

# Paleolimnologie

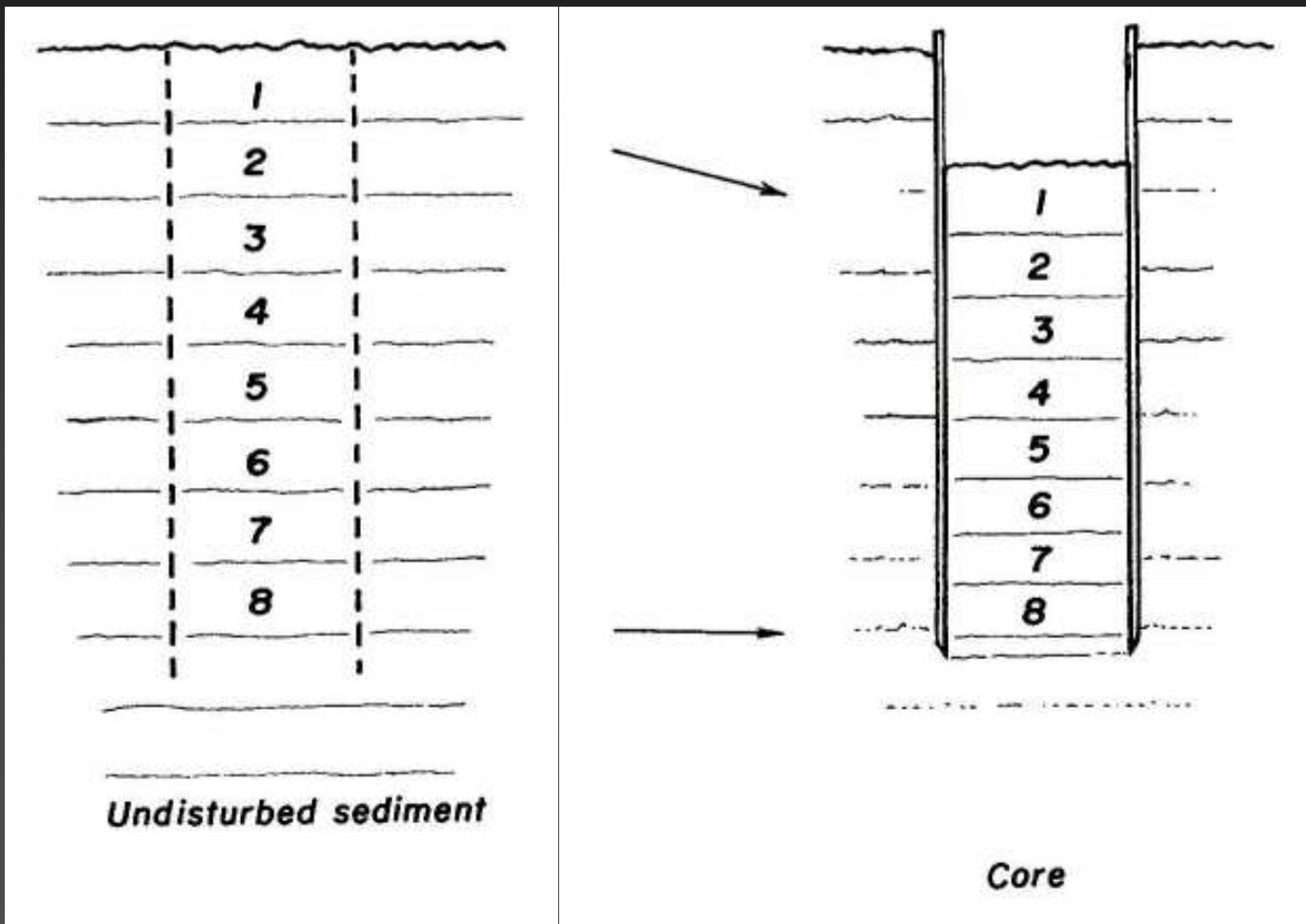
- interpretace minulosti jezera a povodí
- metody vzorkování
- datování
- fyzikální a chemické metody
- biologické indikátory
- stabilní izotopy
- vývoj jezer – příklady
- zazemňování – pohřbené jezero Švarcenberk

# Paleolimnologie – historie jezer

- nauka o **vývoji jezer** (rašelinišť, krajiny)
- historie odvozená z **rozboru sedimentů**
- interpretace **minulých podmínek a procesů v povodí**  
(eroze/land use, eutrofizace/acidifikace/znečištění)
- **multidisciplinární přístup** (fyzika, chemie, biologie)
- klíčová disciplína ve výzkumu **paleoklimatických a globálních změn**
- rozmach v posledních dekádách
- **bioindikátory** = specialisté na **taxonomii a ekologii**

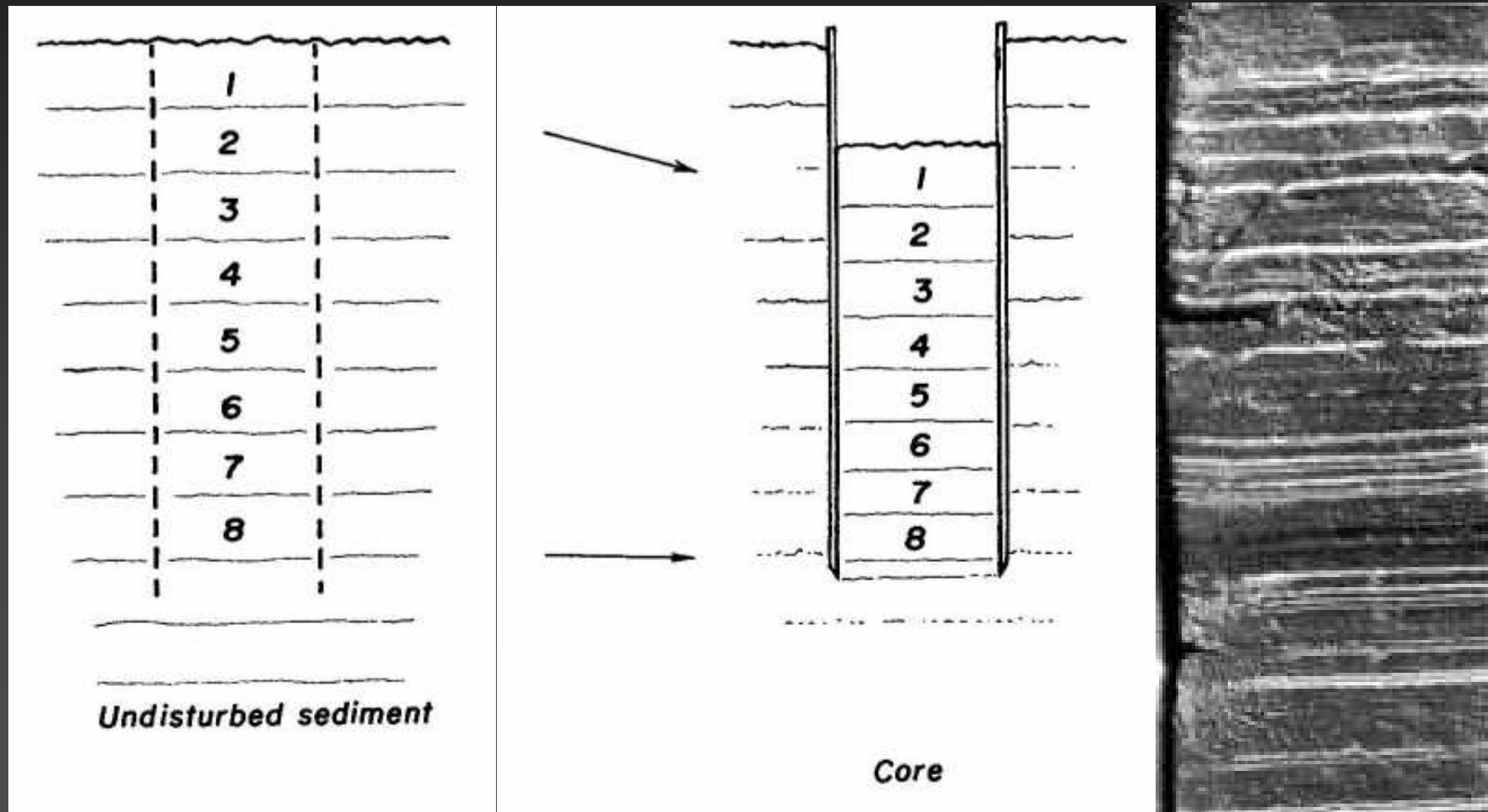
# Paleolimnologie – vzorkování sedimentů

tzv. **sediment core** (jádro)



# Paleolimnologie – vzorkování sedimentů

tzv. **sediment core** (jádro) / **deep-freeze core** (tekutý N)

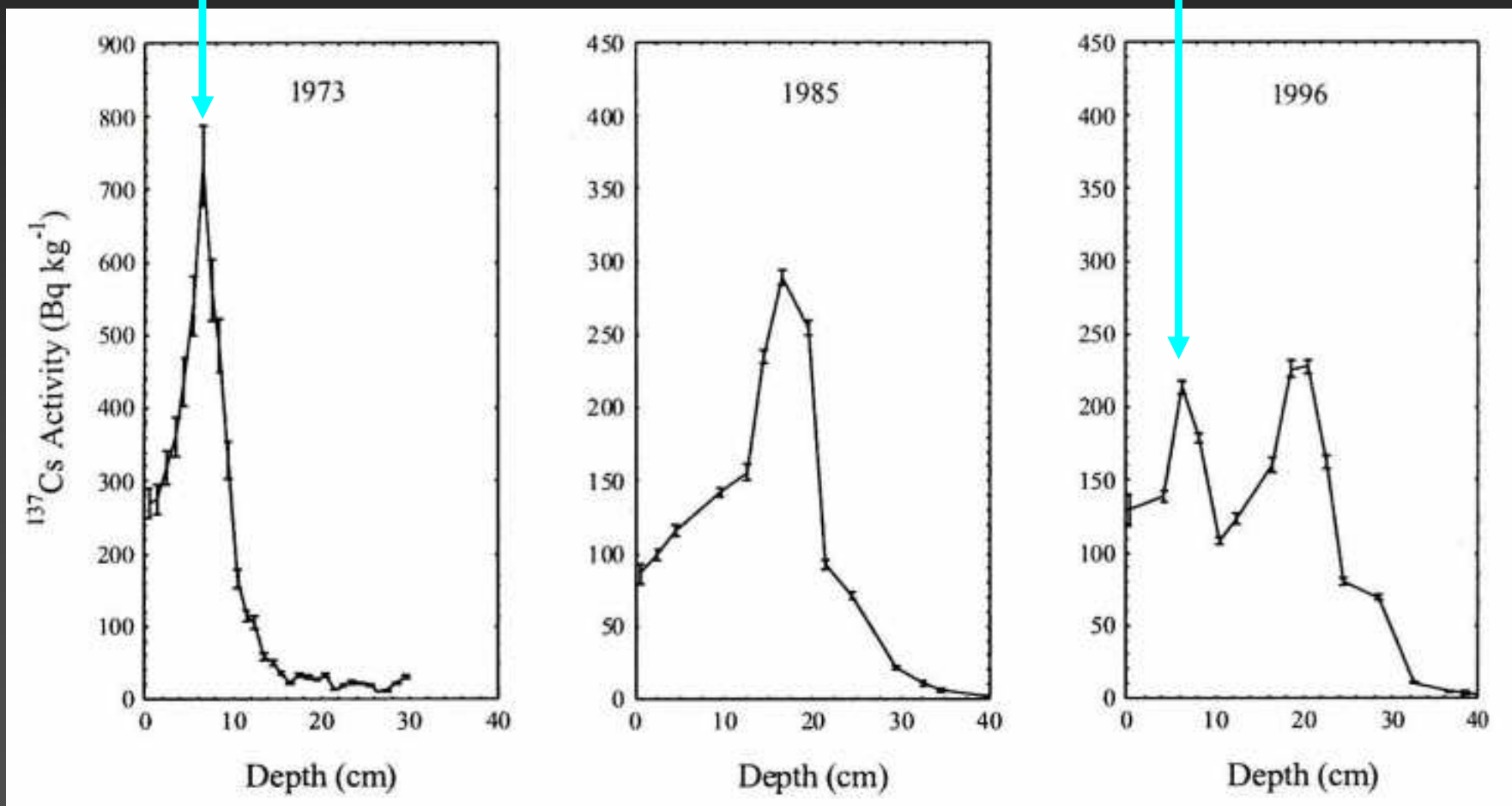


# Datování (recentních) sedimentů – chronologie

korelace: radionuklidové metody –  $^{137}\text{Cs}$

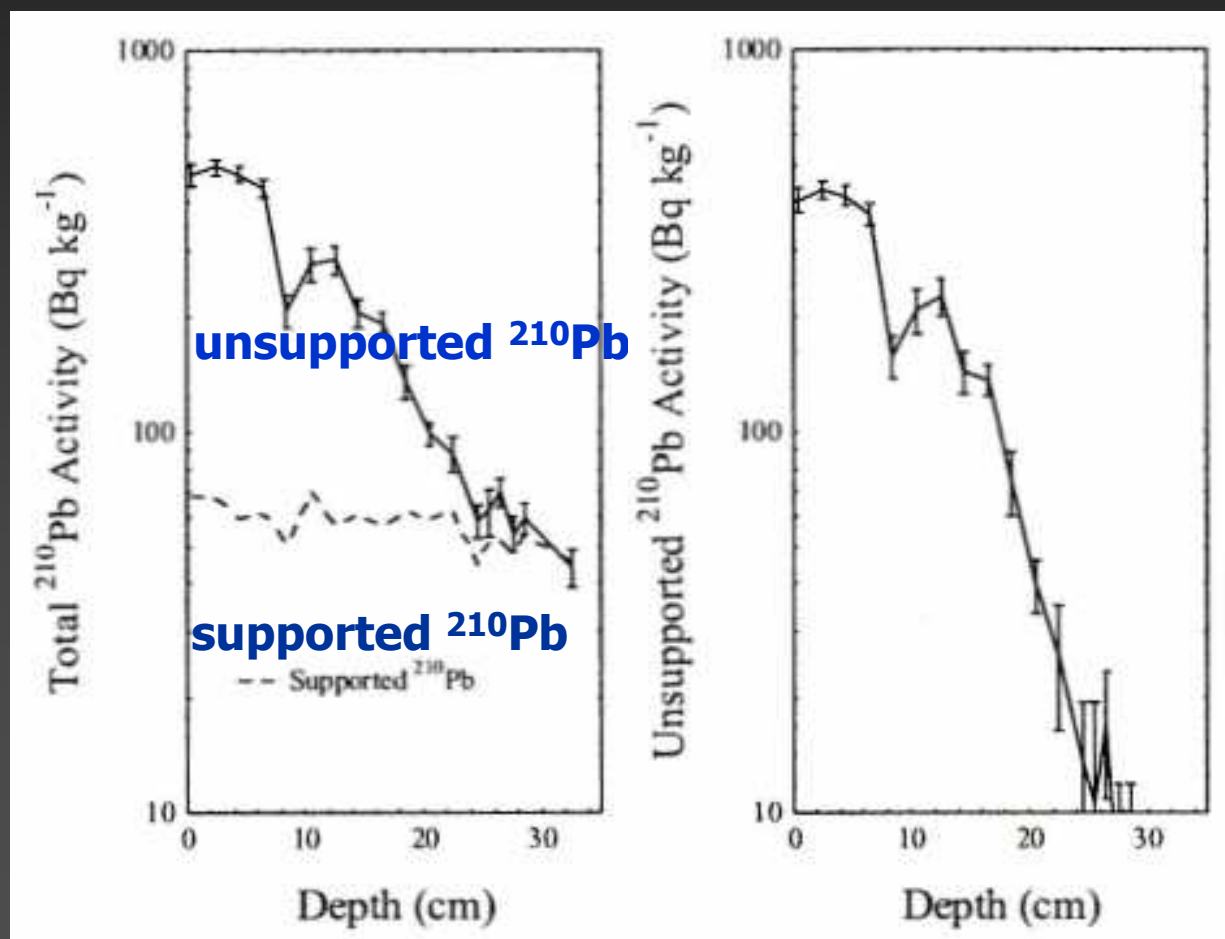
1963 (konec zkoušek v atmosféře)

1986 (Černobyl)



# Datování (recentních) sedimentů – chronologie

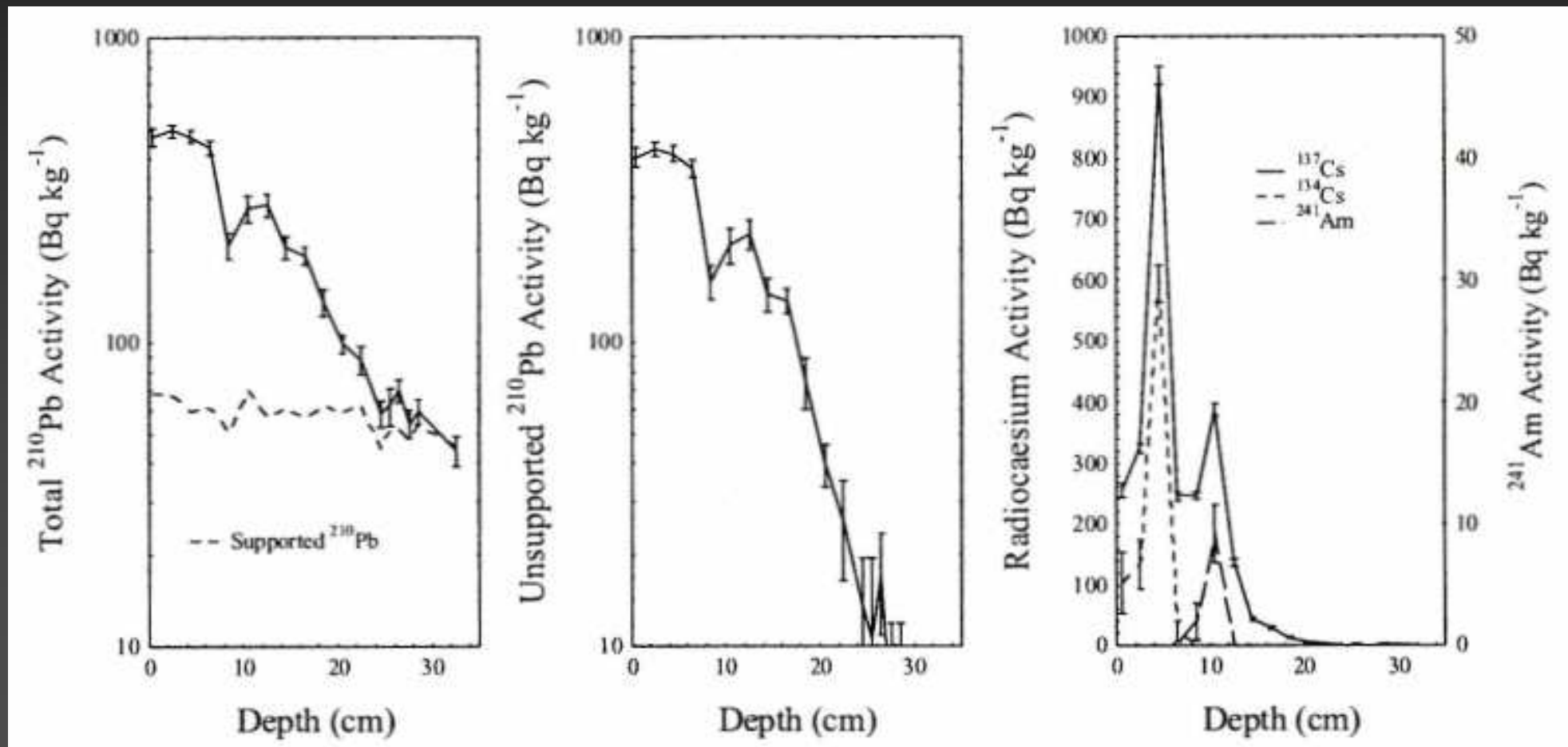
korelace: radionuklidové metody –  $^{210}\text{Pb}$  (22,3 r. = 0–150 let)



