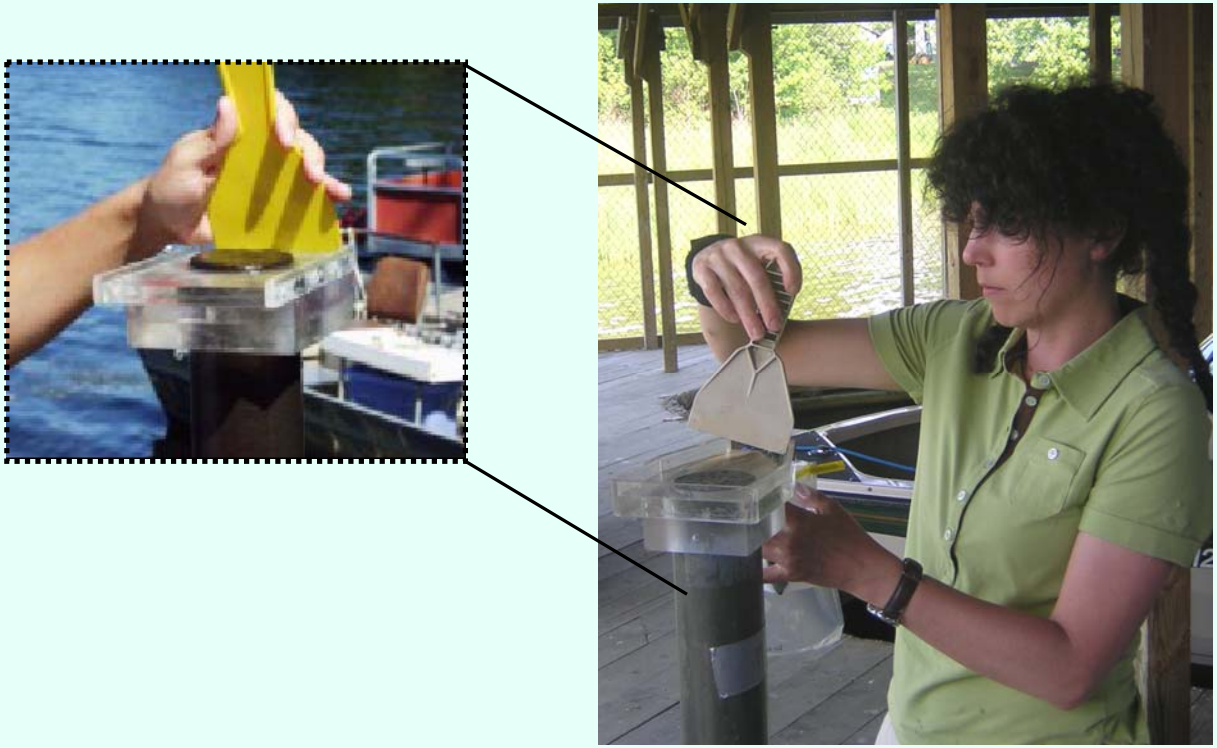
The Paleolimnological Method



Core retrieval

- sediment cores retrieved from deep, quiet locations
- undisturbed water-sediment interface = most recent deposits retrieved

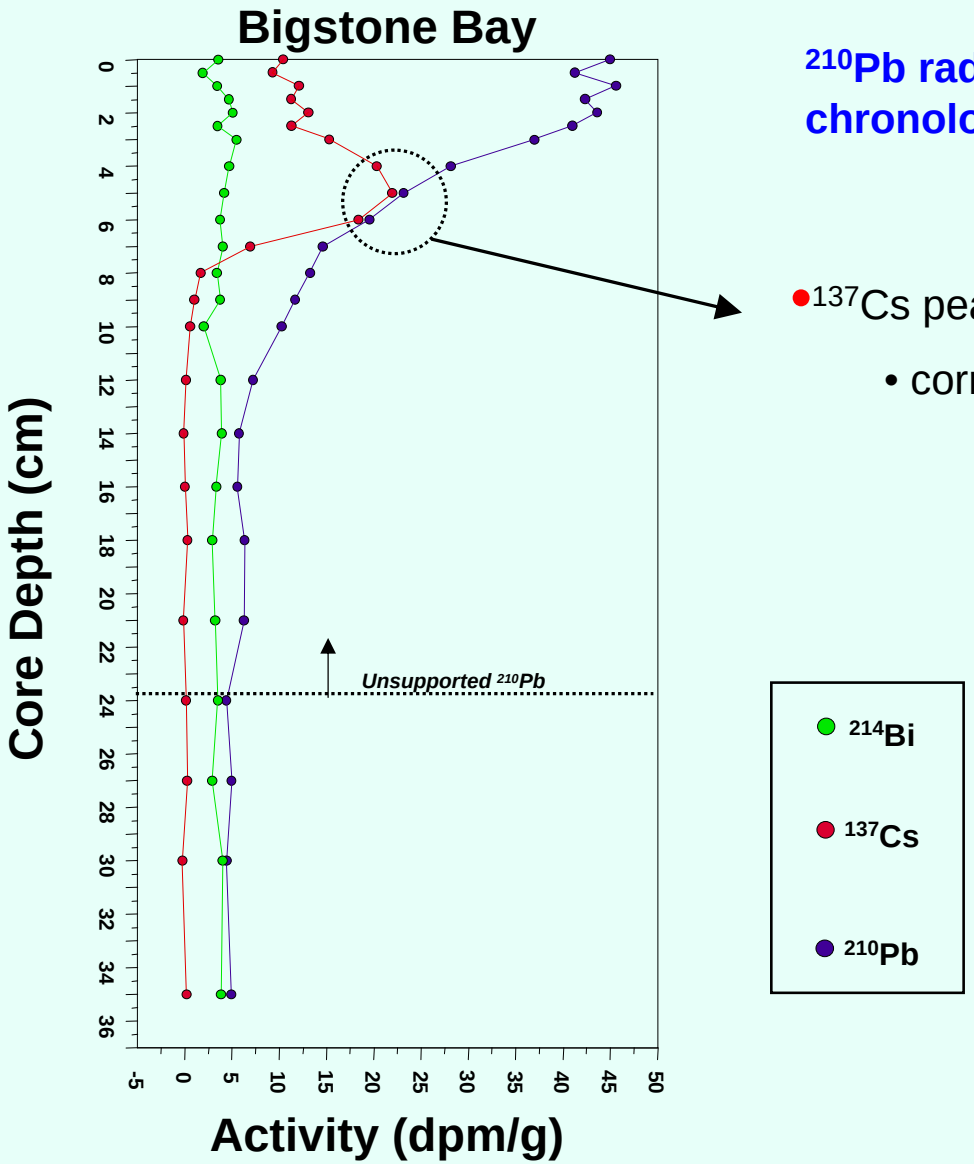
The Paleolimnological Method



Core sectioning

- sediment is sectioned into intervals (Glew 1988 extruder)
- each interval (usually 0.5 cm) extruded into plastic sample bags

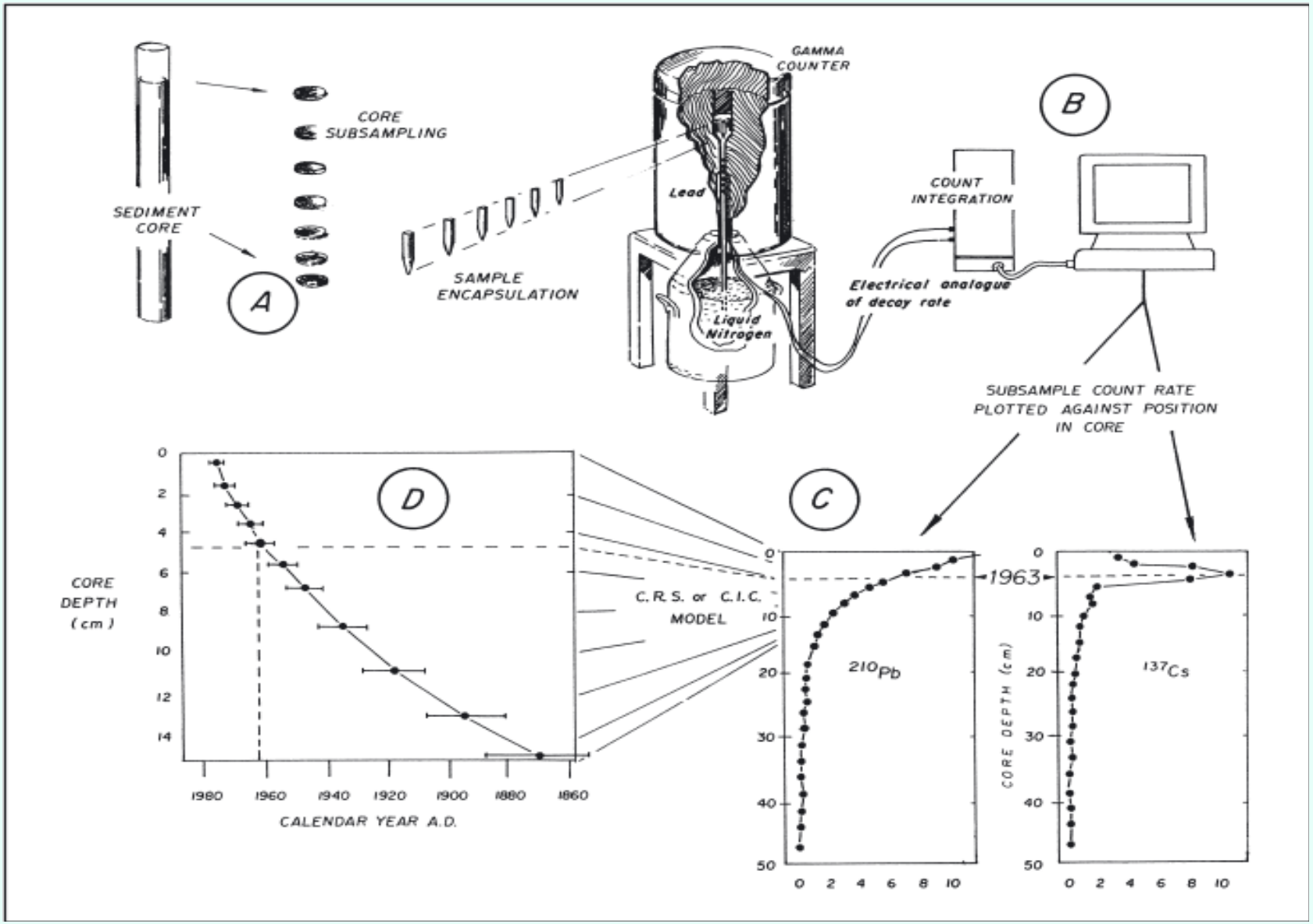
Dating the sedimentary sequences: an example from the LoW