# Datování (recentních) sedimentů – chronologie

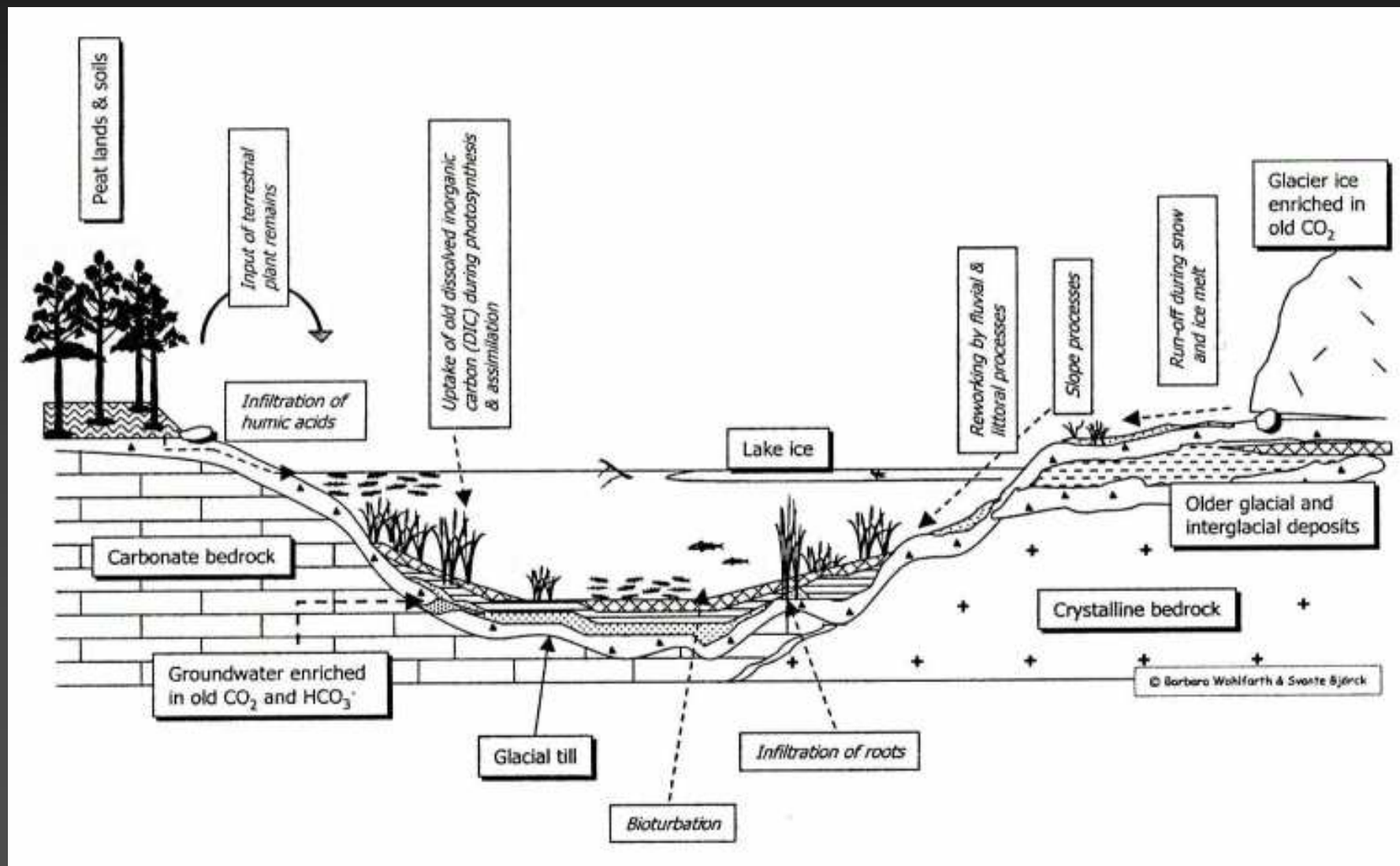
korelace: radionuklidové metody –  $^{210}\text{Pb}$ ,  $^{137}\text{Cs}$ ,

$^{134}\text{Cs}$ ,  $^{241}\text{Am}$



# Datování (glaciálních) sedimentů – chronologie

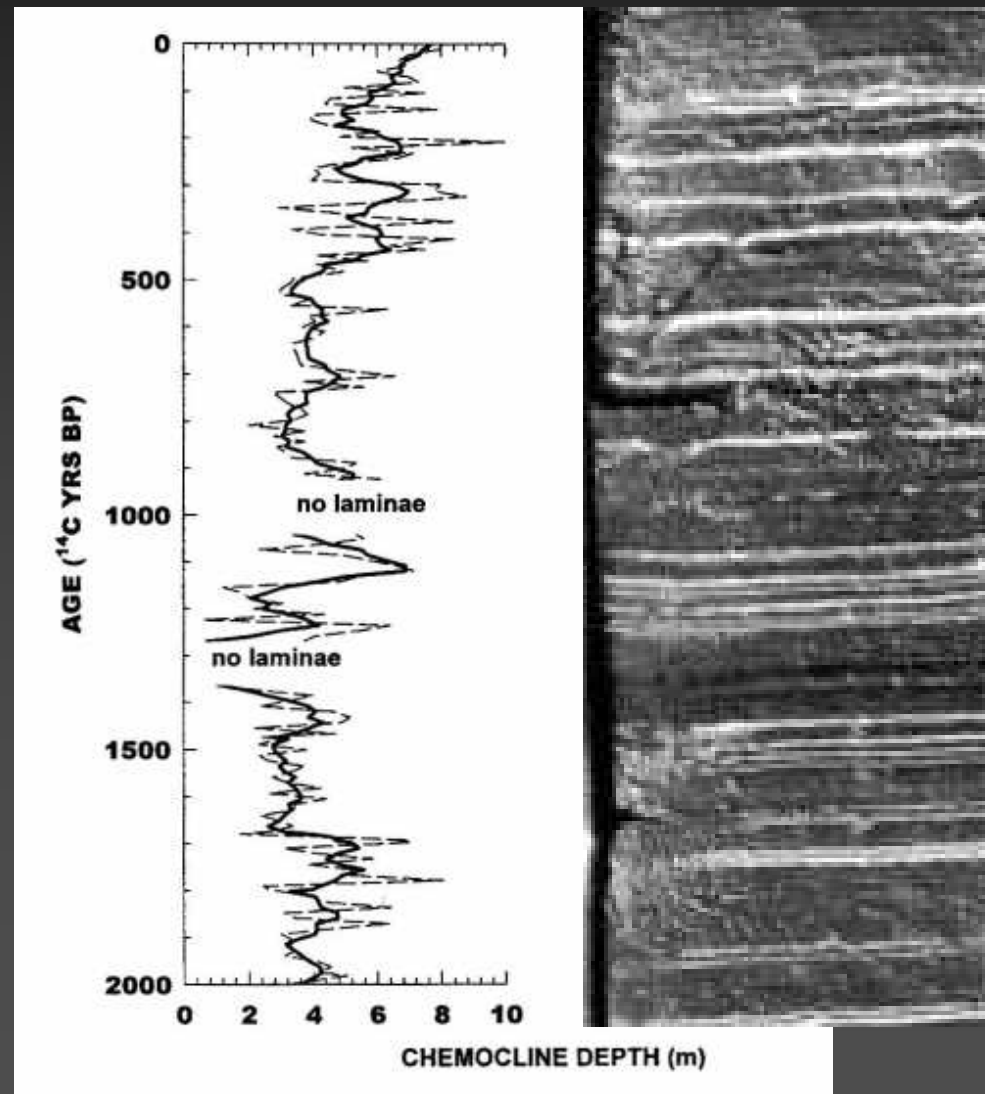
korelace: radionuklidové metody –  $^{14}\text{C}$  (5568 let =  $\sim 40$  tis. let)





# Indikátory enviromentálních změn

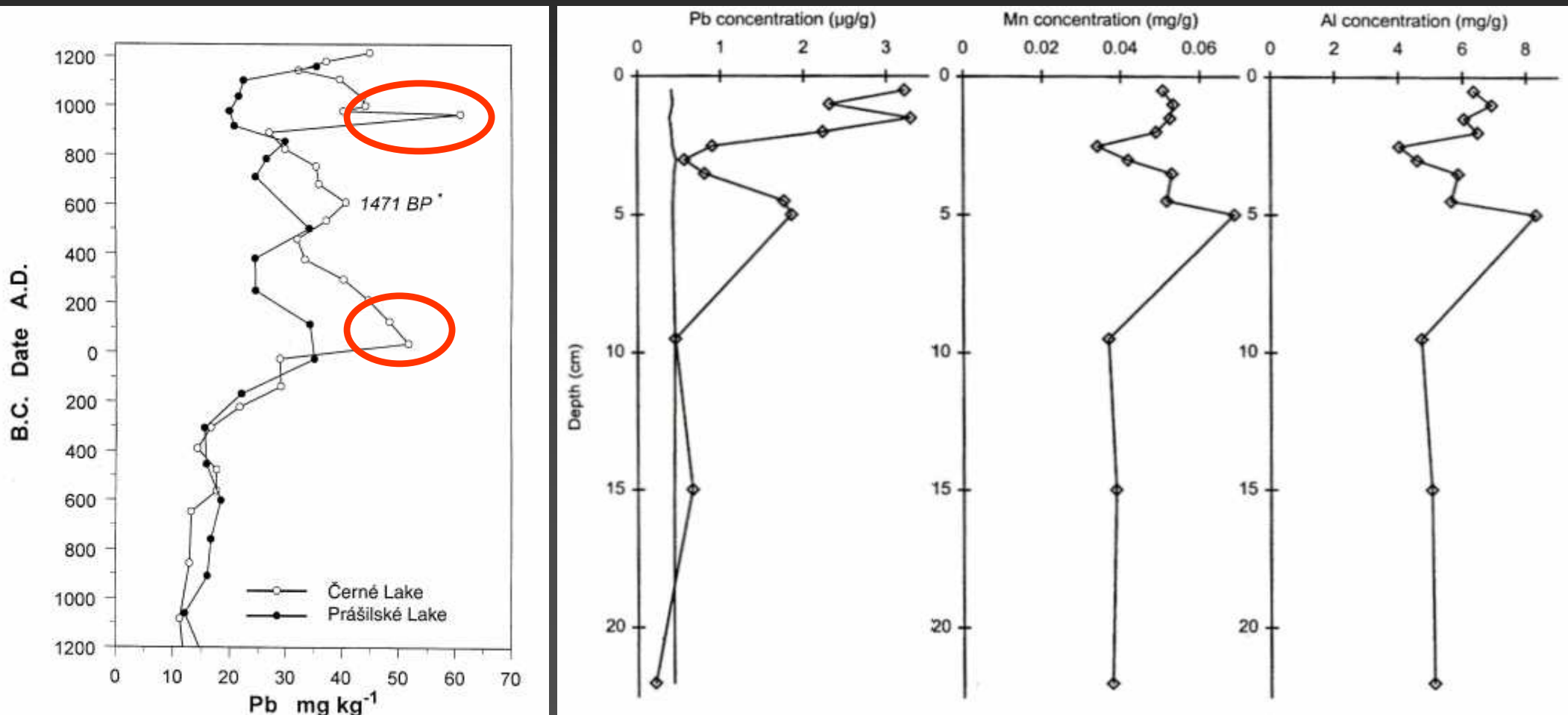
- **trofie a stratifikace** – obsah **P**, redox podmínky (poměr Fe:Mn), meromixie (aragonit) atd.



# Indikátory enviromentálních změn: dálkový přenos

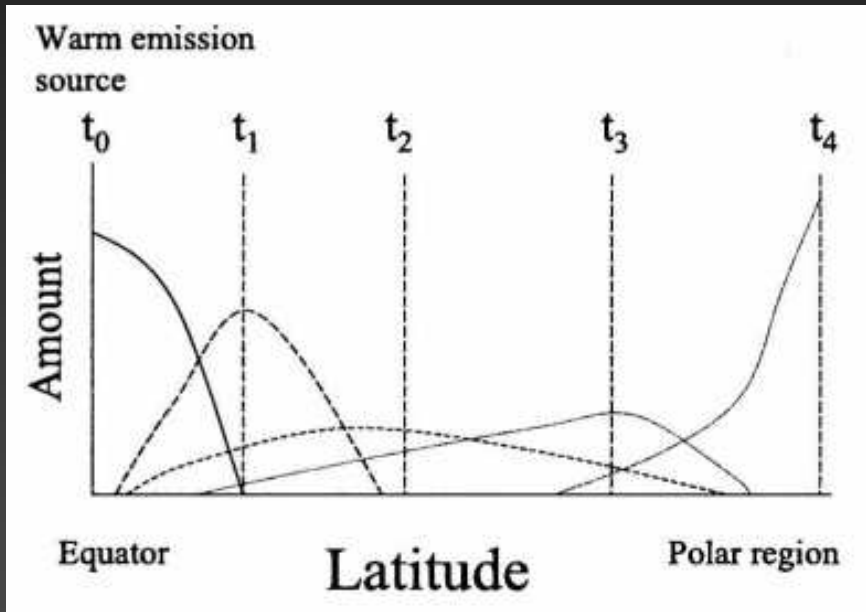
- znečištění – těžké kovy (Pb aj.)

Šumava – těžba Ag/Au Nunatak, Grónsko

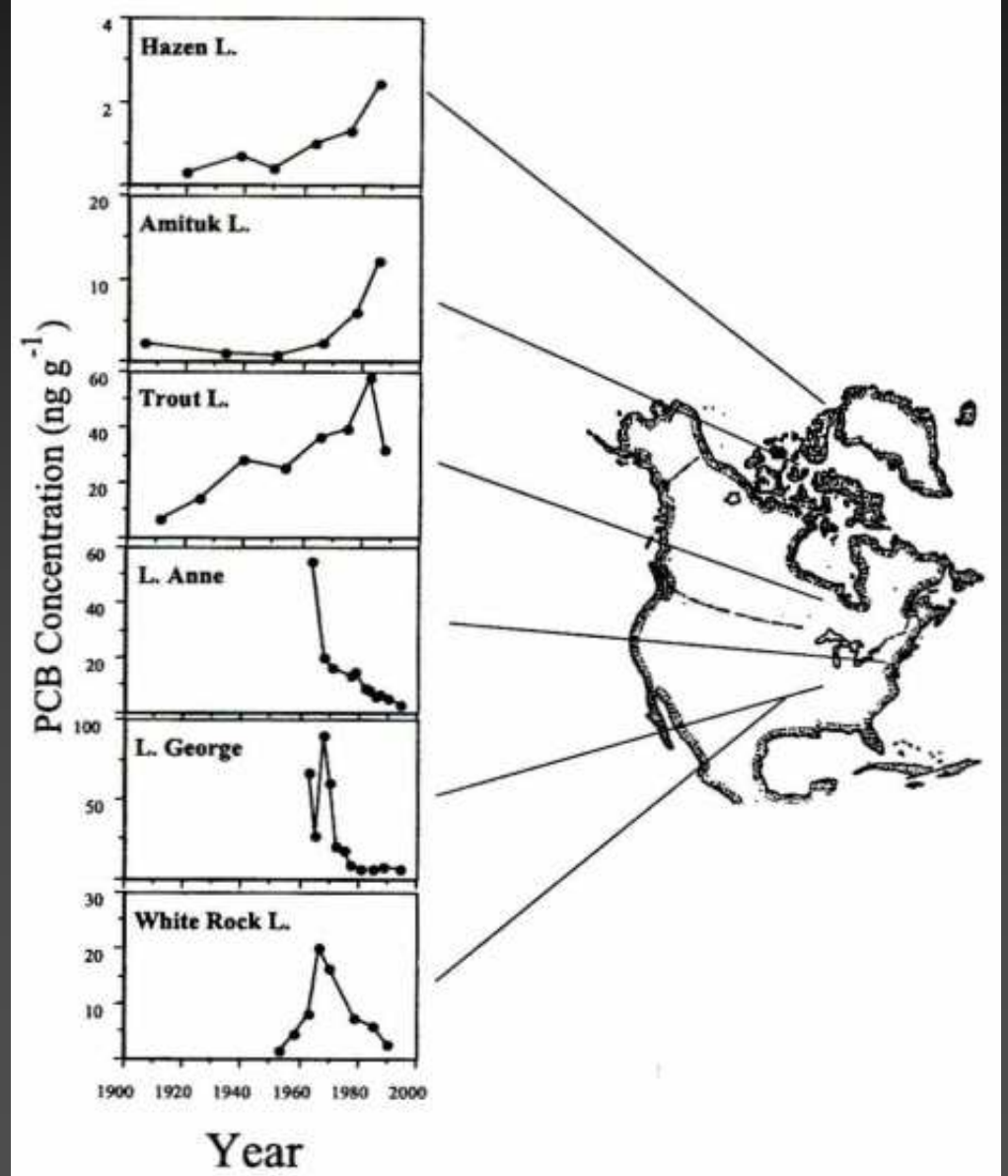


# Indikátory enviromentálních změn: dálkový přenos

- znečištění – těžké kovy, organické látky (PCB, PAC aj.)

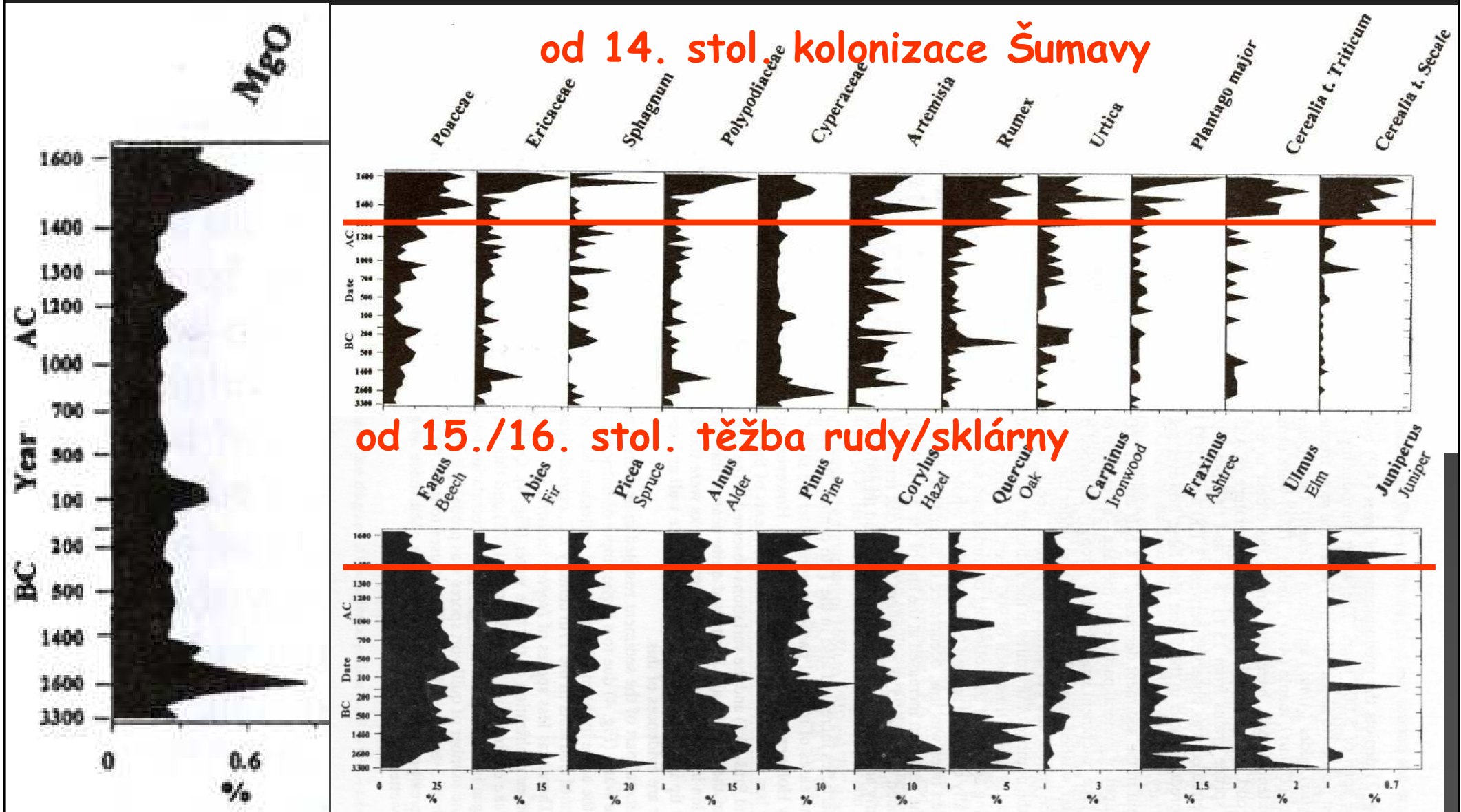


model globálního šíření  
těkavých perzistentních látek  
z teplých oblastí do chladných



# Indikátory enviromentálních změn: tzv. land use

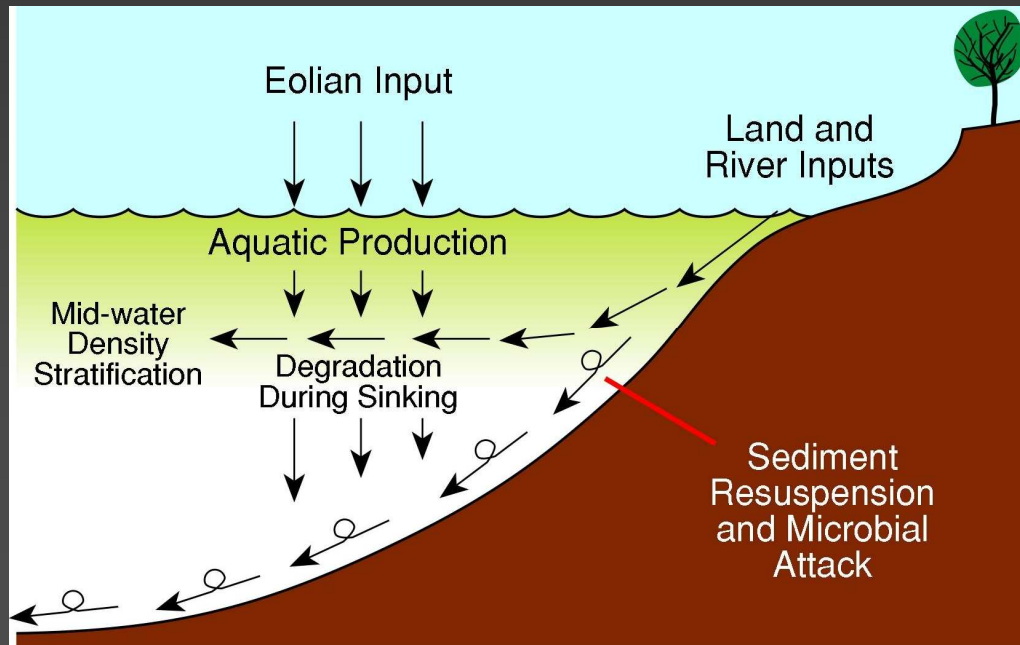
- (civilizační) změny v povodí: eroze (Mg), vegetace (pyl)...



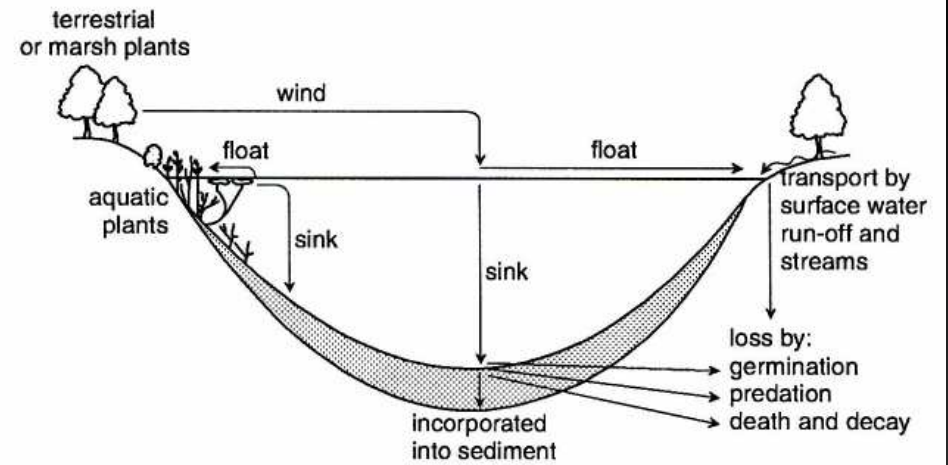
# Biologické indikátory

- mechanismy ukládání ?

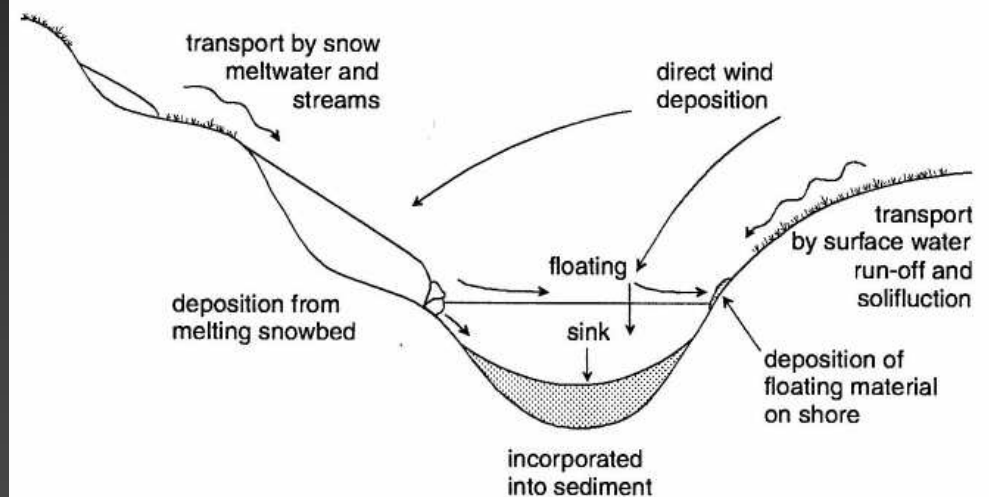
záleží na okolnostech =  
nebezpečí dezinterpretace !



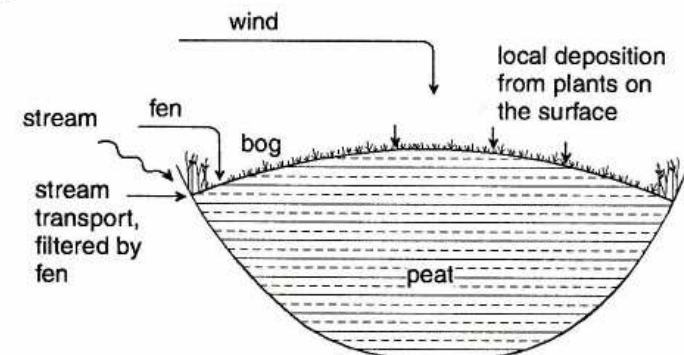
Temperate lake



Arctic or alpine lake



Bog / fen



# Biologické indikátory environmentálních změn

- tzv. **proxy** – např. dřevěné uhlí indikuje **požáry**

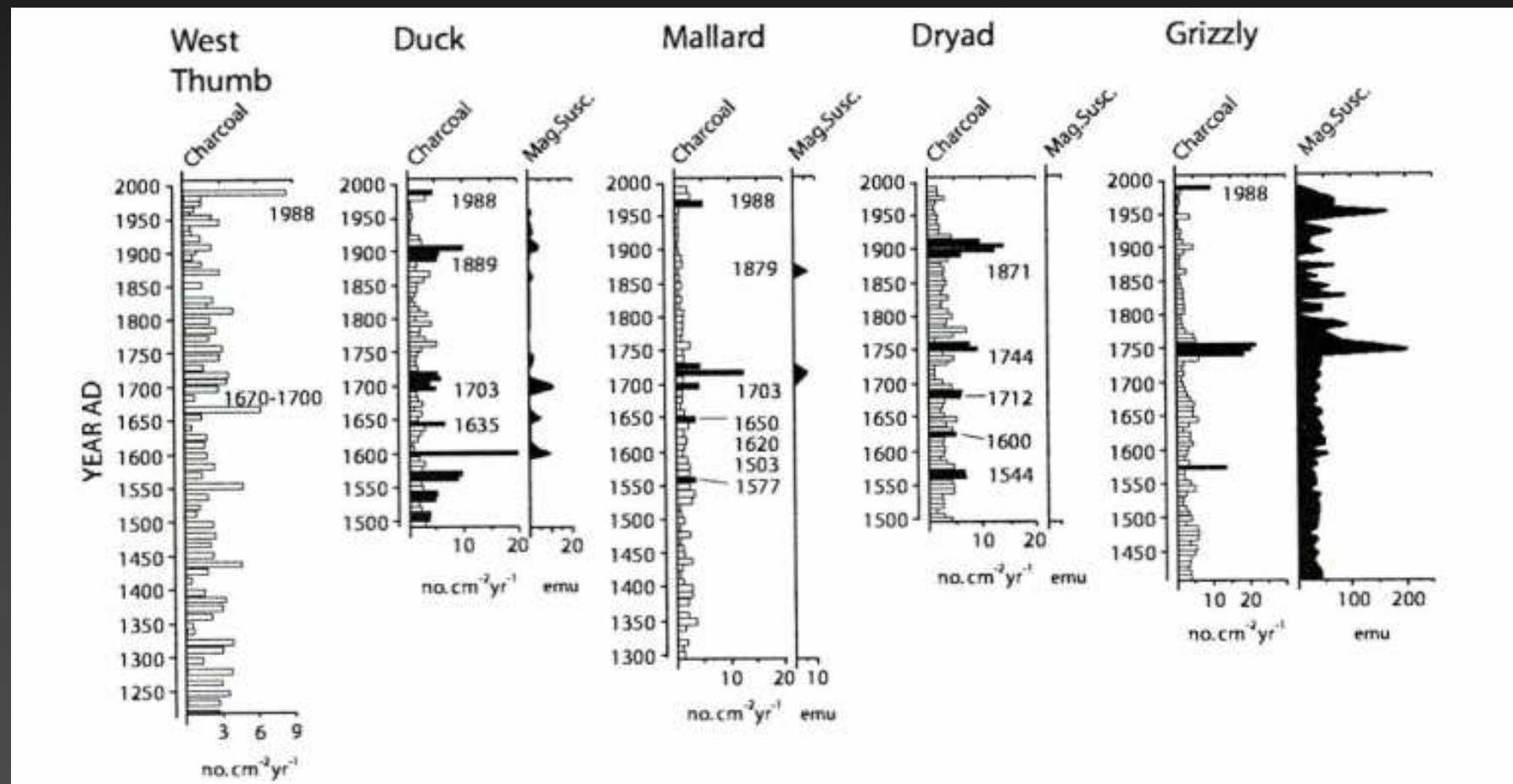
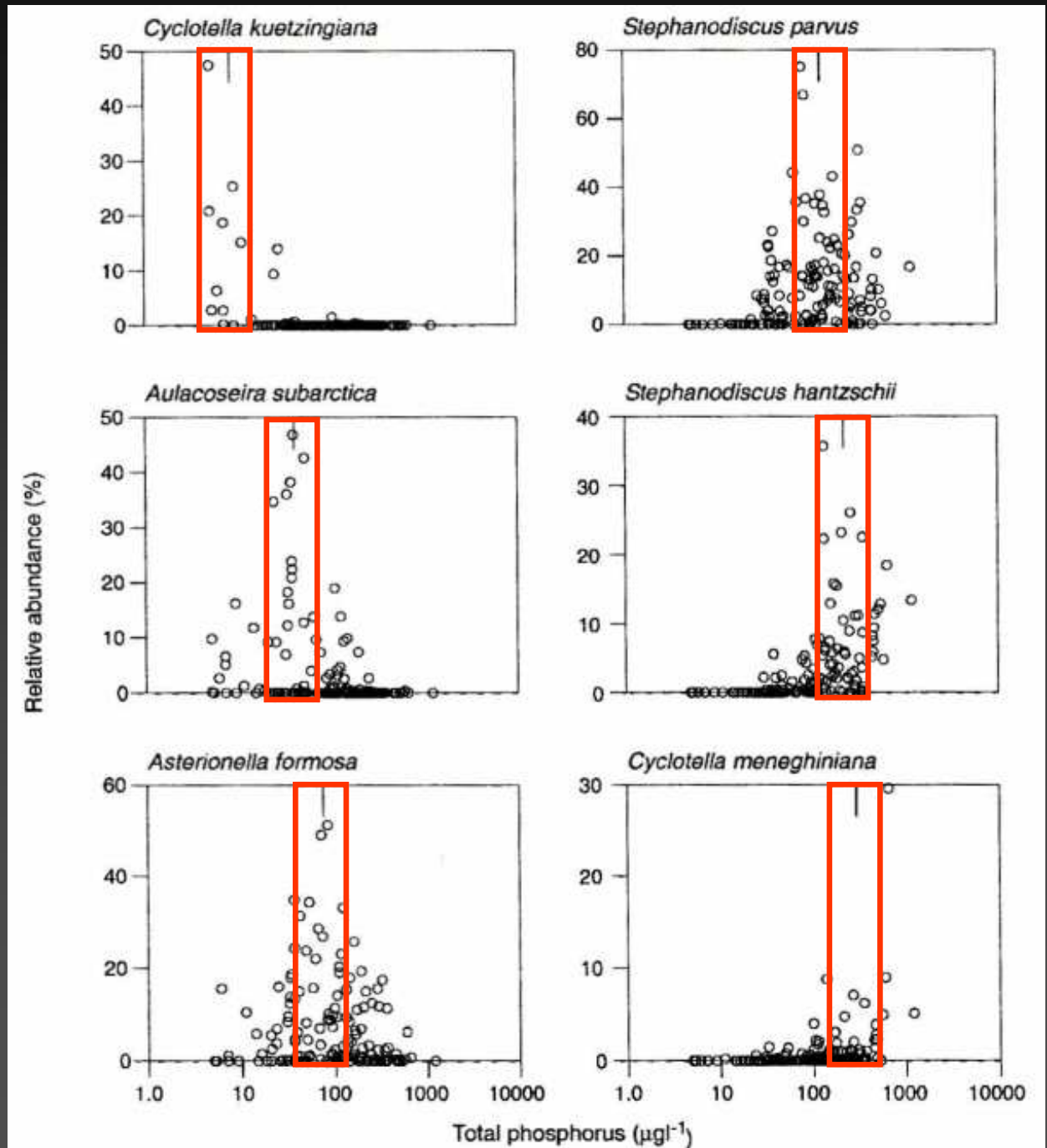


Figure 4. Charcoal accumulation rates (CHAR) and magnetic susceptibility (emu) from sediment cores from a large lake (>4250 ha) and four smaller (14–47 ha) lakes in Yellowstone National Park (after Millspaugh & Whitlock, 1995). Chronology is based on an age model extrapolated from a series of lead-210 dates. Black bars indicate charcoal peaks inferred to represent a local fire event. Dates of known local fires, based on tree-ring studies, are shown next to appropriate peaks. The stratigraphic record extends the fire history beyond the tree-ring record.