^{210}Pb radioisotopes used to establish chronology for the last ca. 150 years

- ^{137}Cs peak ca. 1963
  - corresponds to nuclear test ban treaty

Dating the sedimentary sequences: schematic

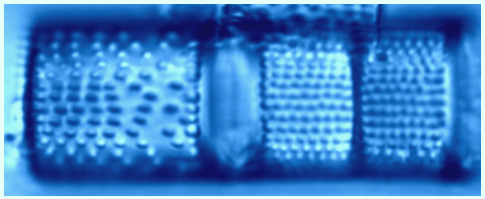


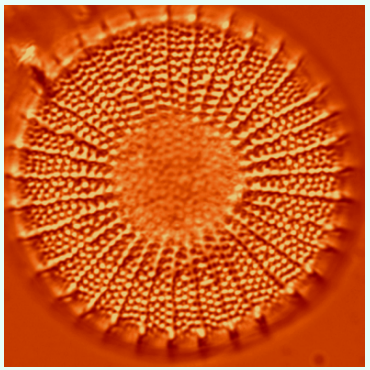
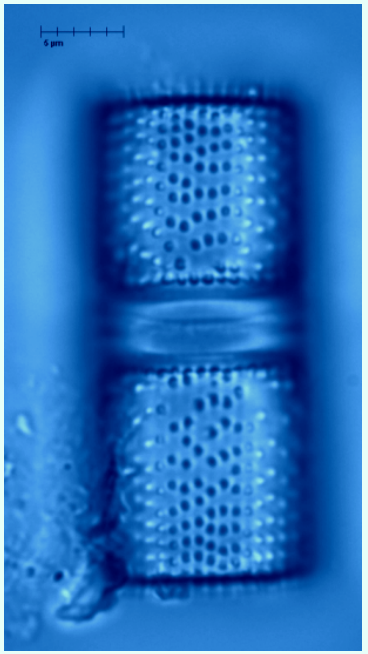
From Smol (2008)

The Paleolimnological Method

Diatoms as Indicators of Environmental Change

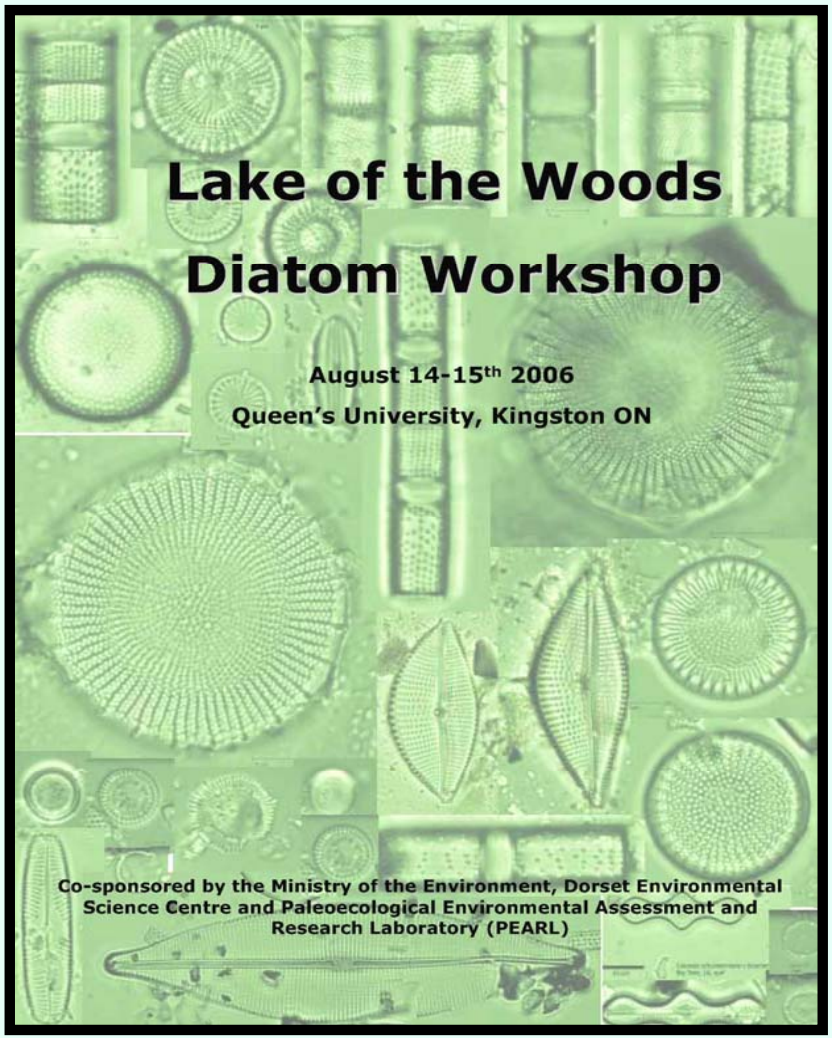
- well preserved in lake sediments
- remain stable in sedimentary sequences
- taxonomically specific ornamentation
- many have narrow optima and tolerances
- respond rapidly to environmental change



The Paleolimnological Method

Diatoms as Indicators of Environmental Change



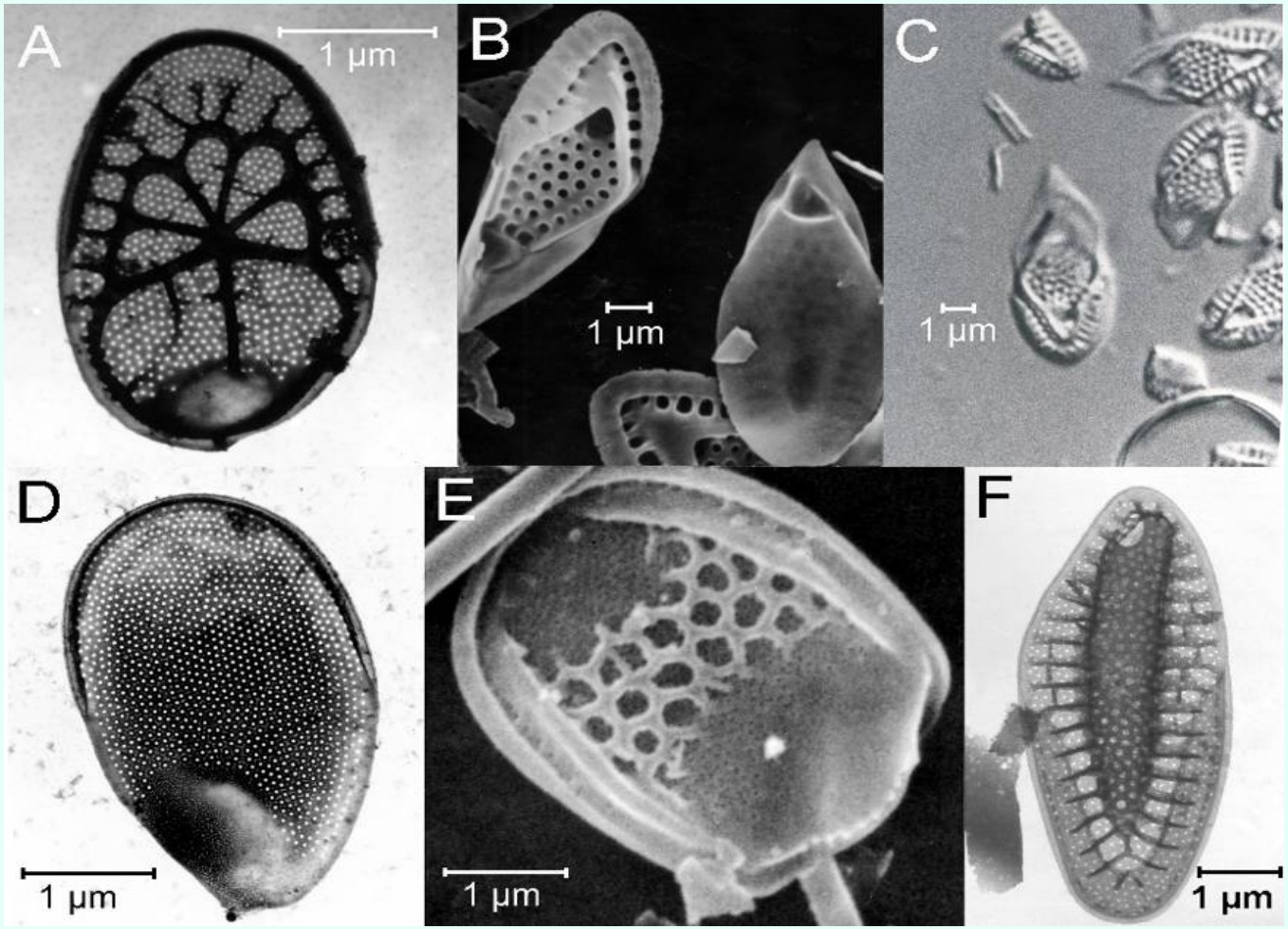
- Exchange of diatom datasets requires taxonomic consistency

- Diatom workshop, August 2006

To view our taxonomy workshop notebook go to the Research button and then Click on Diatoms