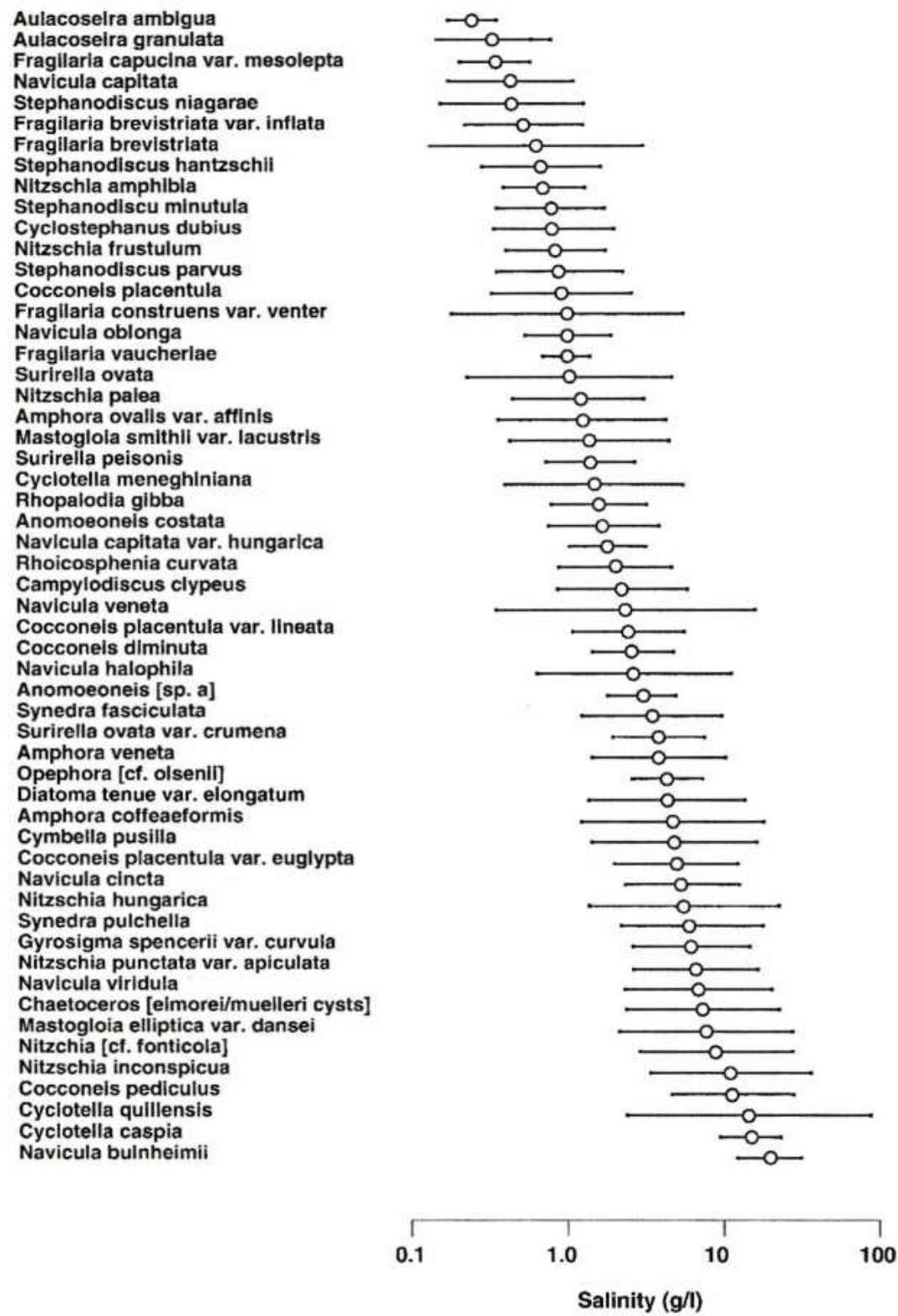
# Rozsivky = bioindikátory trofie, pH, salinity

- ekologická valence
- euryekní
- stenoekní



Rozsivka

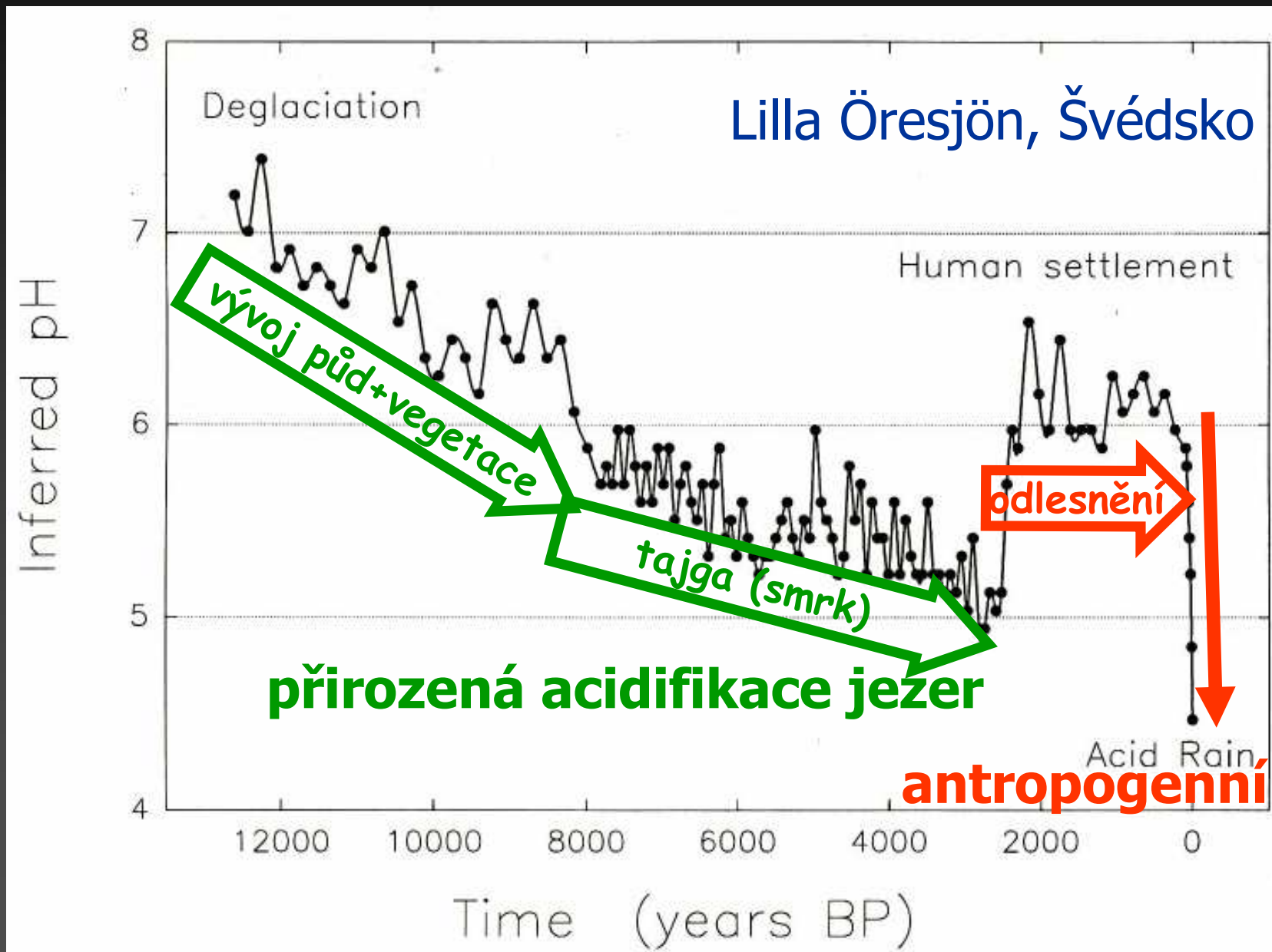
salinity







# Diatom-inferred pH – acidifikace jezer



# Acidifikace jezer – různé (časové) faktory

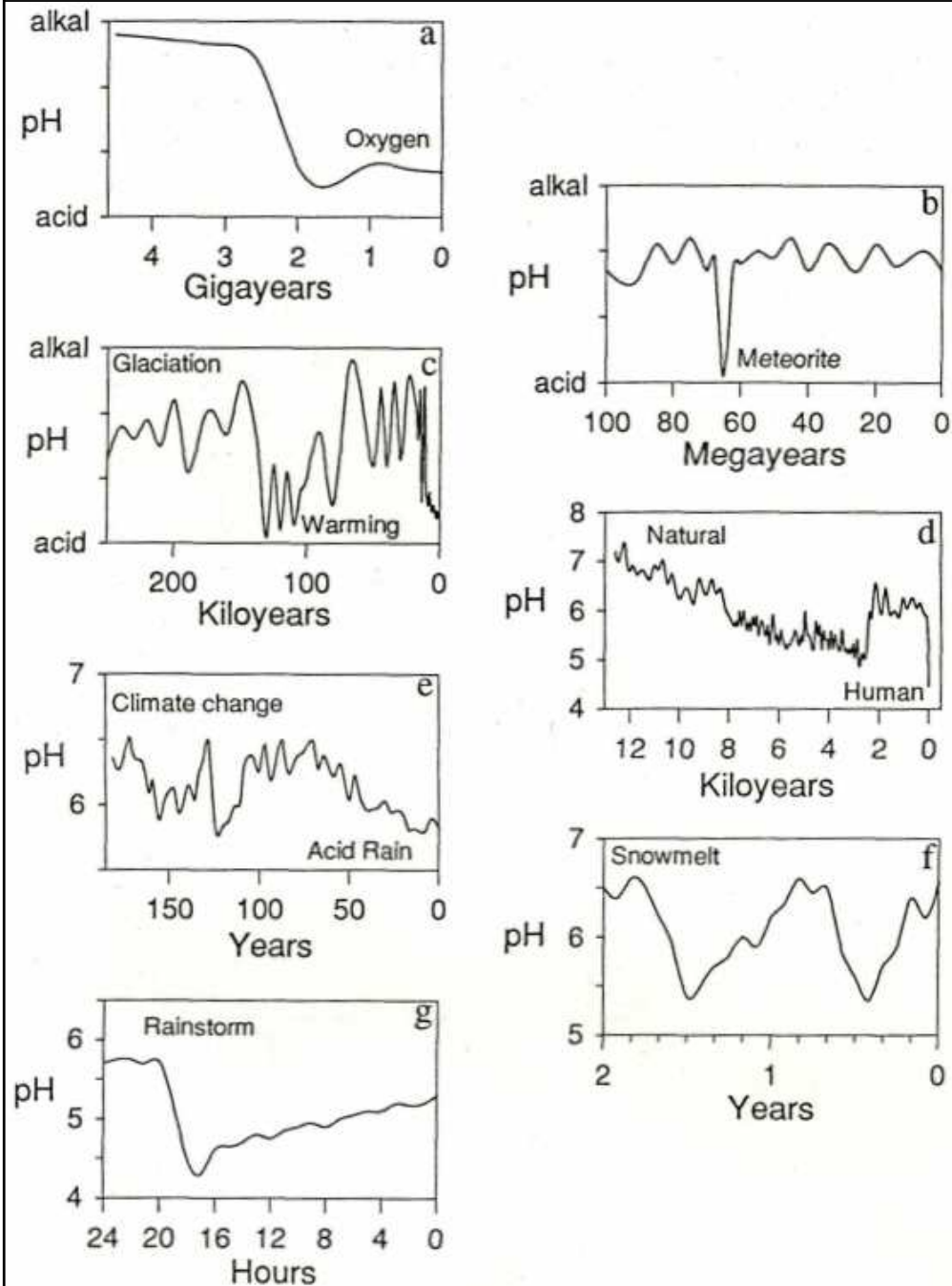
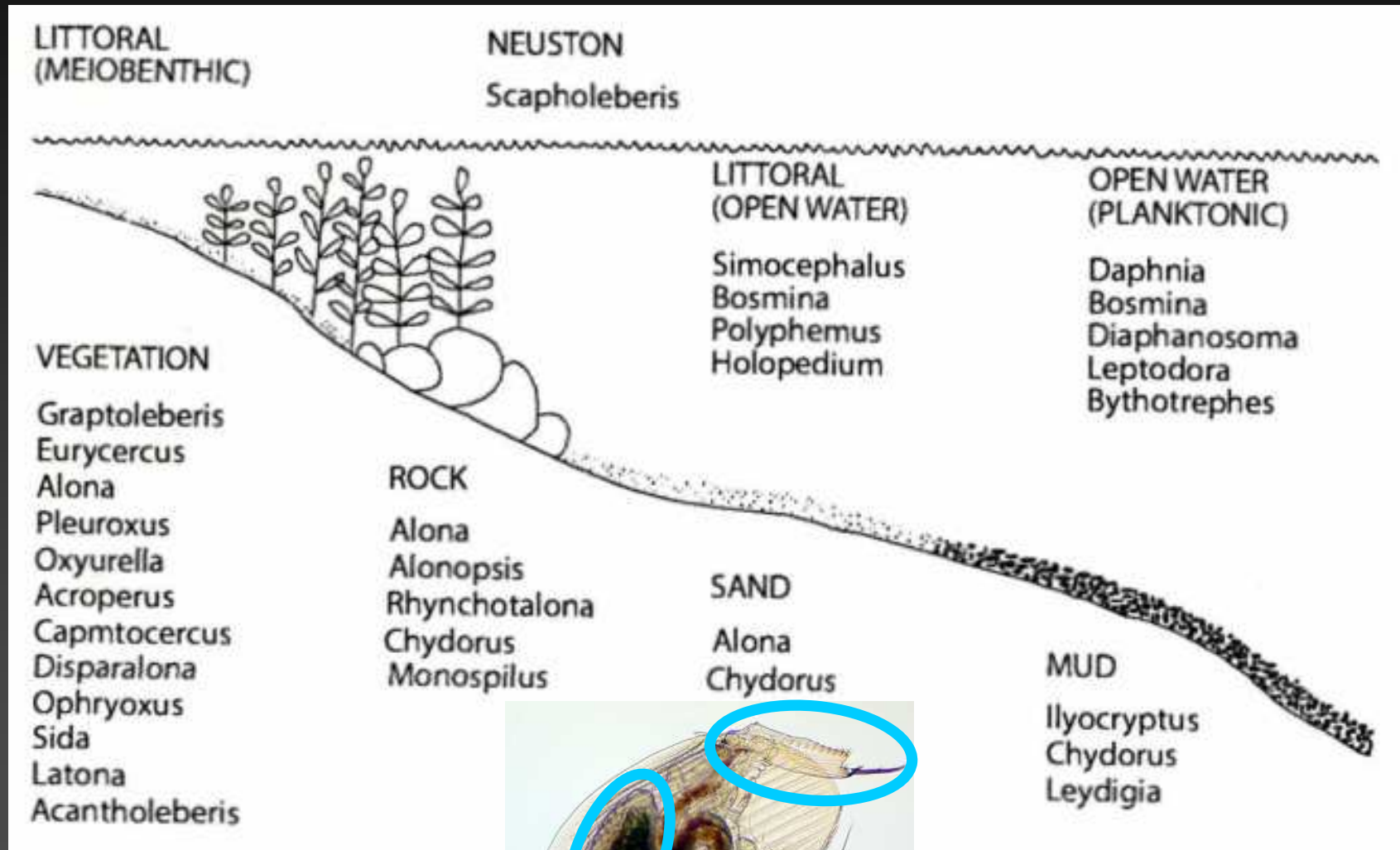


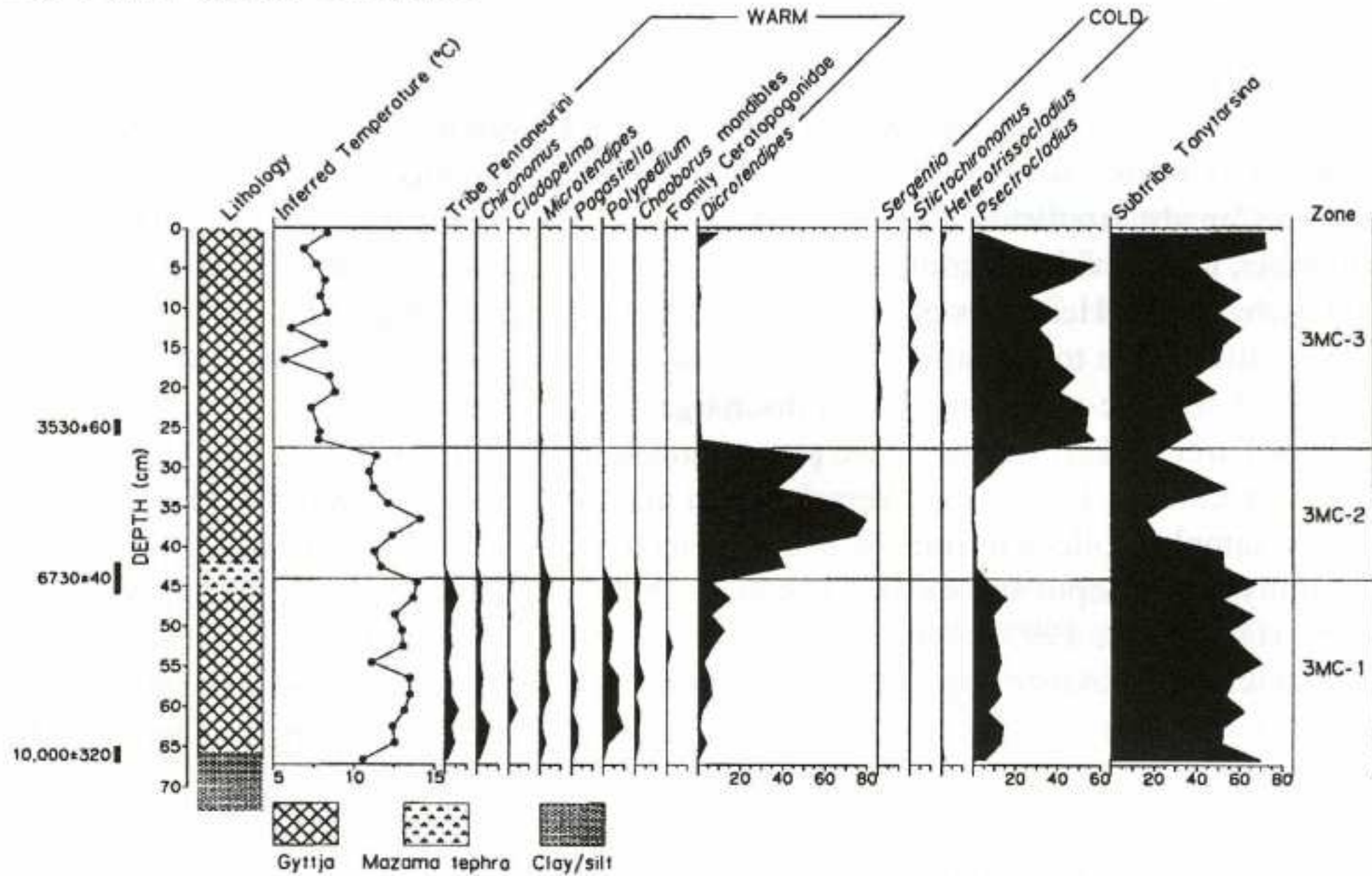
Figure 32. Time scales of acidification from  $10^3$  to  $10^9$  years; (a) hypothetical pH shift caused by the appearance of oxygen in the atmosphere; (b) acidification inferred from sudden changes in strontium isotope ratios caused by the increase in weathering rate due to the release of  $\text{CO}_2$ ,  $\text{NO}_x$  and/or  $\text{SO}_x$  (meteoric impact or tectonic processes); (c) alkalinity/acidity changes inferred from Antarctic ice cores and related to the higher amount of dust during glaciation periods (after Delmas, 117); (d) diatom-inferred long-term natural acidification, pH shift by eutrophication and acid rain in Lilla Öresjön, Sweden (after Renberg, 119); (e) diatom inferred pH shifts in Rassa See, Italy, caused by temperature oscillations (19th century) and acid deposition (20th century); (f) seasonal changes in pH in a high altitude lake in Tyrol, Austria, induced by freezing, biological activity and snowmelt; (g) short-term pH drift in Birkenes catchment, Norway, after heavy rainfall. Modified from Christophersen (53).

# Perloočky = bioindikátory trofie, pH, změn klimatu

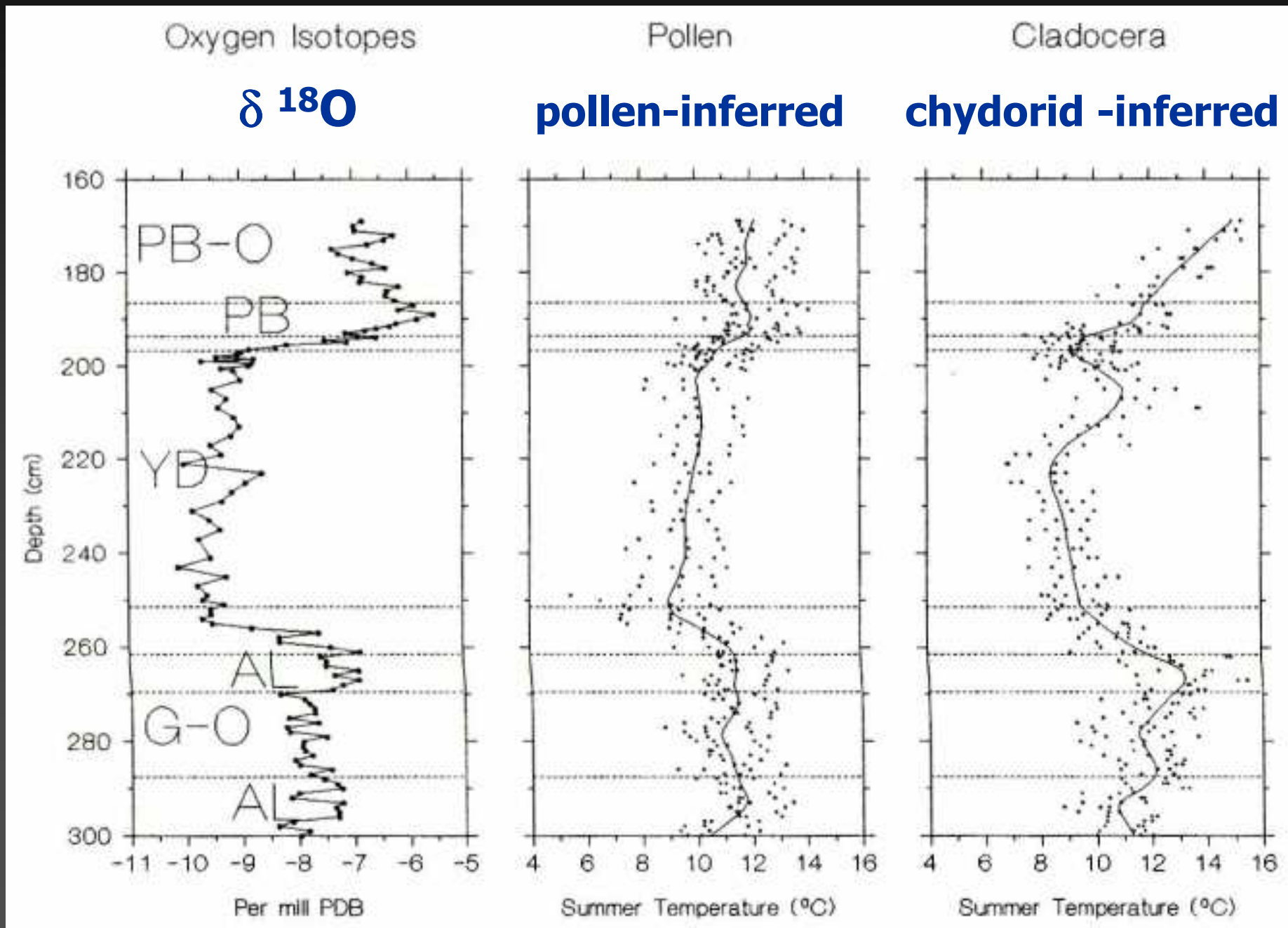


# Pakomáři = bioindikátory trofie, pH, změn klimatu

3M Pond, British Columbia



# Indikátory změn klimatu (letních teplot)



# Stabilní nuklidy – biologická diskriminace

$$^{12}\text{C} / ^{13}\text{C} = \delta^{13}\text{C}$$

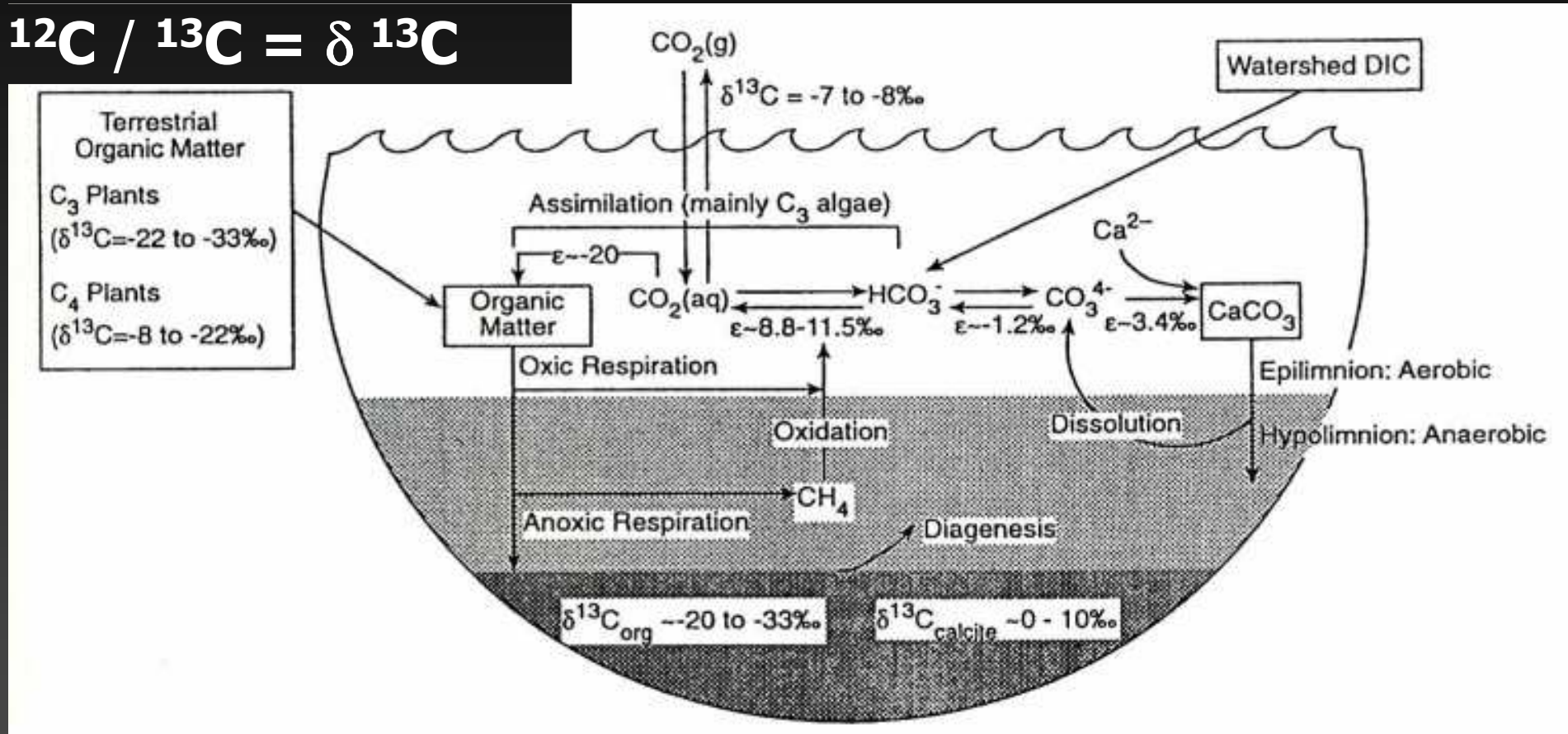


Figure 3. Idealized carbon isotope cycle in a small stratified lake. The isotopic composition of organic matter buried in sediments is determined by the proportions of different terrestrial and lacustrine organic matter, the carbon isotopic composition of dissolved inorganic carbon (DIC), and the rates of primary production and respiration within the water column. Isotope enrichment factors ( $\epsilon$ ), listed here as the difference between the product and the substrate, vary with the form of DIC that lake algae assimilate (e.g.,  $\text{CO}_2(\text{aq})$  or  $\text{HCO}_3^-$ ). Inorganic carbonate ( $\text{CaCO}_3$ ) typically forms in isotopic equilibrium with the dissolved inorganic carbon pool and, as such, is indirectly affected by organic matter sources and primary production and respiration rates.

# Stabilní nuklidy – biologická diskriminace

$$^{14}\text{N} / ^{15}\text{N} = \delta^{15}\text{N}$$

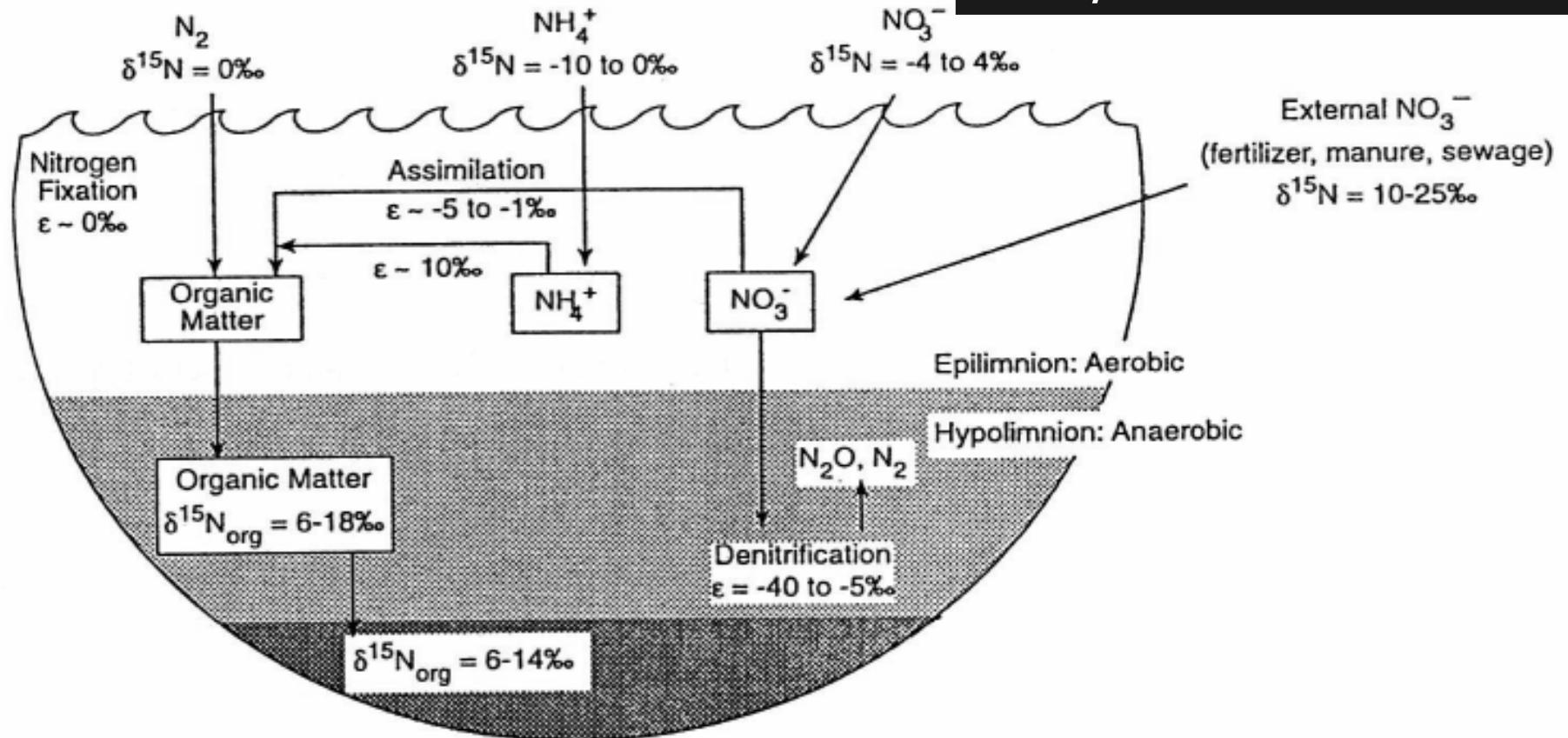


Figure 4. Idealized nitrogen isotope cycle in a small stratified lake. The isotopic composition of organic matter buried in sediment is determined by sources of nitrogen, rates of primary production and respiration, and the types of denitrification processes. Isotopic values for external sources of atmospheric and combined forms of nitrogen are from Kendall (1998). Isotope enrichment factors ( $\epsilon$ ) are from Fogel & Cifuentes (1993) and vary with the form of inorganic nitrogen that lake algae assimilate. Note that nitrogen isotopes are not fractionated by algal fixation of atmospheric  $\text{N}_2$  and that the importance of nitrogen fixation can vary greatly from lake to lake.

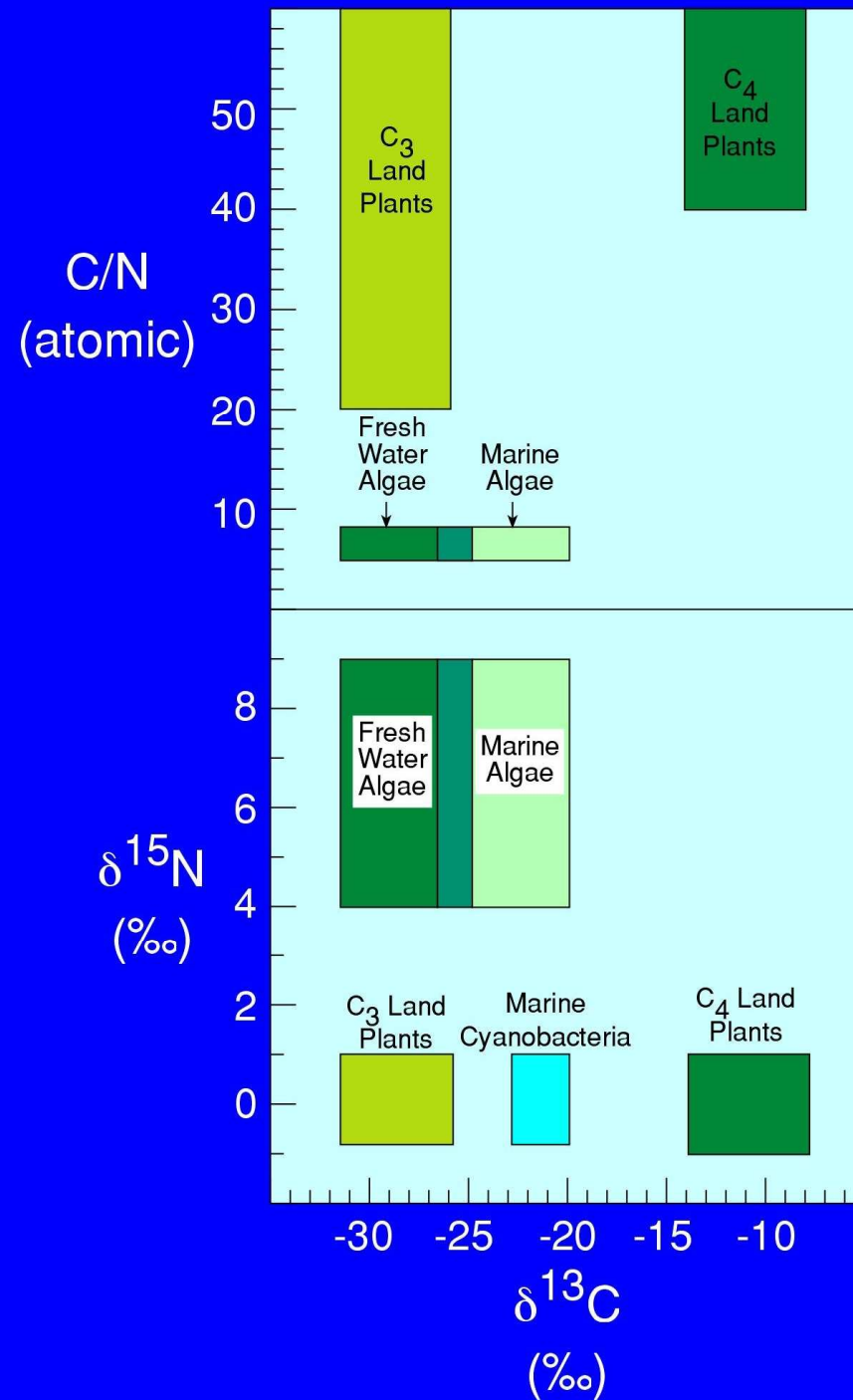


# Stabilní nuklidy – biologická diskriminace

- proxy zdrojů organických látek
  - C/N ratios - algae <8; land plants >20
  - $\delta^{13}\text{C}$  values -  $\text{C}_3$  plants (-25‰ to -30‰)  
 $\text{C}_4$  plants (-10‰ to -15‰)
  - $\delta^{15}\text{N}$  values - land plants and cyanobacteria (~0‰);  
phytoplankton (+3‰ to +8‰)
- Biomarker molecules
  - Plant wax hydrocarbons ( $\text{C}_{27}$ ,  $\text{C}_{29}$ ,  $\text{C}_{31}$ ,  $\text{C}_{33}$ )
  - Algal hydrocarbons ( $\text{C}_{15}$ ,  $\text{C}_{17}$ ,  $\text{C}_{19}$ )
  - Fatty acids ( $\text{C}_{16}$ ,  $\text{C}_{16:1}$ ,  $\text{C}_{18}$ ,  $\text{C}_{18:1}$  and  $\text{C}_{24}$ ,  $\text{C}_{26}$ ,  $\text{C}_{28}$ )