The Paleolimnological Method

Chrysophyte Scales as Indicators of Environmental Change



From Smol (2008)

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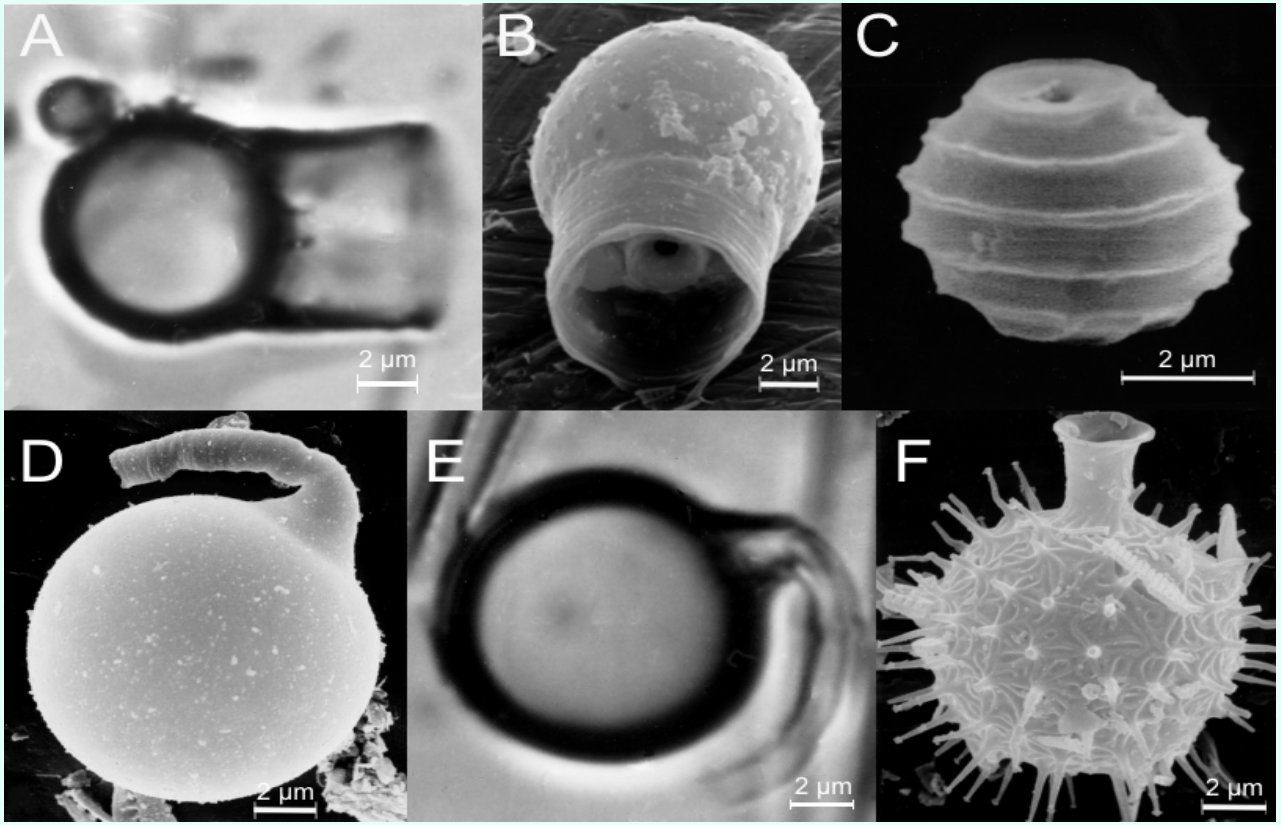
Modified from Duff *et al.* (1995)

Chrysophyte Stomatocysts as Indicators of Environmental Change



From Smol (2008)

Chrysophyte cysts can be used as biomonitors of

- pH
- Climate
- Trophic status
- Lake-level changes
- Habitat availability
- Metal concentrations
- Salinity

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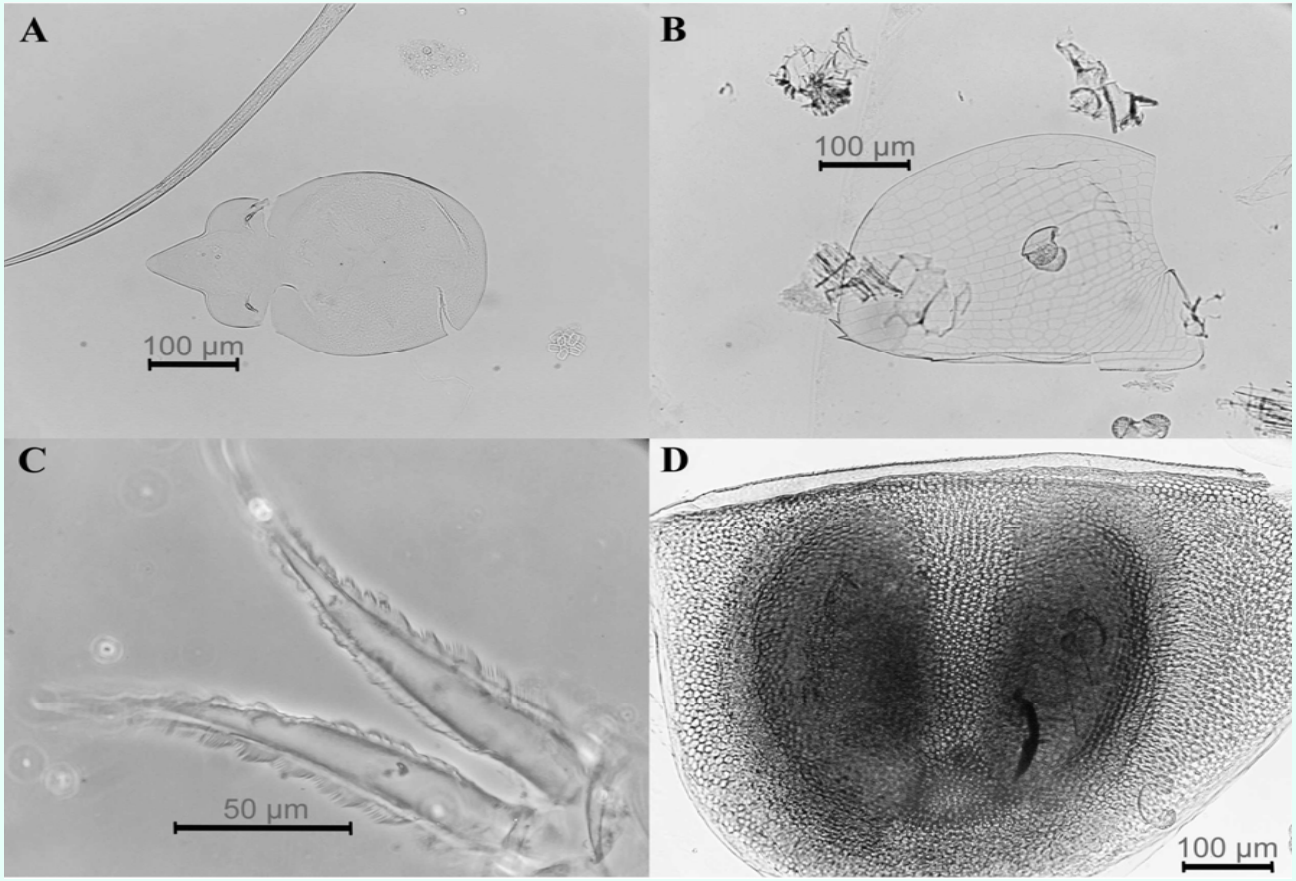
Cladocera as Indicators of Environmental Change



Photographs taken by Darren Bos

From Smol 2008

Cladocerans used to track

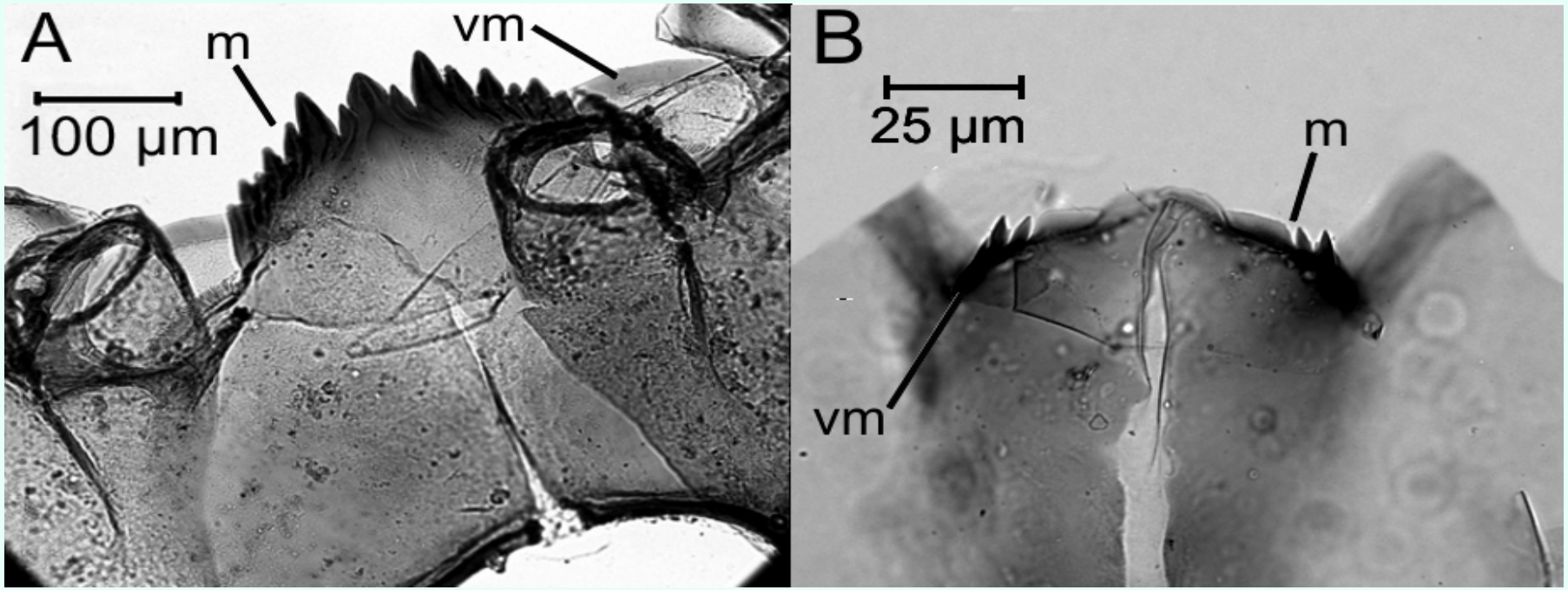
- Climatic changes
- Trophic oscillations
- Acidification
- Water-level changes

The Paleolimnological Method

Chironomids as Indicators of Environmental Change

Hypolimnetic oxygen

- Climate
- Salinity
- Lake productivity



Photographs taken by Saloni Clerk

From Smol 2008

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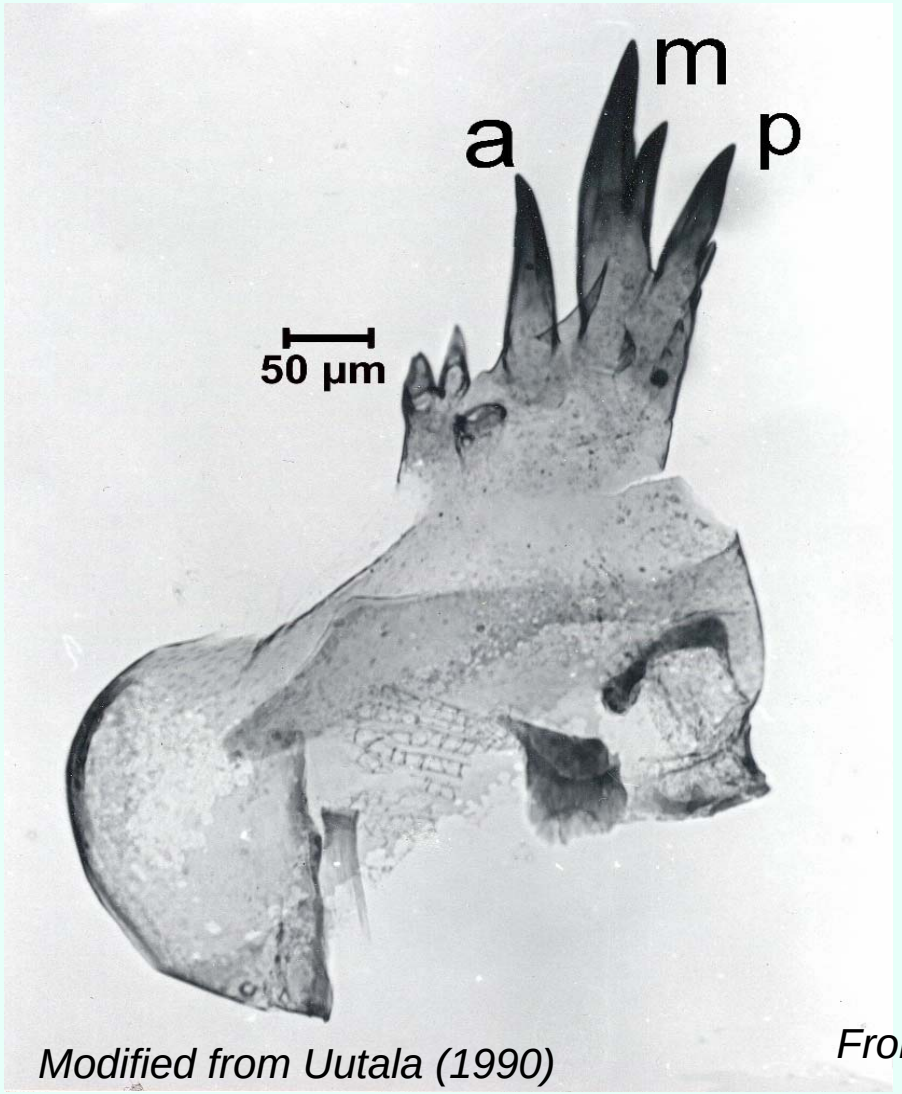
Chaoborus as Indicators of Environmental Change



Modified from Uutala (1990)

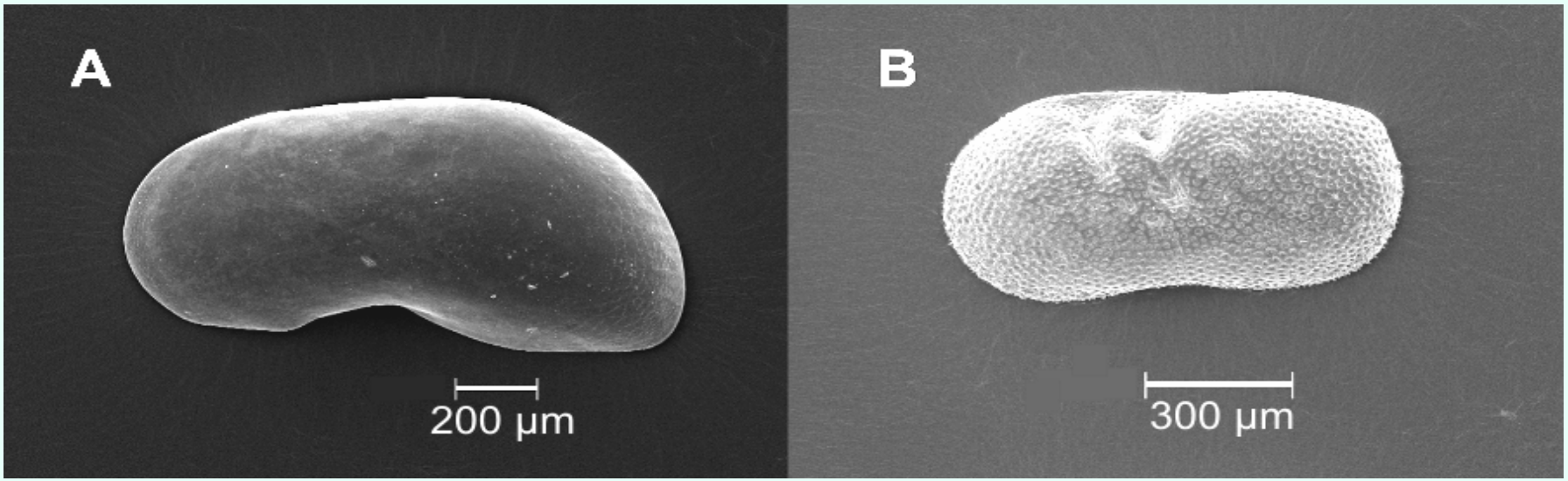
Chaoborus americanus – presence of this taxon is a good indication of fishless conditions

From Smol 2008

The Paleolimnological Method

Ostracodes as Indicators of Environmental Change

- Nutrient status
- Salinity
- Temperature
- Chemical composition of their host water
- Trace element (especially Mg and Sr) content and stable isotope ($^{18}O/^{16}O$ and $^{13}C/^{12}C$) ratios of their shells reflect important limnological variables such as water temperature, water chemistry, and productivity.



Photographs by Jordon Bright

From Smol 2008

The Paleolimnological Method

Sedimentary Pigments as Indicators of Environmental Change

From Leavitt and Hodgson (2001): *In*:J. P. Smol, H. J. B. Birks & W. M. Last (eds.), 2001. *Tracking Environmental Change Using Lake Sediments. Volume 3:Terrestrial, Algal, and Siliceous Indicators*. KluwerAcademic Publishers, Dordrecht, The Netherlands.

Pigments from algae, phototrophic bacteria and higher plants often preserve in lake sediments long after all morphological structures have disappeared.

These lipophilic molecules are widespread in suitable sedimentary environments (organic, anoxic, aphotic).

Fossil pigments are now used as indicators of a wide variety of ecological questions/problems including algal and bacterial community composition, changes in the physical structure of lakes, as well as anthropogenic impacts on aquatic ecosystems, including eutrophication, land-use practices and climate change.