# Stabilní nuklidy –

- indikátory organických látek: stechiometrie a diskriminace = **C:N**,  $\delta^{13}\text{C}$  a  $\delta^{15}\text{N}$



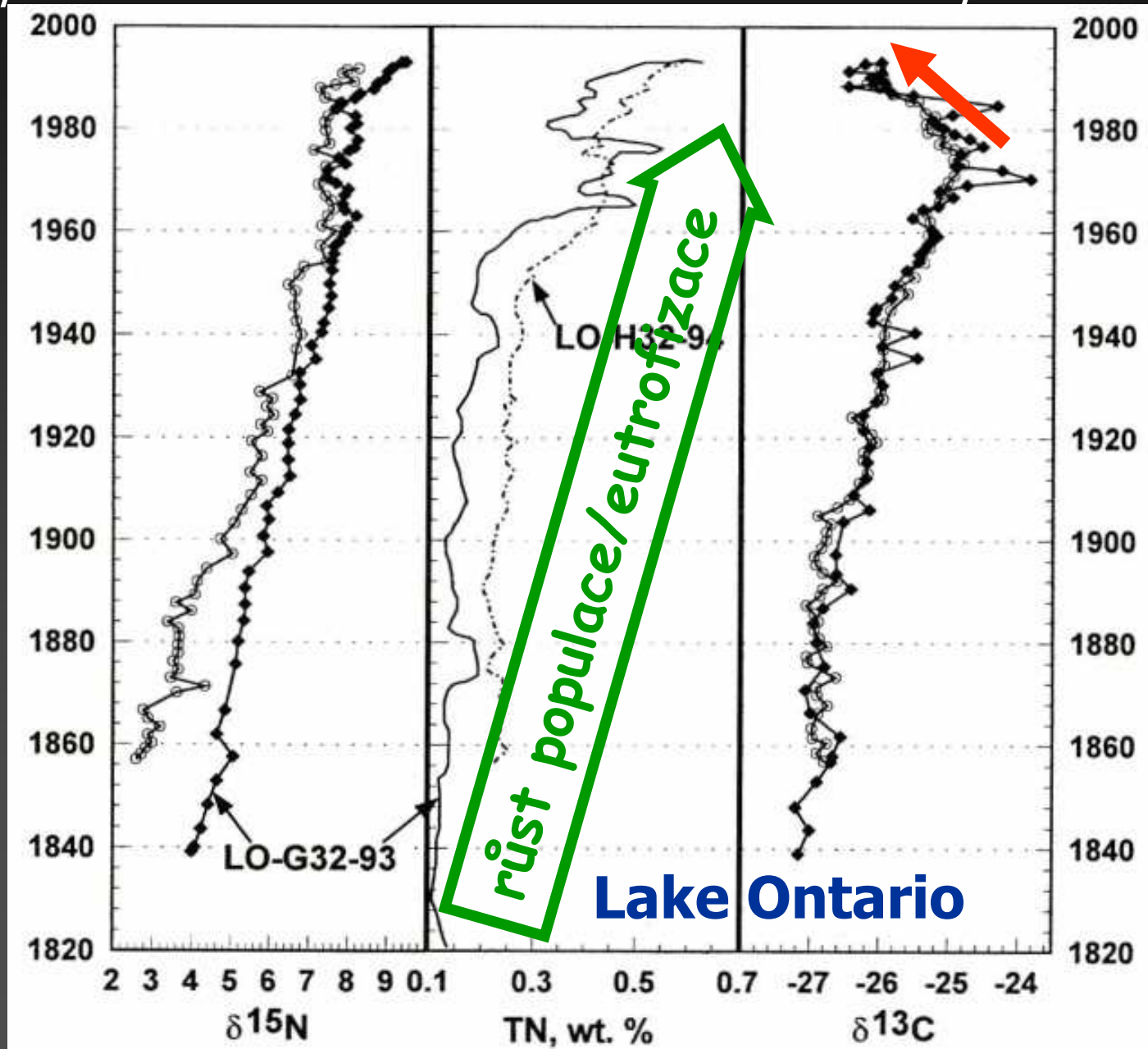
# Stabilní nuklidy – biologická diskriminace

- **paleoklimatické proxy** organických látek
  - $\delta^{13}\text{C}$  values -  $\text{C}_3$  plants (-25‰ to -30‰) - moist  
 $\text{C}_4$  plants (-10‰ to -15‰) - dry
  - $\delta\text{D}$  (or  $\delta^2\text{H}$ ) values - meteoric water balance
  - Compound-specific  $\delta^{13}\text{C}$  and  $\delta\text{D}$  values
  - **ACL (Average Chain Length)** - temperature record
    - Plant wax hydrocarbons ( $\text{C}_{27}$ ,  $\text{C}_{29}$ ,  $\text{C}_{31}$ ,  $\text{C}_{33}$ )
    - Plant wax fatty acids ( $\text{C}_{24}$ ,  $\text{C}_{26}$ ,  $\text{C}_{28}$ )

# Stabilní nuklidy v paleolimnologii

$$^{12}\text{C} / ^{13}\text{C} = \delta^{13}\text{C}$$

$$^{14}\text{N} / ^{15}\text{N} = \delta^{15}\text{N}$$

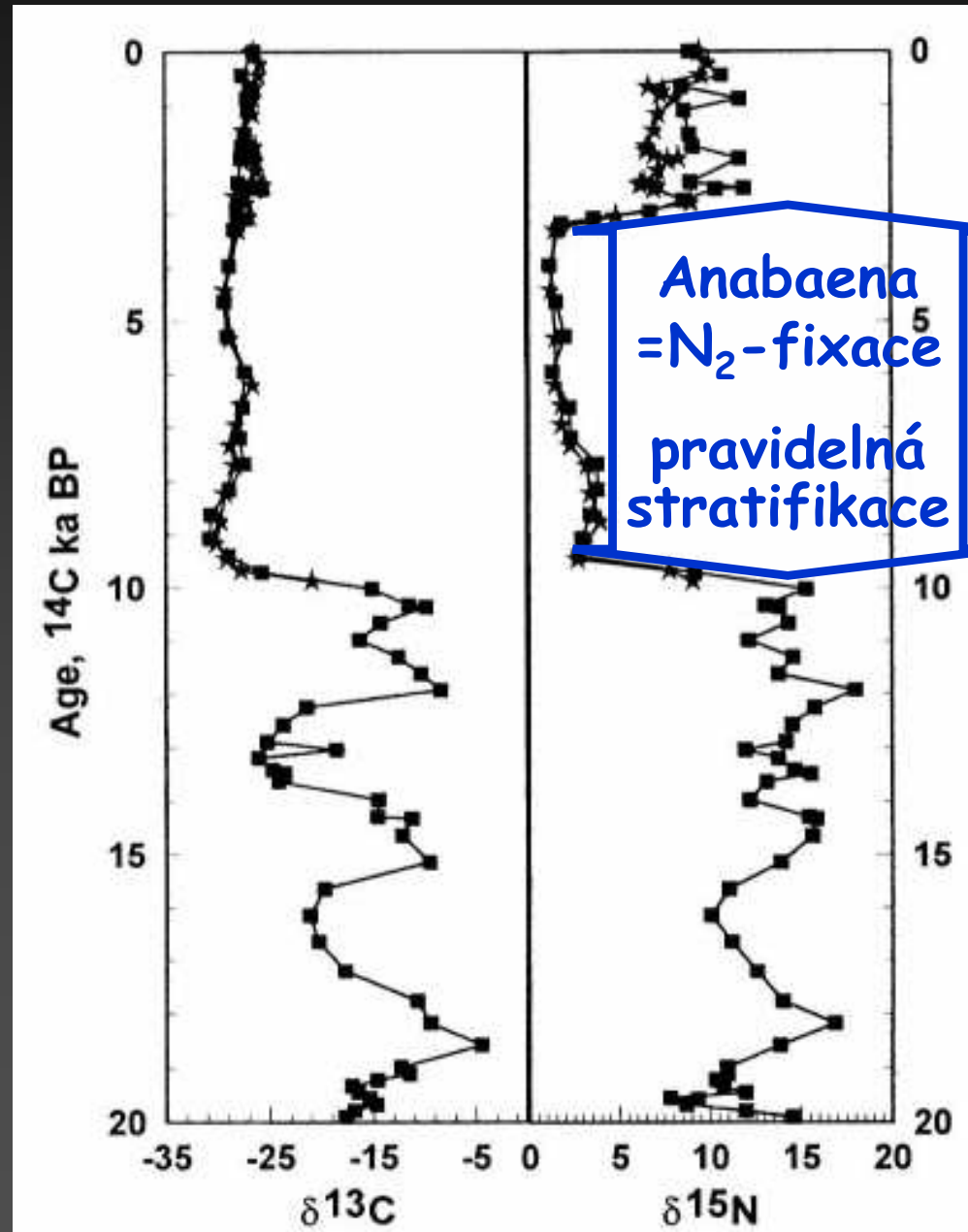


# Stabilní nuklidy v paleolimnologii

$$^{12}\text{C} / ^{13}\text{C} = \delta^{13}\text{C}$$

$$^{14}\text{N} / ^{15}\text{N} = \delta^{15}\text{N}$$

endorheické  
tropické jezero  
**Bosumtwi,**  
**Ghana**

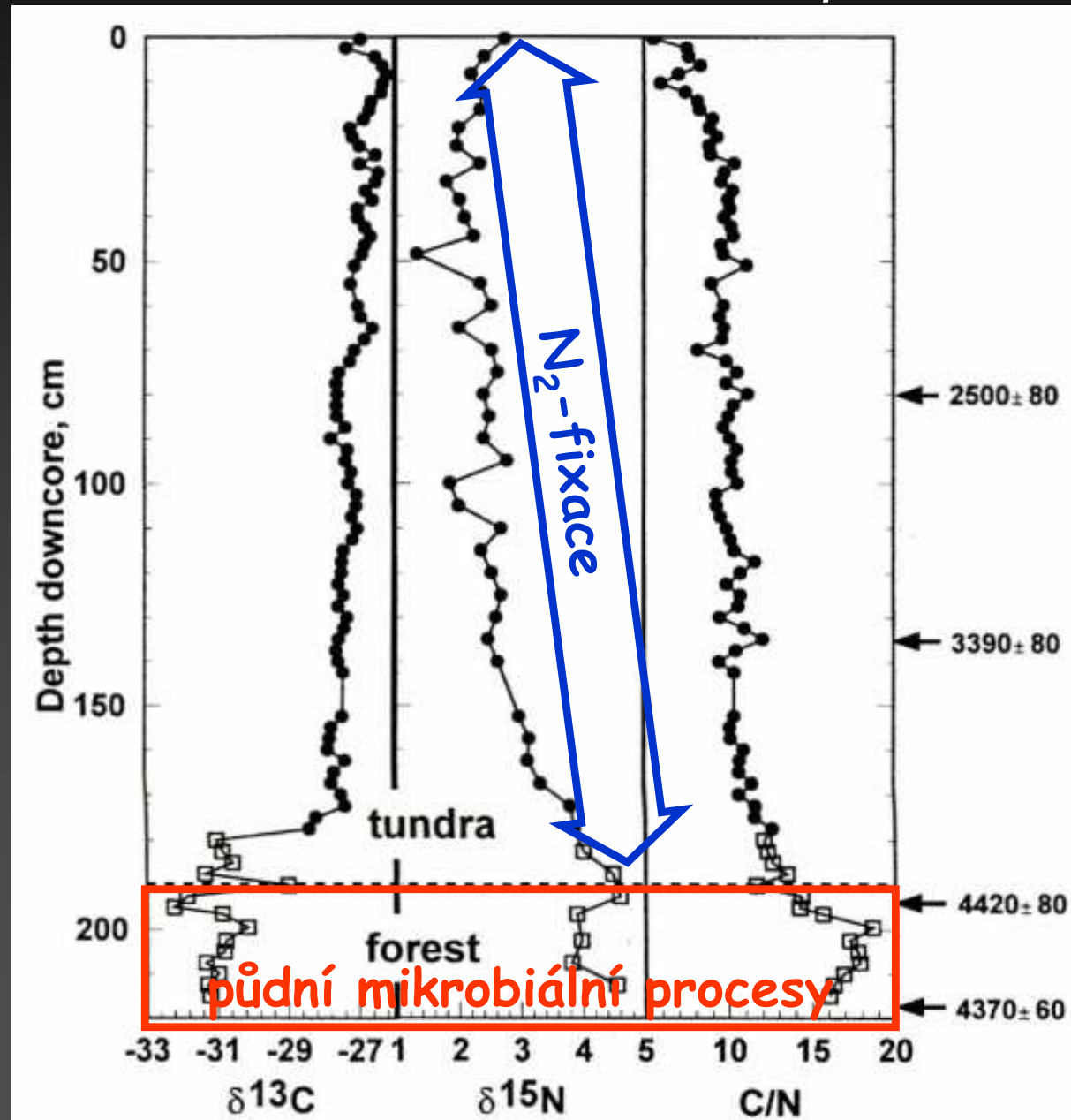


# Stabilní nuklidy v paleolimnologii

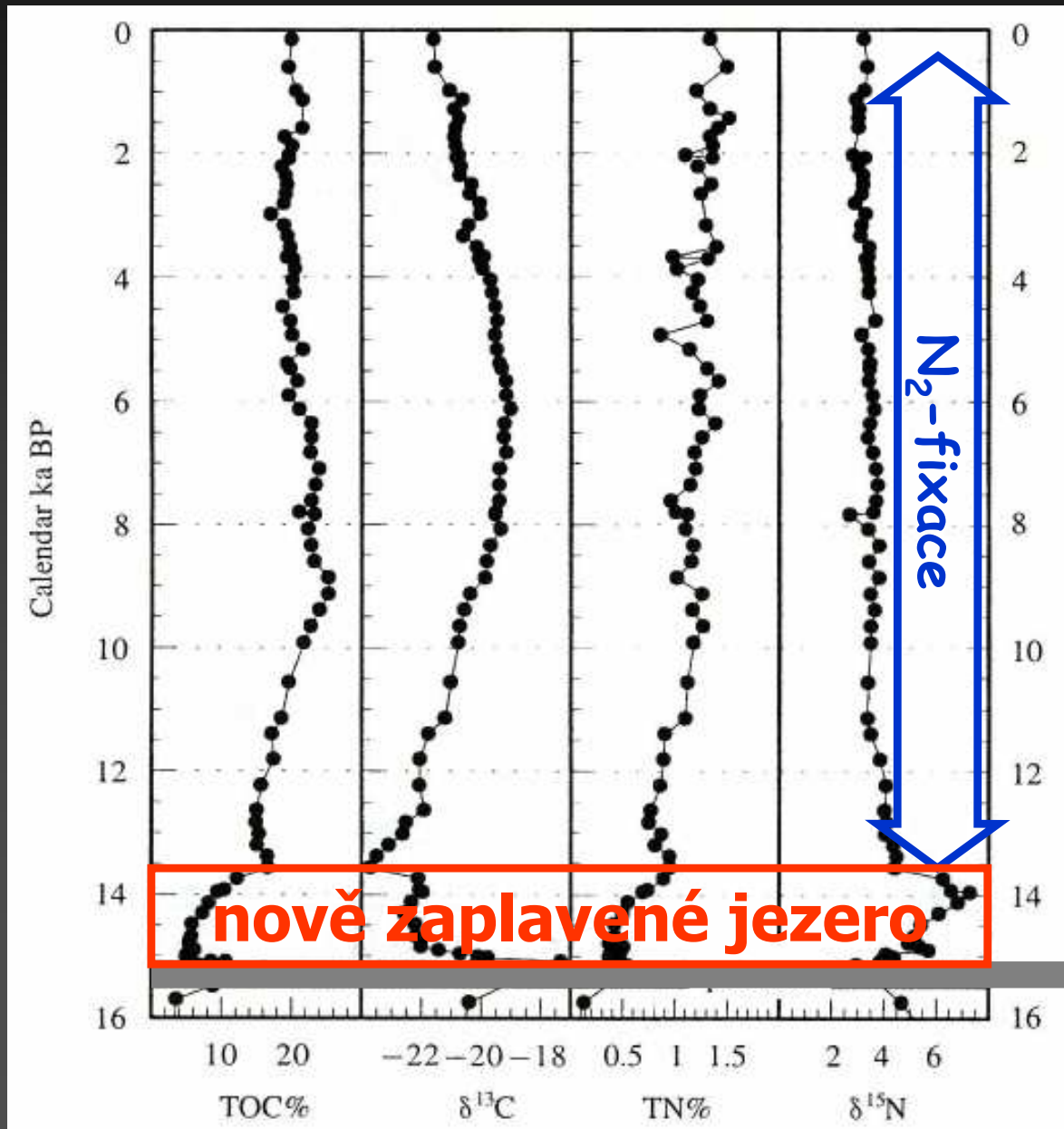
$$^{12}\text{C} / ^{13}\text{C} = \delta^{13}\text{C}$$