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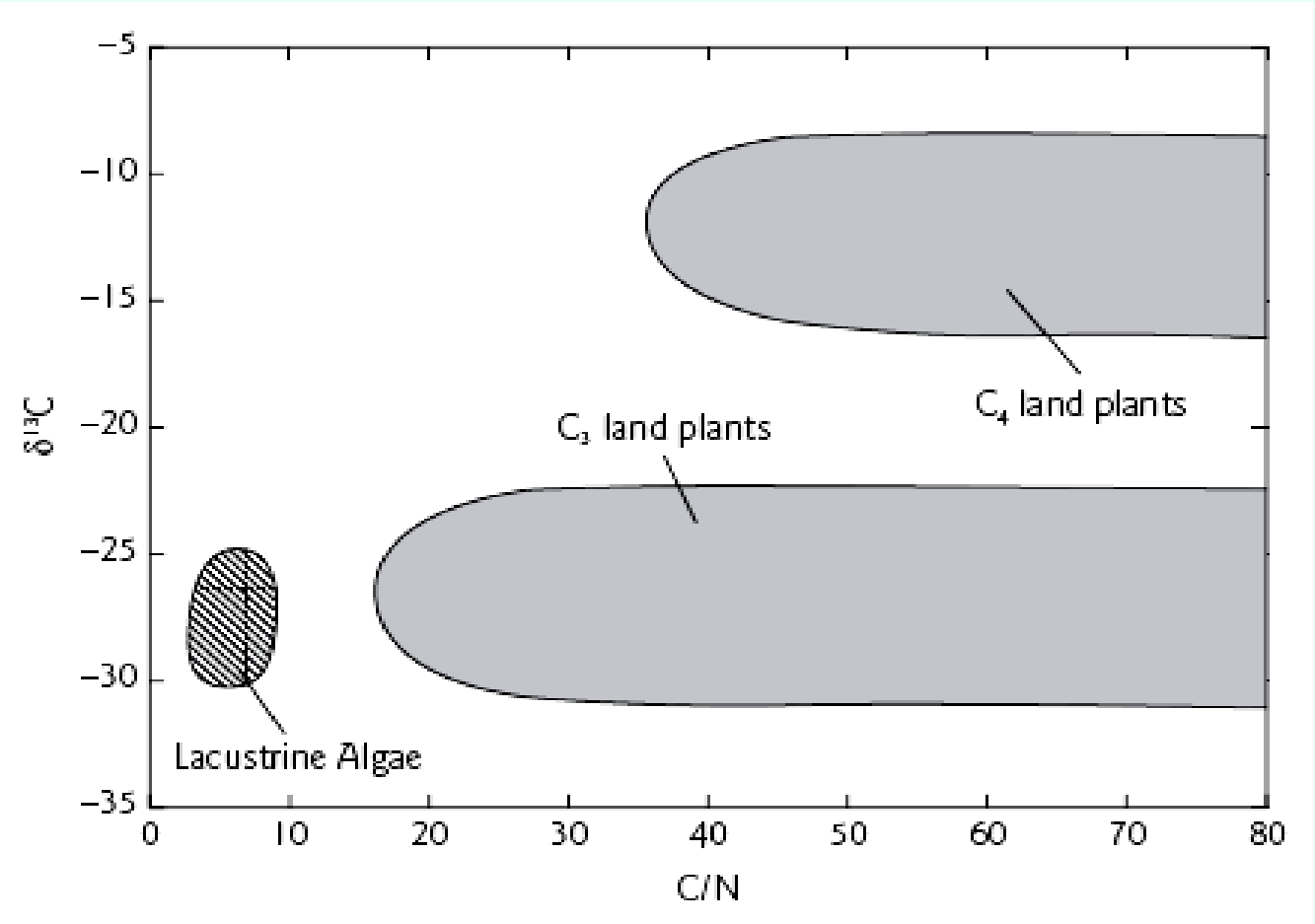
Stable Isotopes (C/N) as Indicators of Environmental Change

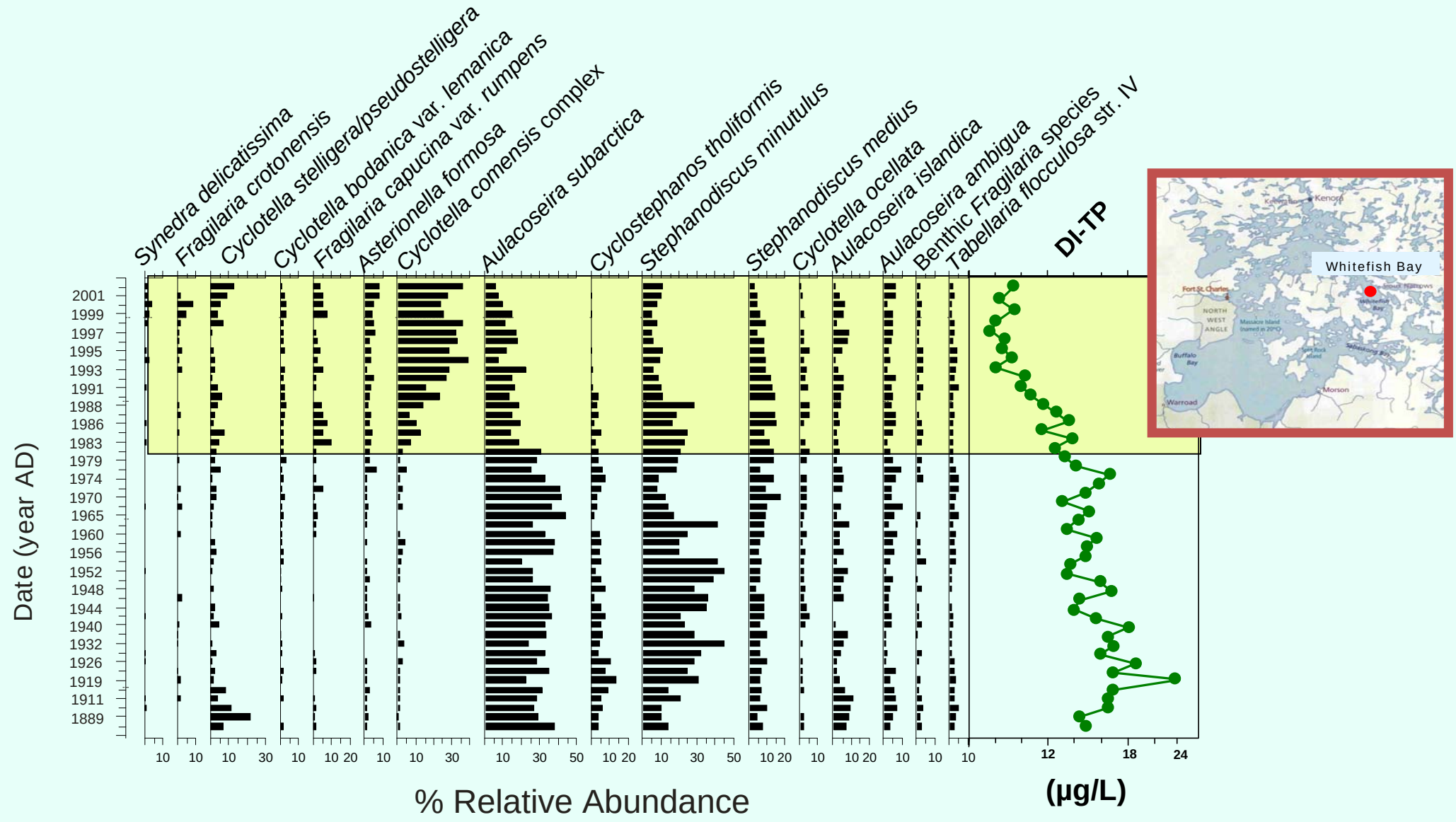


From Meyers and Lallier-Vergès (1999)

From Smol (2008)

A Dated Diatom Stratigraphy

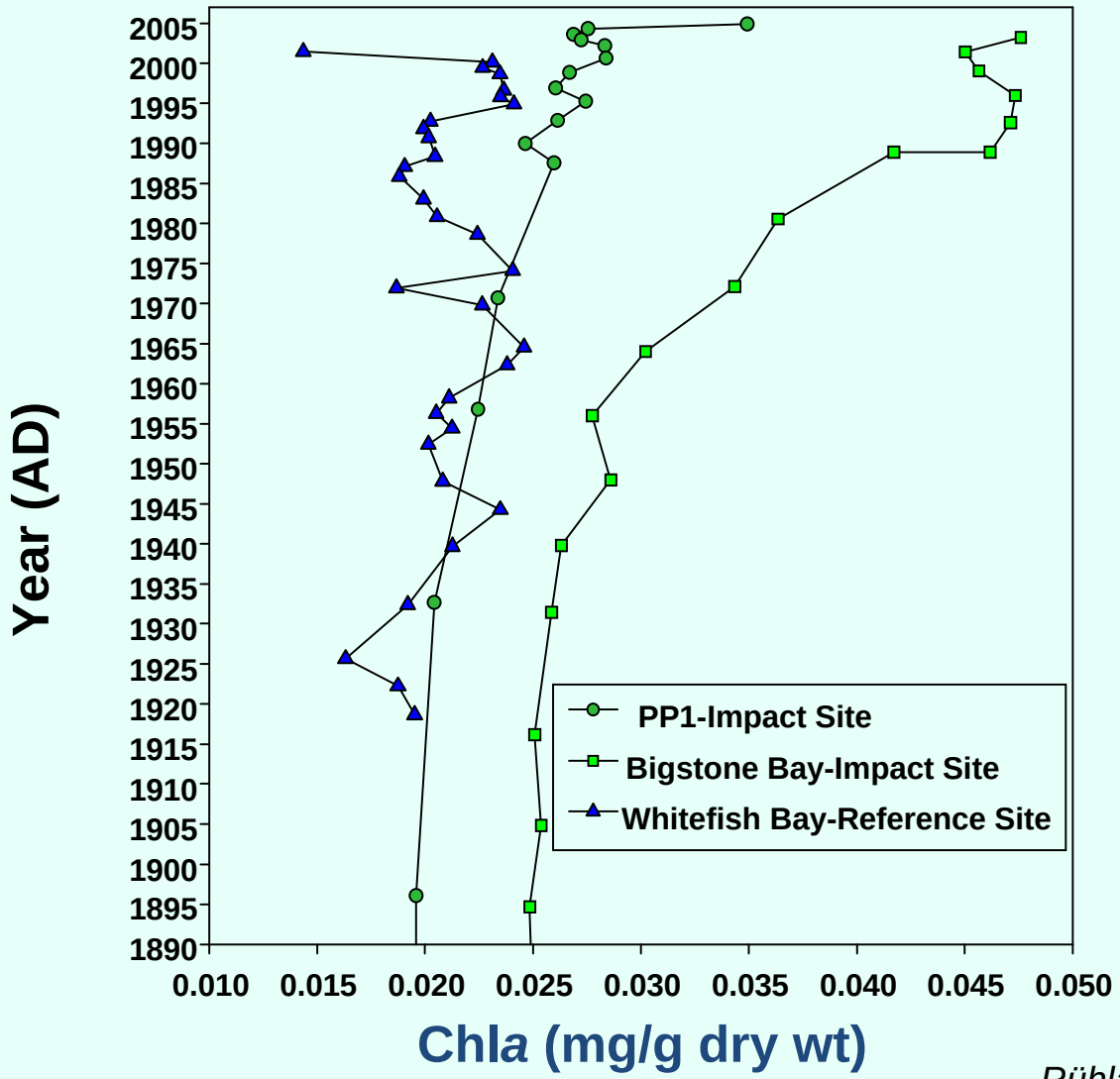
Whitefish Bay, Lake of the Woods: reference site



Rühland et al. in preparation

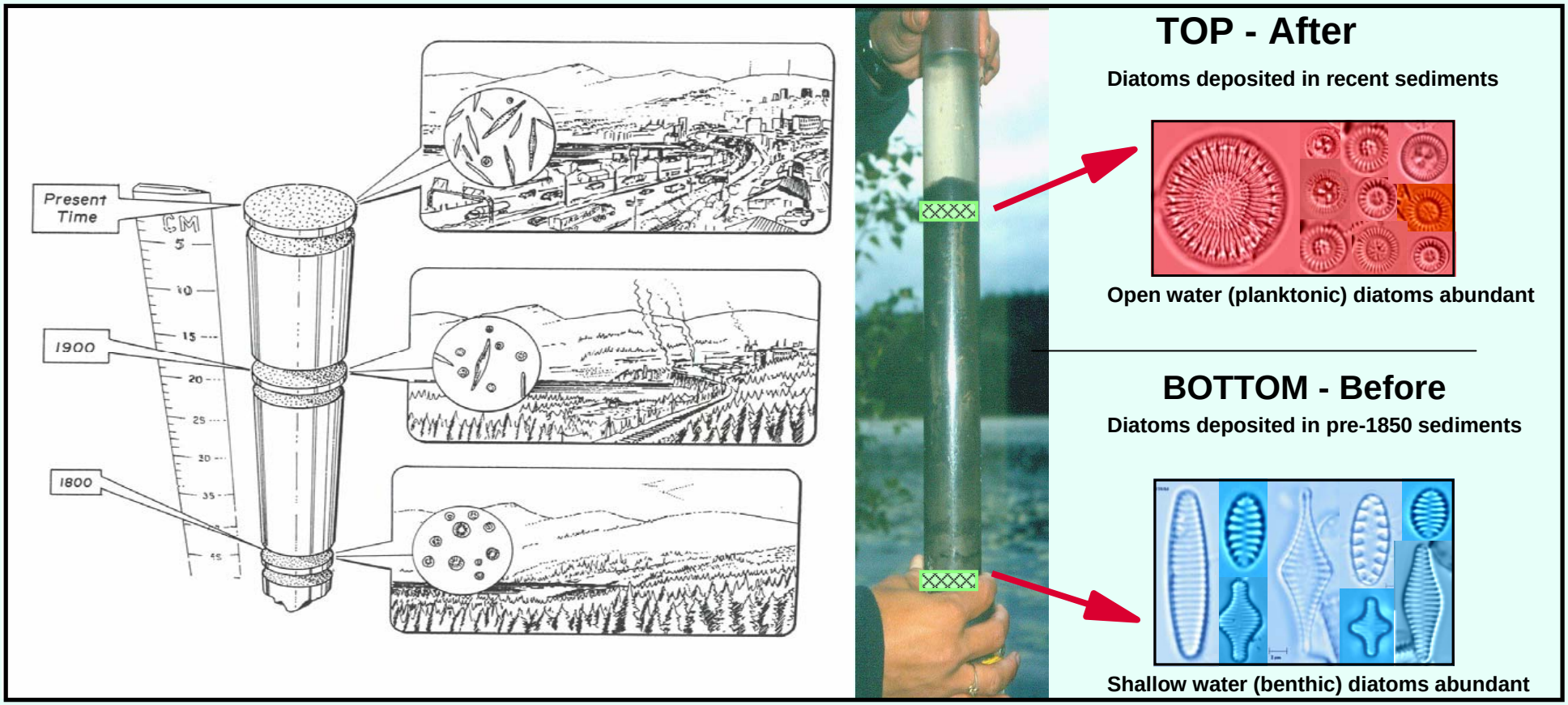
Lake of the Woods

An example of spectrally-inferred Chla trends from 3 sites in the LoW



Rühland et al. in preparation

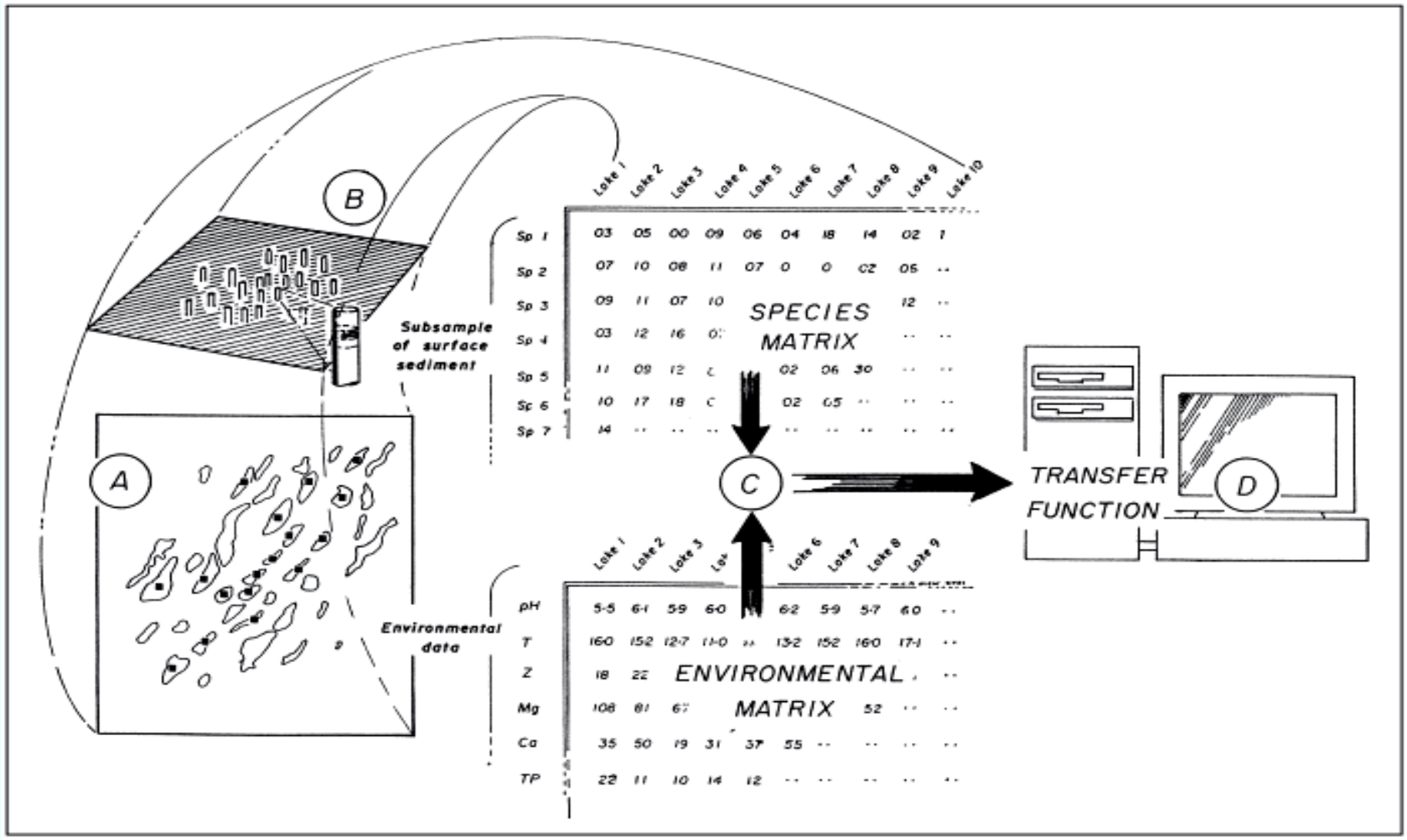
The “Top-Bottom” or “Before-After” approach in paleolimnology



Modified from Smol (2008)

Example from Rühland et al. 2003

Calibration sets: quantitative paleolimnological methods



From Smol (2008)

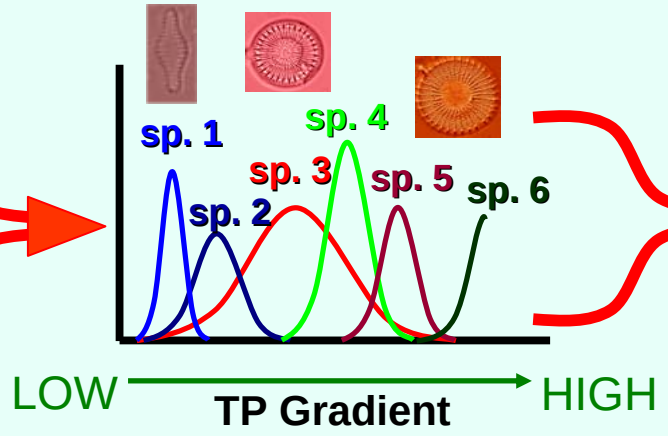
Development of a paleolimnological inference model