$$^{14}\text{N} / ^{15}\text{N} = \delta^{15}\text{N}$$

malé arktické  
ozero  
Middendorfa,  
sev. Rusko

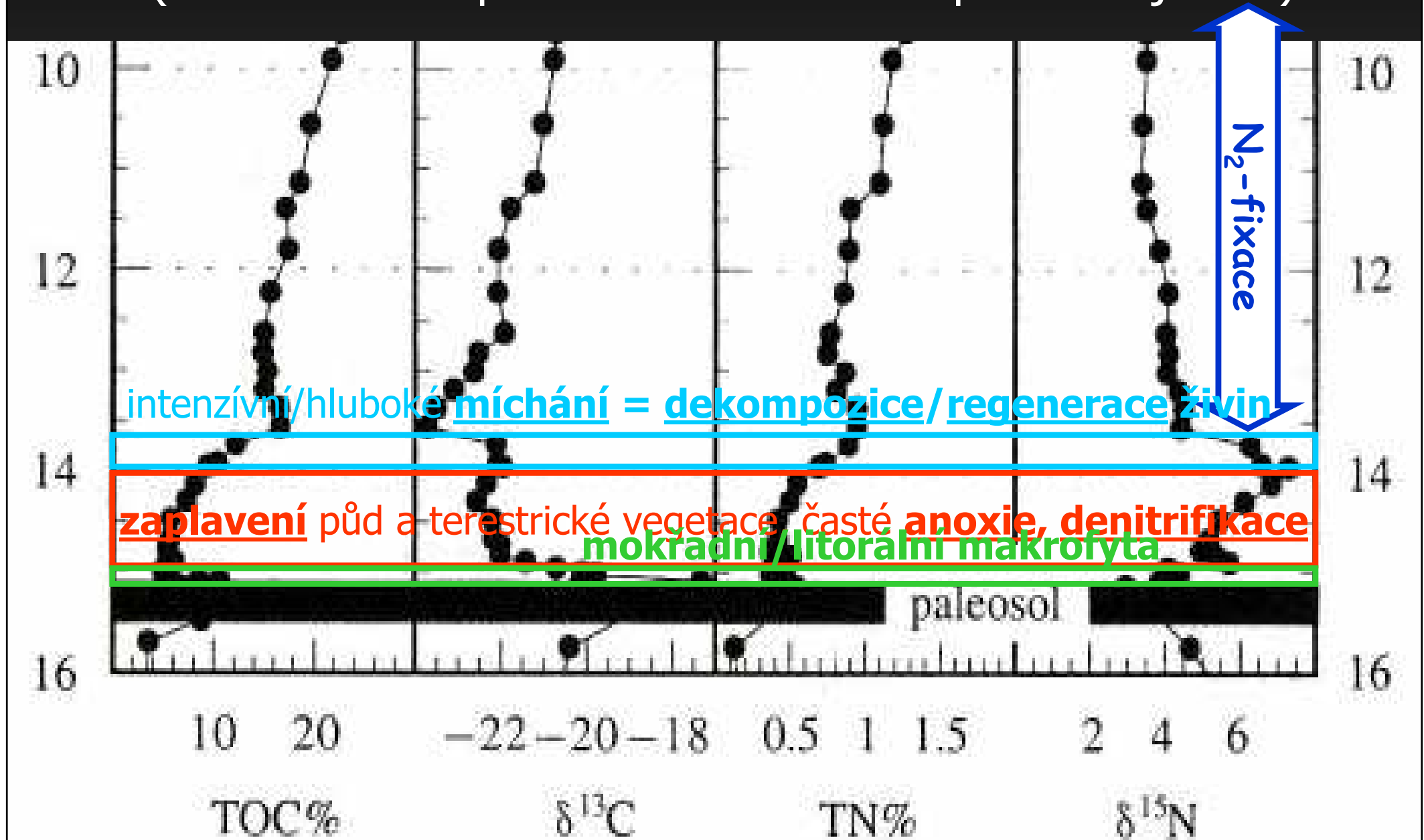


# Ukerewe (Viktoriino j.) – plnění obrovského jezera (relativně malé povodí, „mělké“ 69 m)



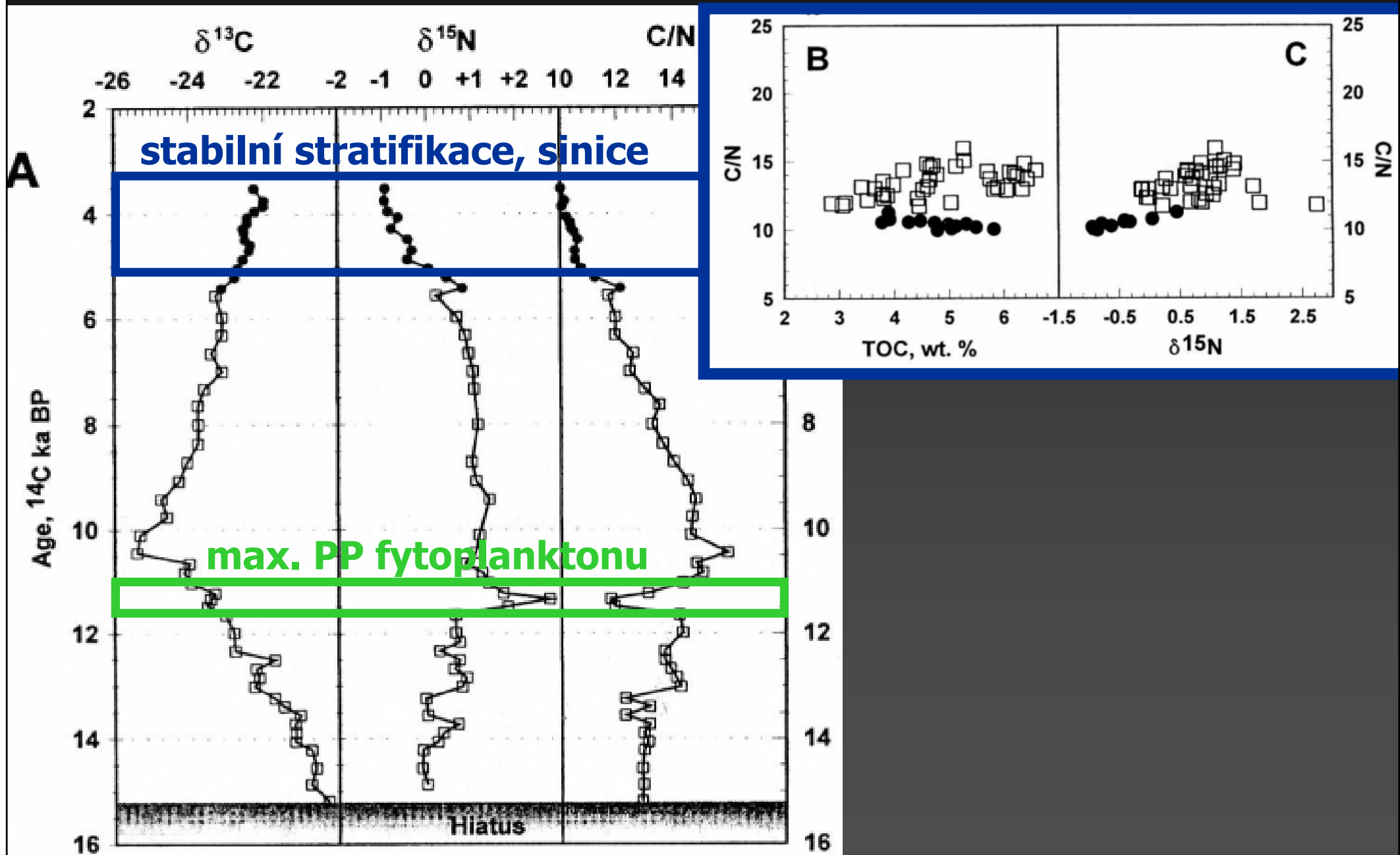
tzv. paleosol = vyschlé !  
(pozdní Pleistocén)

# Ukerewe (Viktoriino j.) – plnění obrovského jezera (relativně malé povodí = 80 % srážek přímo do jezera)

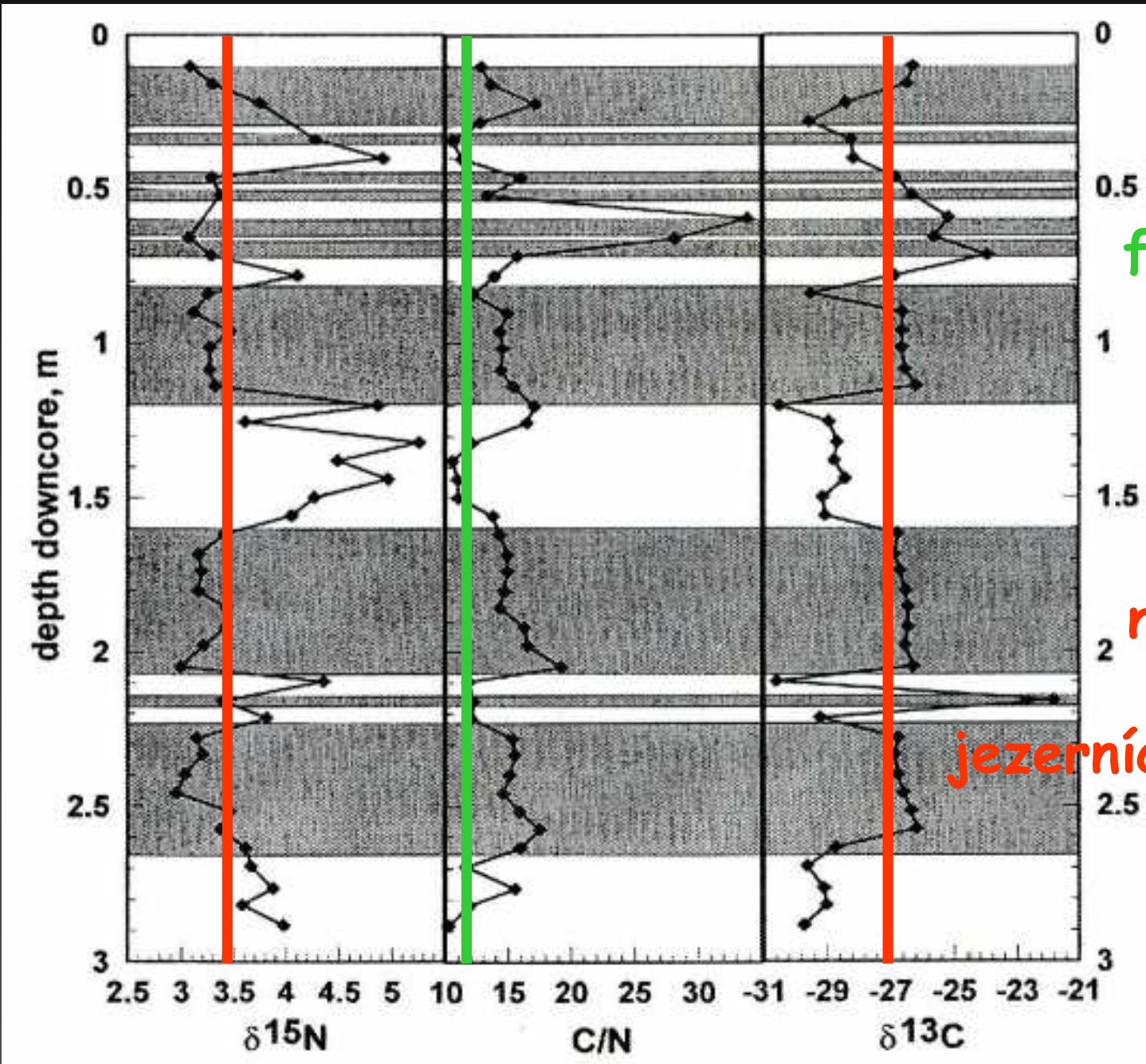




# Tanganika – změny hladiny a míchání



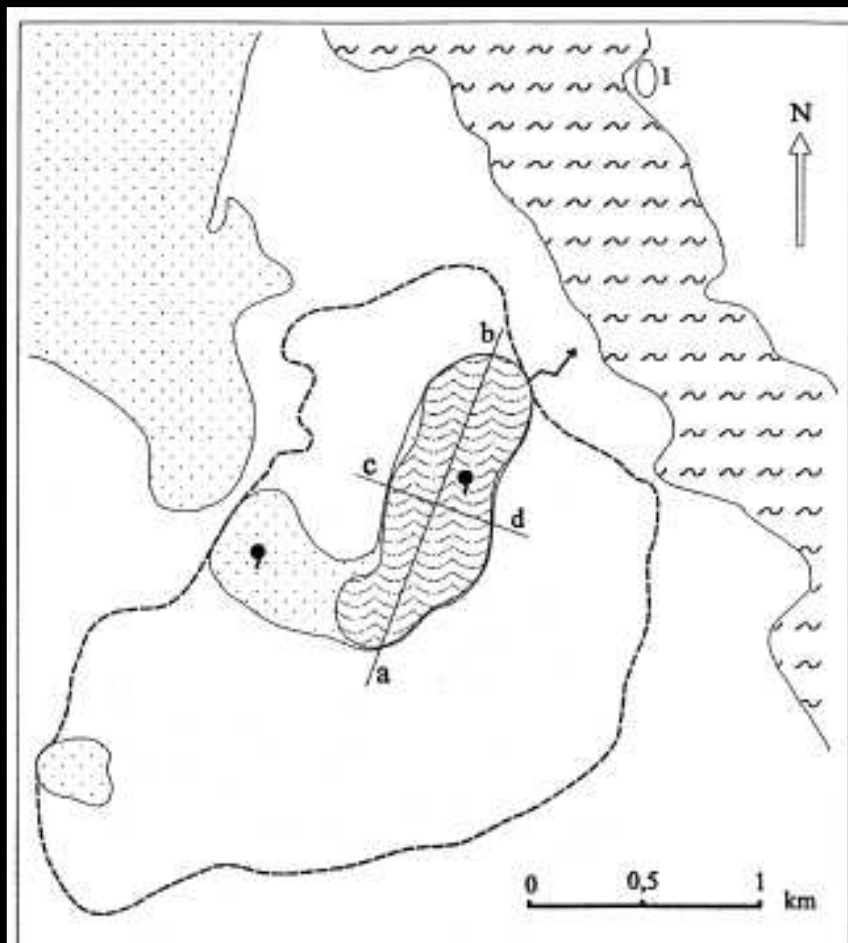
# Bajkal – změny turbidity



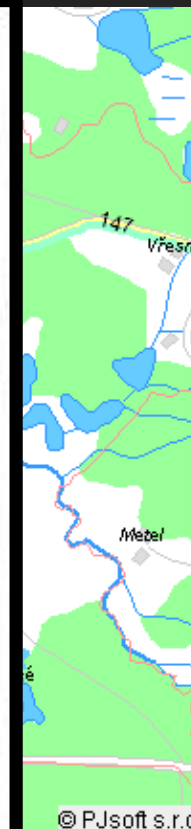
autochtonní  
primární  
produkce  
fytoplanktonu

náhlé sesuvy  
mělčích  
jezerních sedimentů

# Zazemňování – pohřbené jezero Švarcenberk v Třeboňské pánvi



- |  |                       |  |                        |
|--|-----------------------|--|------------------------|
|  | - lake sediments      |  | - main water sources   |
|  | - peat                |  | - outlet from the lake |
|  | - Holocene floodplain |  | - lake catchment       |