A

lake surface sediments

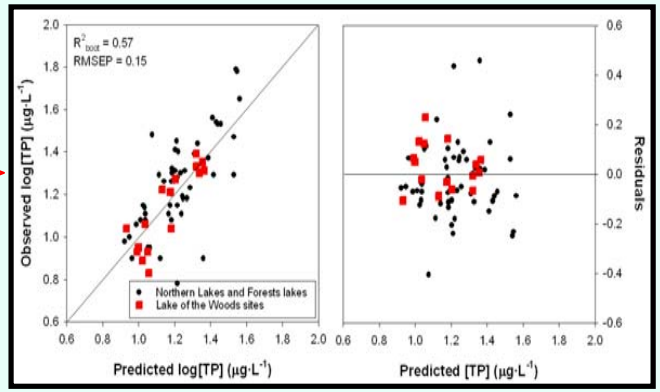
environmental data

B



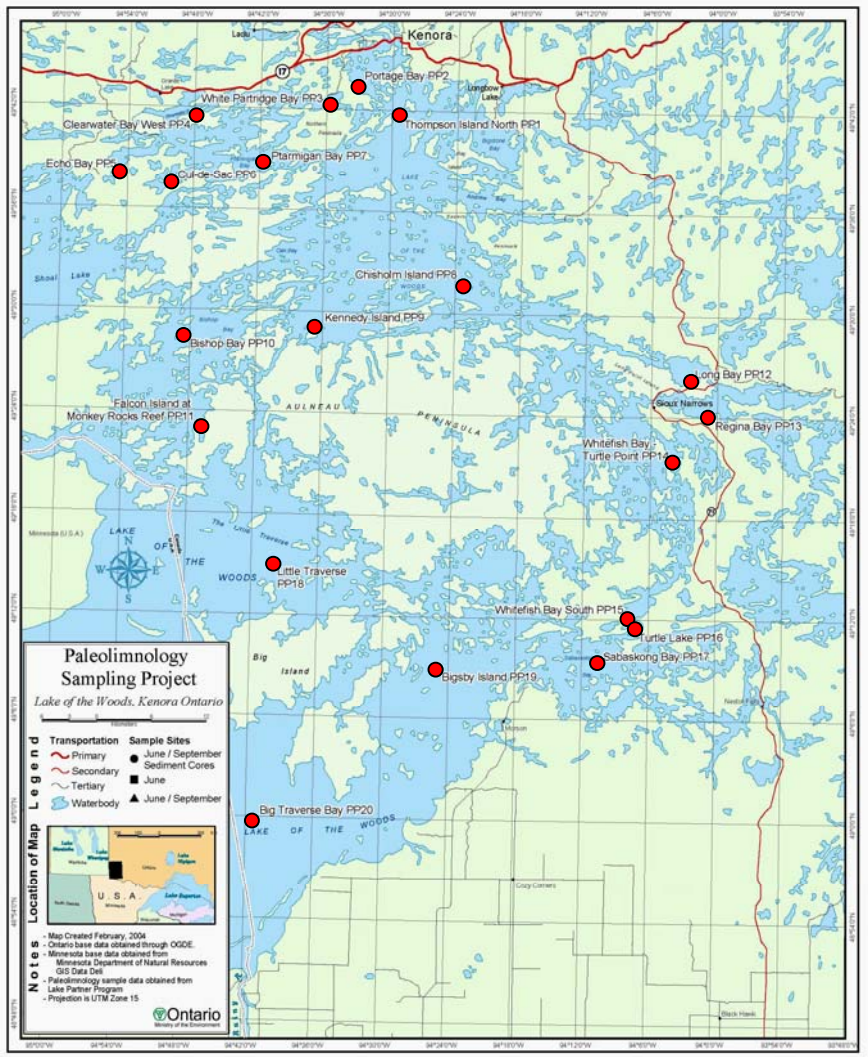
species response curves

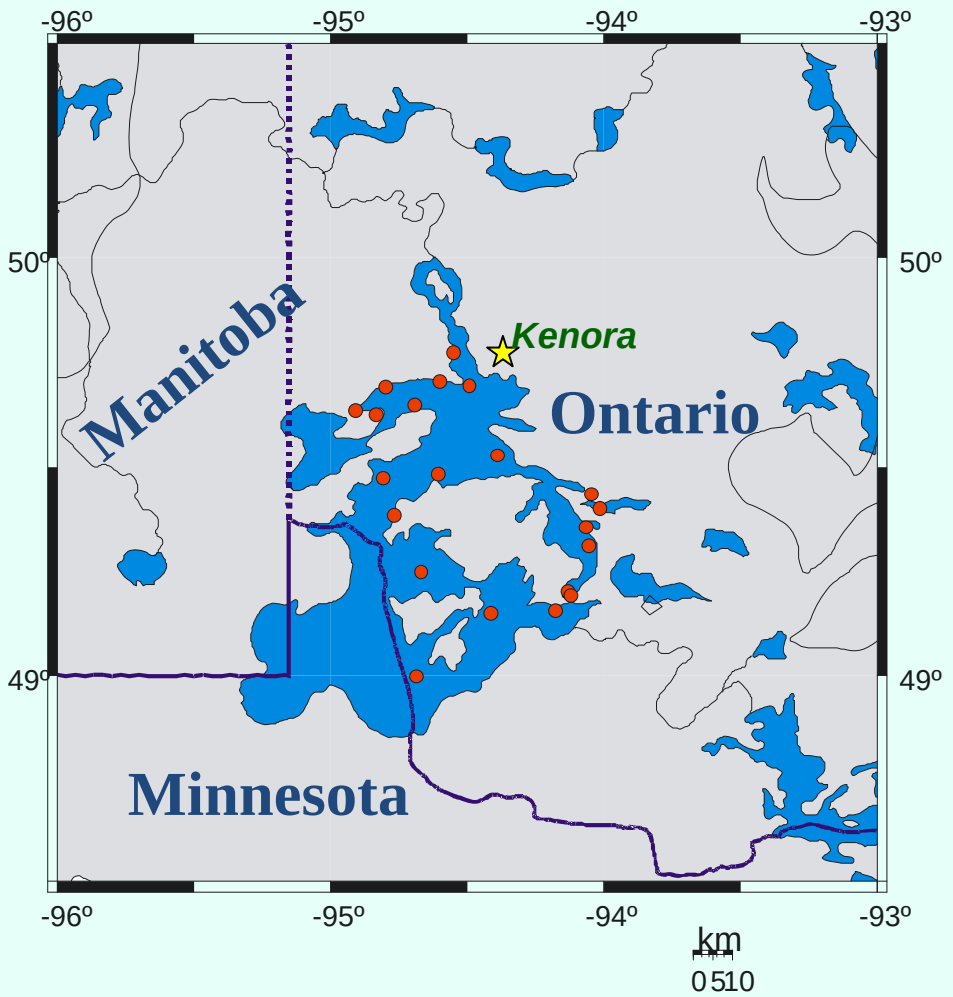
C



Model assessment

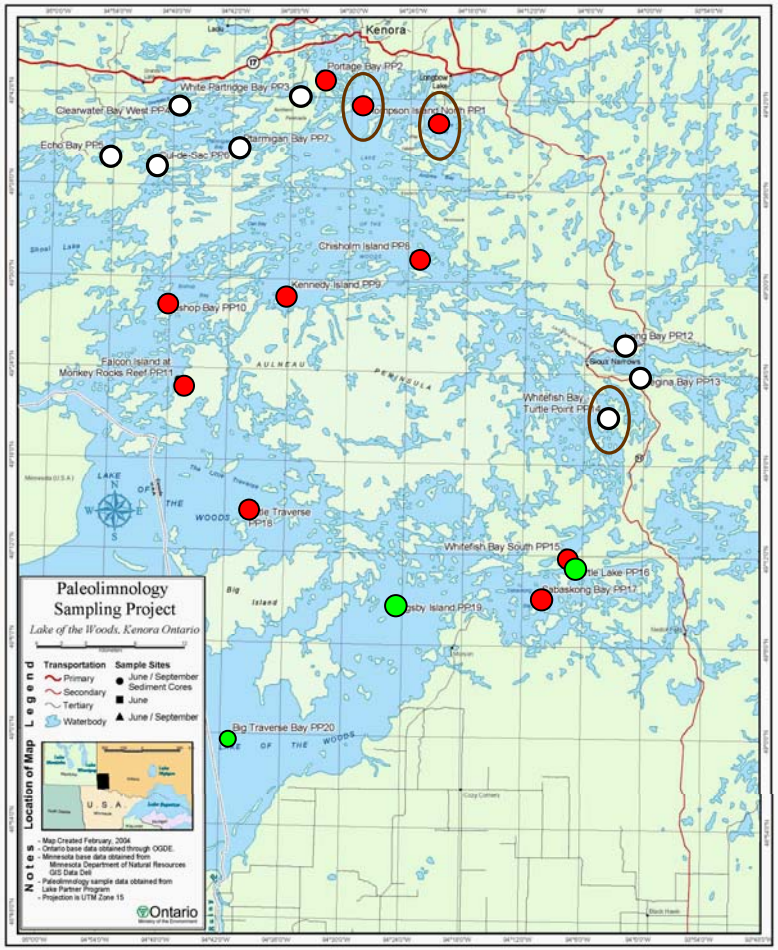
Developing Models for Total Phosphorus on the LoW

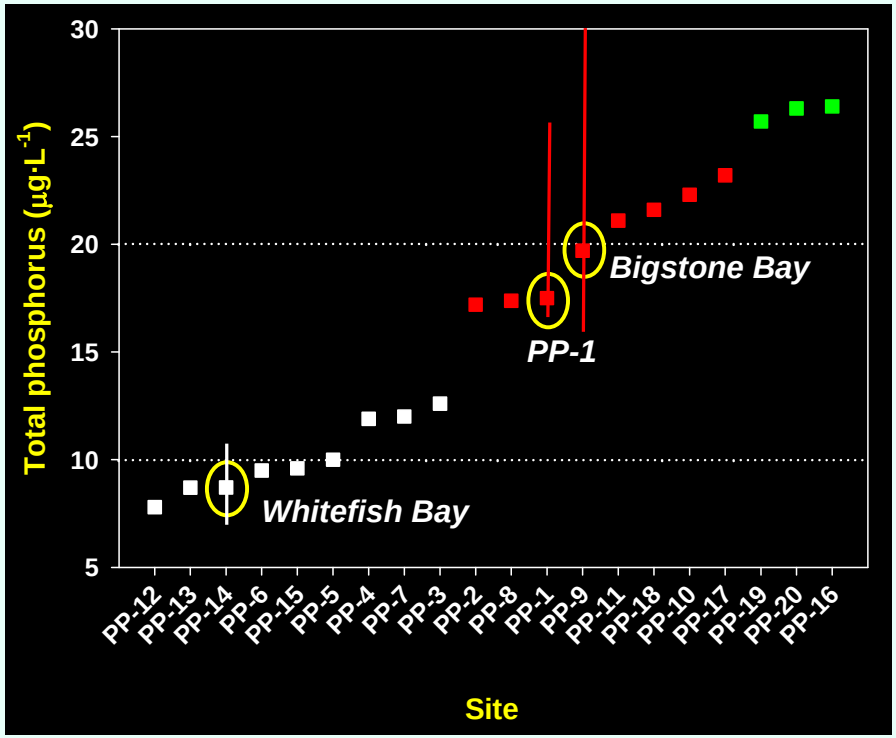




Lake of the Woods training set

Developing Models for Total Phosphorus on the LoW



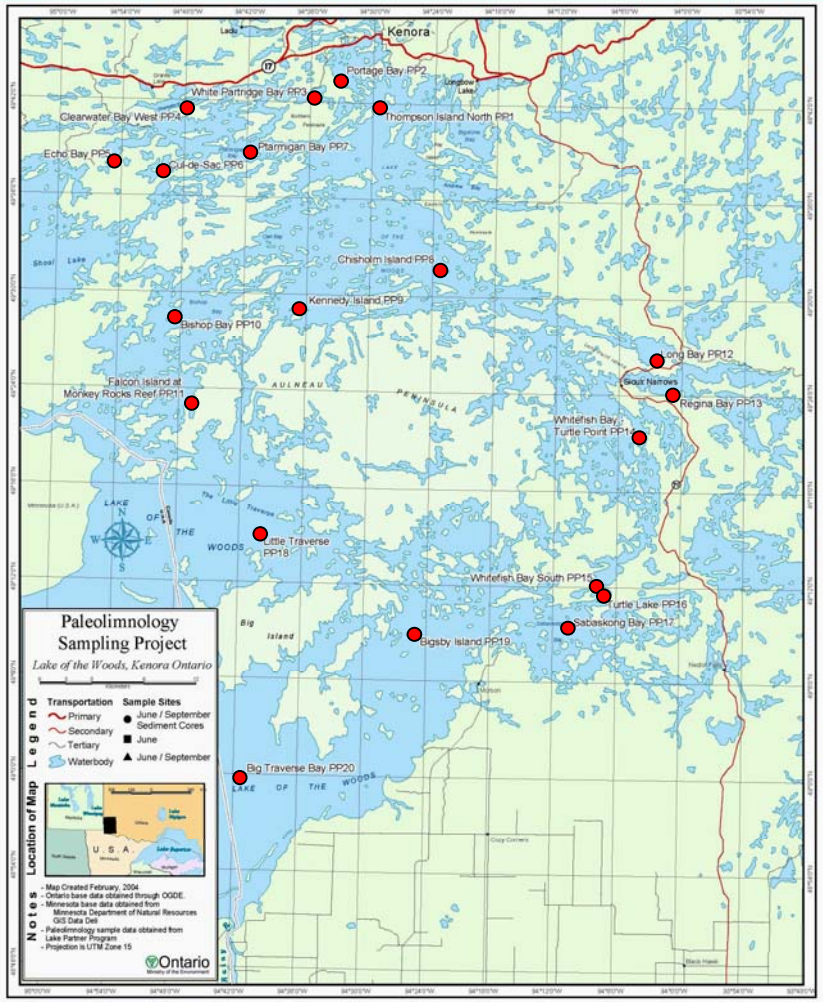


Summer measurements

Lake of the Woods training set

Developing Models for Total Phosphorus on the LoW

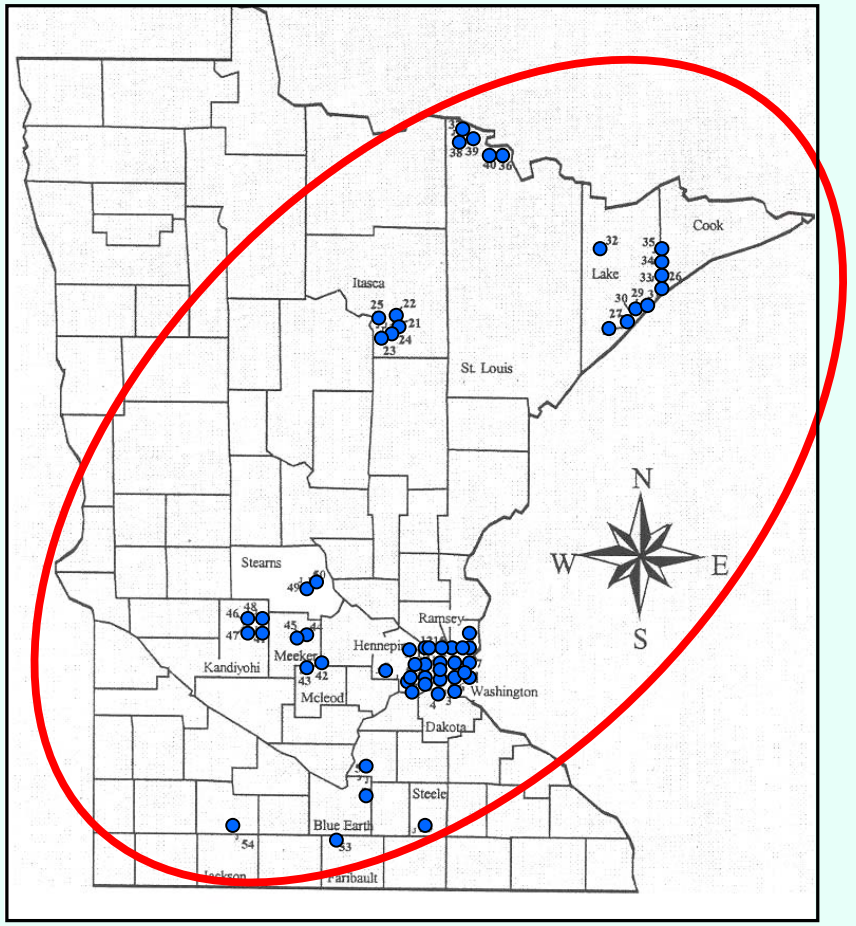
16 sites in LOW



Lake of the Woods training set

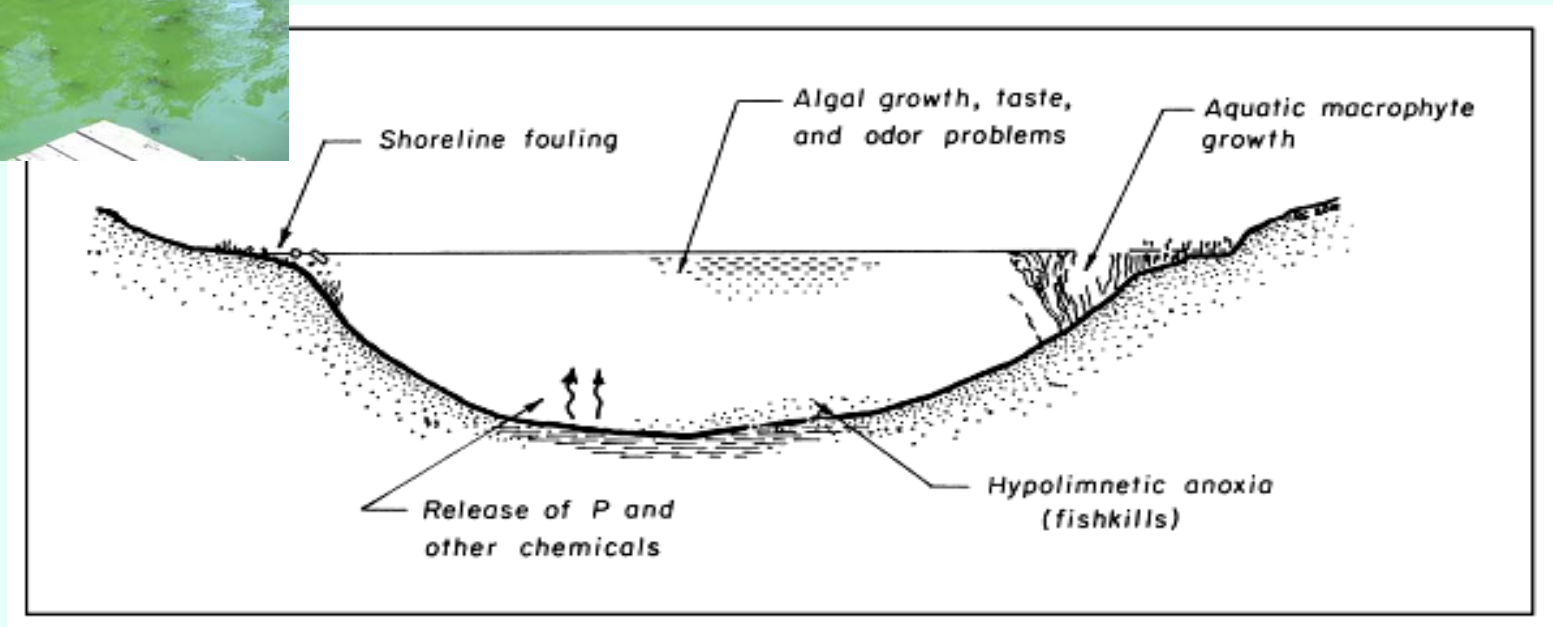
+

55 Minnesota lakes



Northern Lakes and Forests (NLF) sites

Eutrophication: an important water quality issue



From Smol (2008)

Development of an Algal Bloom on the LoW- 2003

(Terra MODIS images – G. McCullough, U. of Winnipeg)

Algal blooms on the LoW

- Total phosphorus (TP) is an important, limiting nutrient for algal growth
- Much interest in determining whether TP has changed historically

Long-term data are essential for understanding environmental & ecological problems

- ***Has TP been historically high in LoW?***
- ***Has TP increased recently?***

- Historical documents back to early 1820s describe algal blooms on the LoW

Some Important Lake Management Questions:

1) What is the ‘natural’ or baseline condition of the lake?

2) Has the water quality changed since pre-development (or pre-industrial) times?

3) If so, when did these changes occur?

4) What is the direction and magnitude of this change?

5) What are the possible reasons for this change?