# Zazemňování – pohřbené jezero Švarcenberk

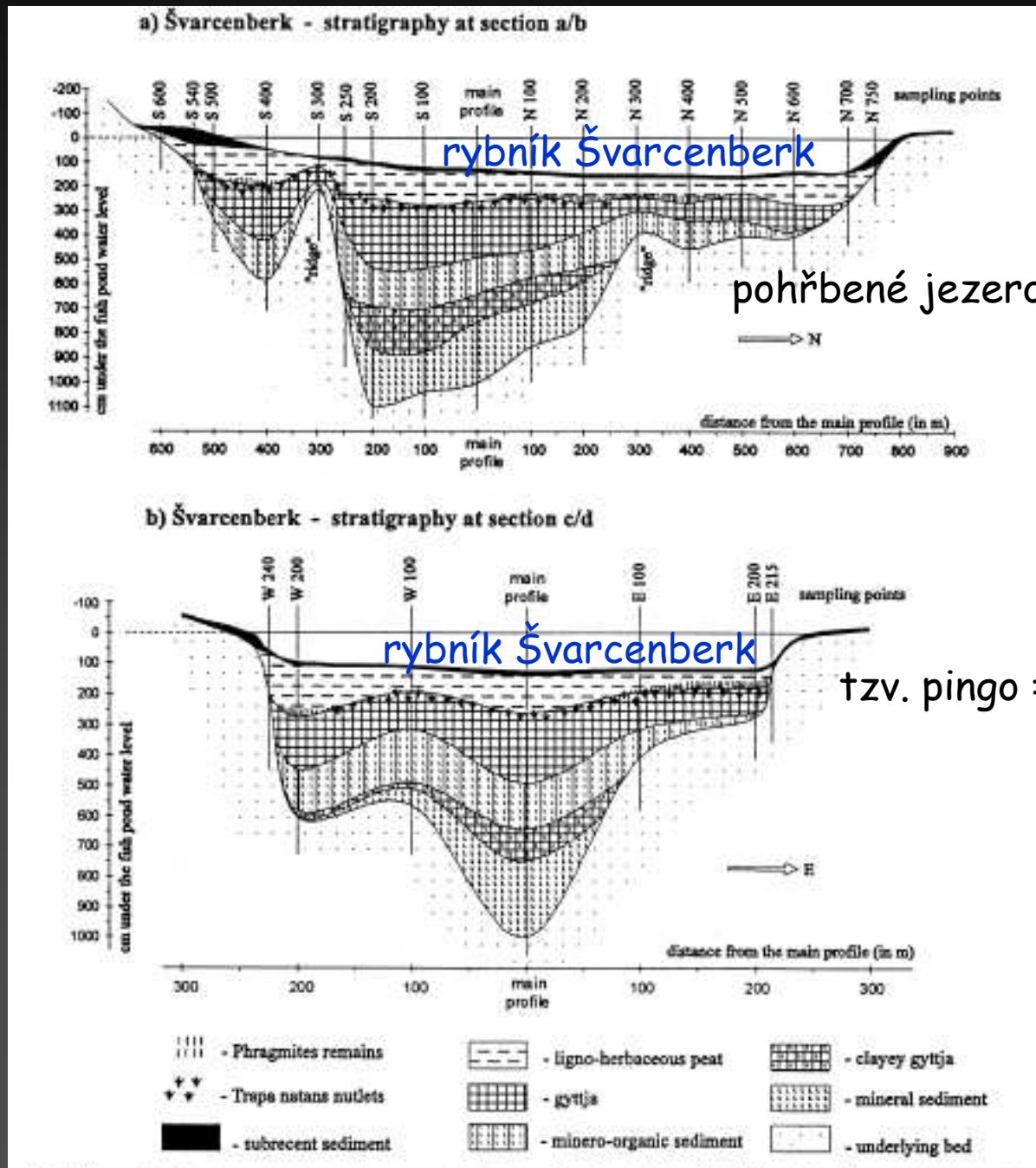
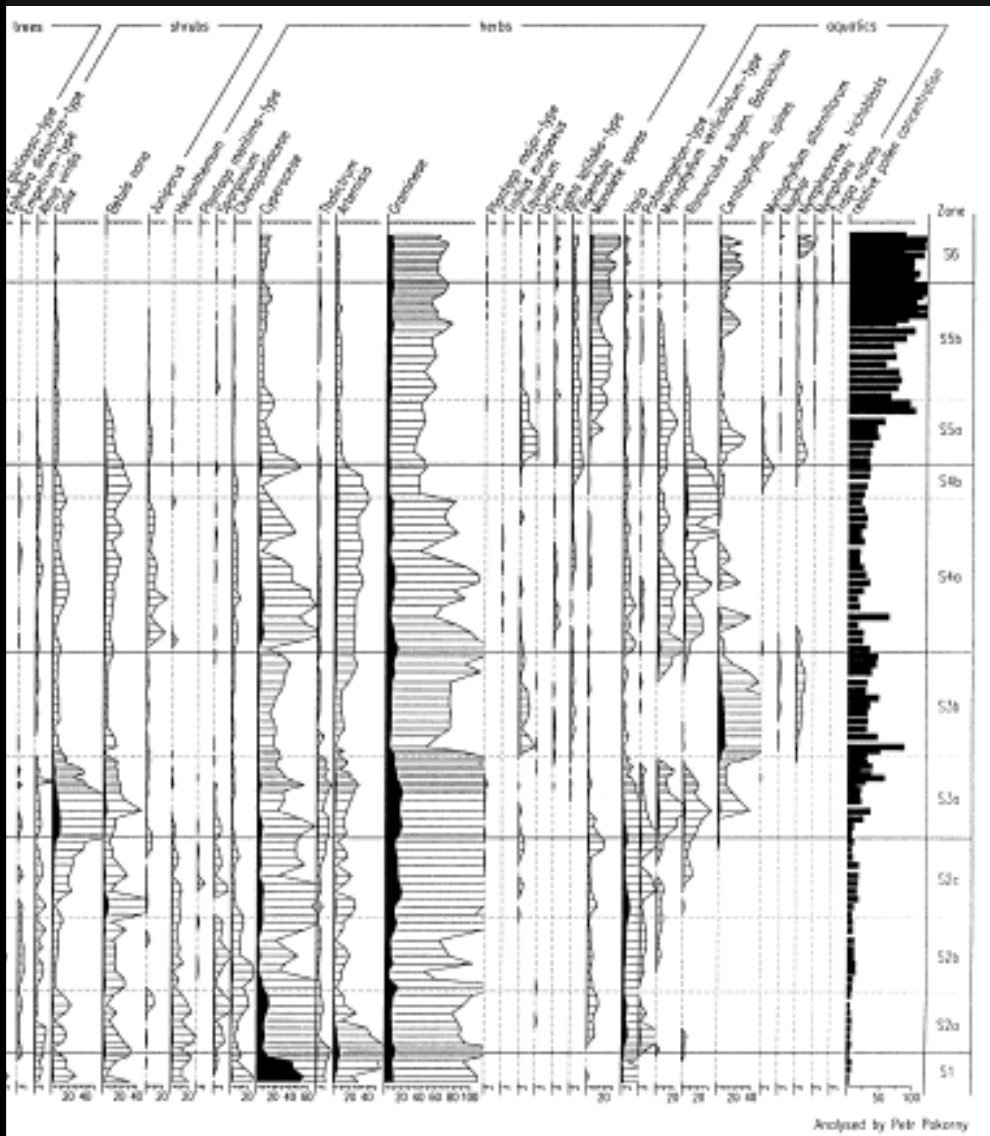
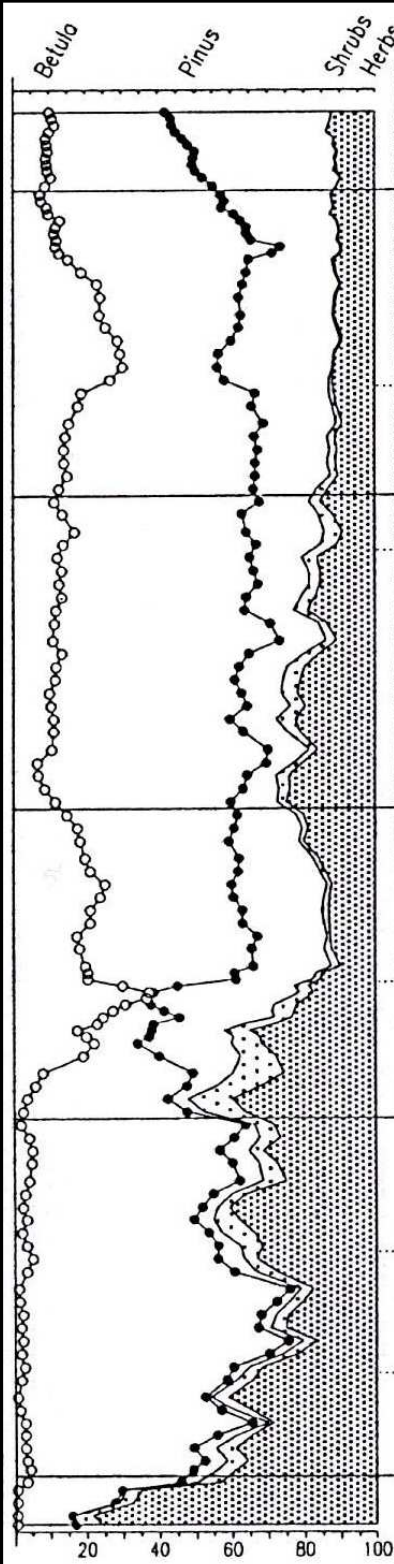
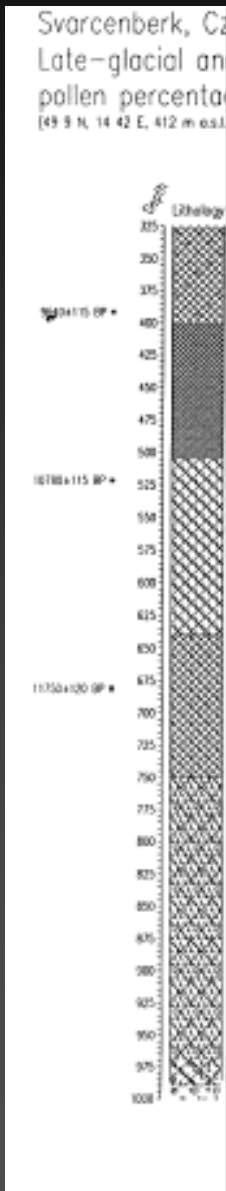


Fig. 2. Two selected orthogonal stratigraphic cross-sections (their position described on Fig. 1) through the Švarcenberk lake basin.

# Zazem

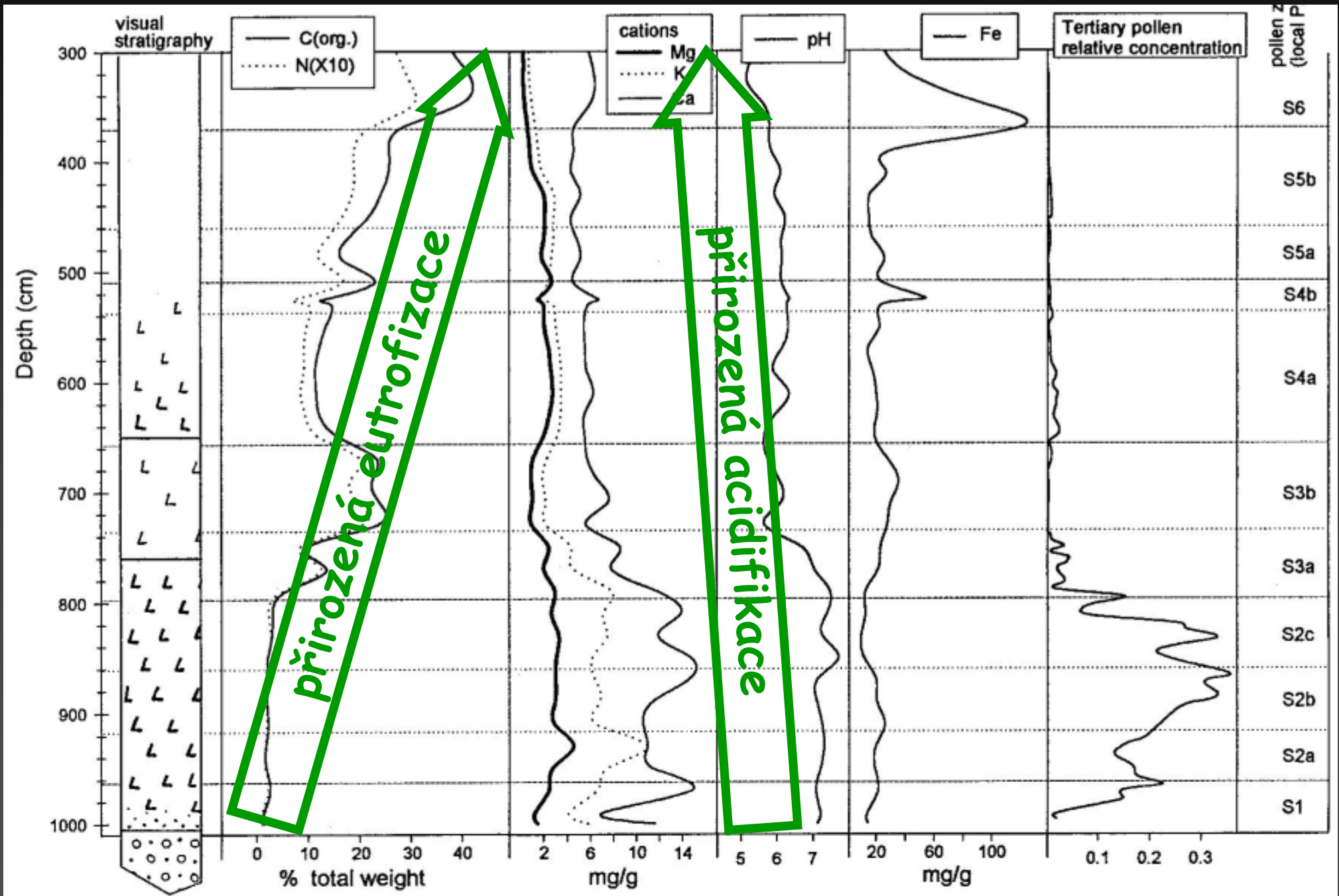
# poohřbené jezero Švarcenberk



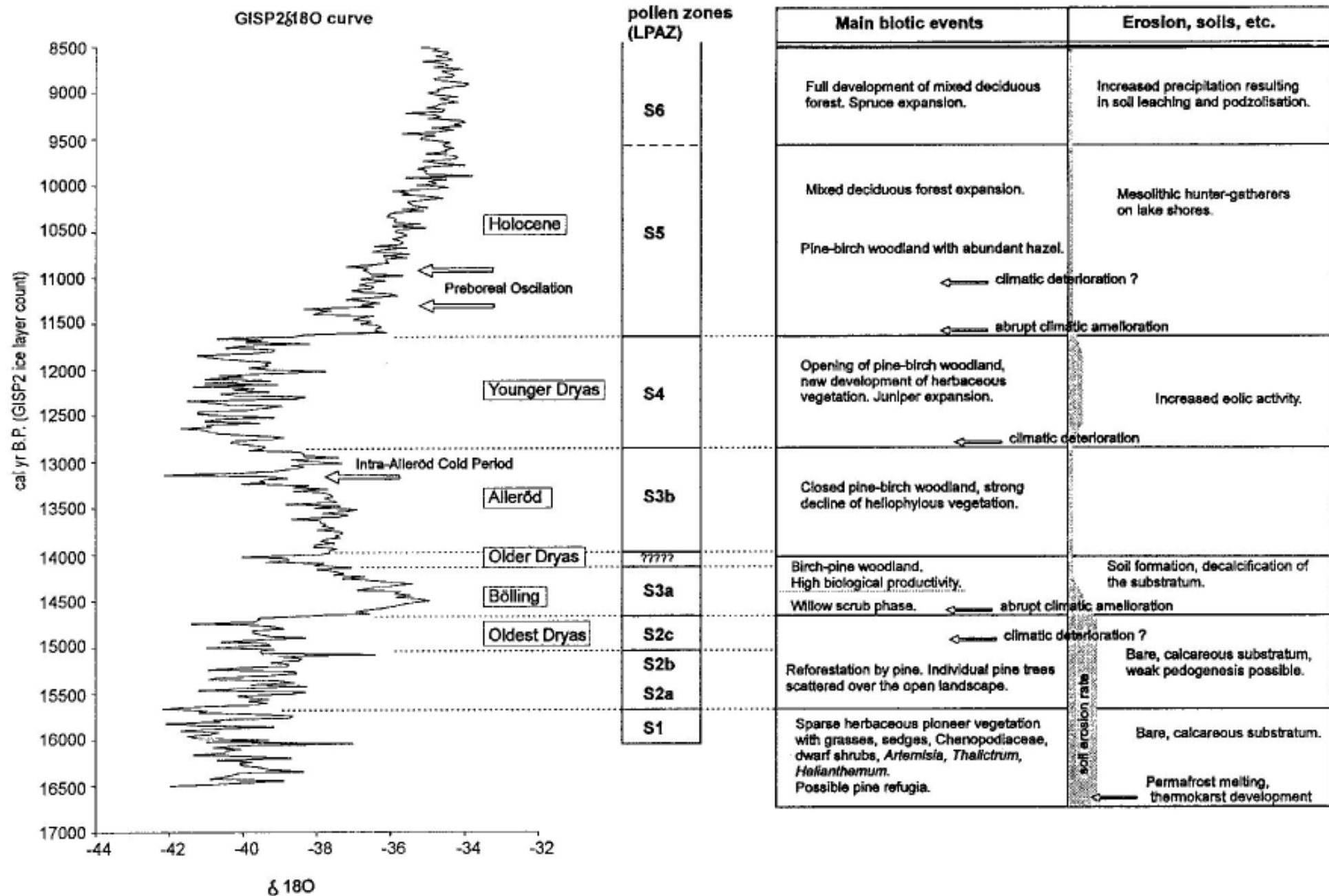
pollen diagram of the "main profile". Only selected types are included.

Analysed by Petr Pokorný

# Zazemňování = eutrofizace jezera Švarcenberk



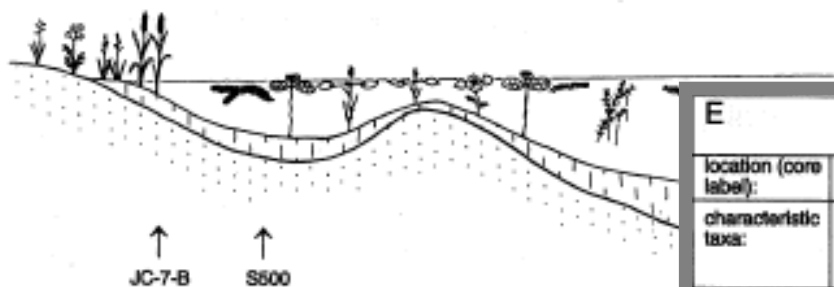
# Švarcenberk = postglaciální klimatické změny



# Švarcenberk – zánik jedného jezera

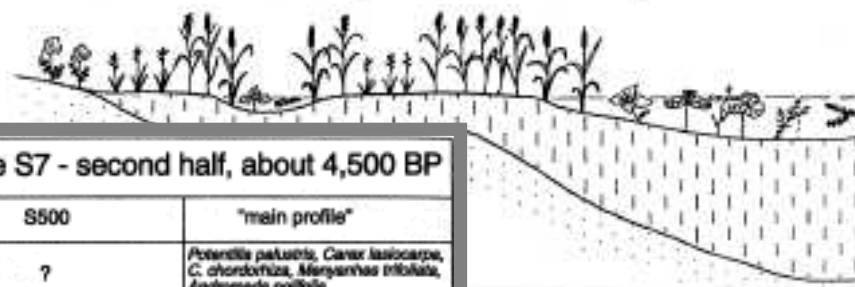
**A** subzone S5b, about 9,500 BP

location (core label):	JC-7-B	S500	"main profile"
characteristic taxa:	<i>Potamogeton</i> , <i>Ranunculus</i> subgen. <i>Batrachium</i> , <i>Ceratophyllum demersum</i> , <i>Myriophyllum verticillatum</i>	<i>Najas</i> , <i>Potamogeton</i> , <i>Ranunculus</i> subgen. <i>Batrachium</i> , <i>Ceratophyllum demersum</i> , <i>Myriophyllum verticillatum</i>	<i>Najas marina</i> , <i>Najas minor</i> , <i>Najas</i> , <i>Nymphaea</i> , <i>Typha natans</i> , <i>Ceratophyllum demersum</i> , <i>Myriophyllum spicatum</i>
interpretation:	open water	open water	open water



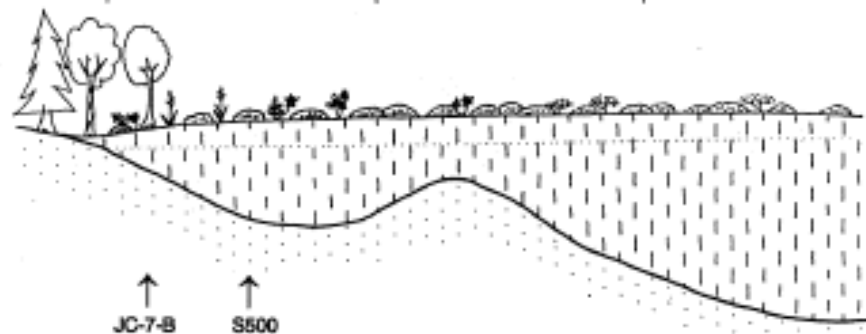
**B** zone S6 - first half, about 6,500 BP

location (core label):	JC-7-B	S500	"main profile"
characteristic taxa:	<i>Carex</i> , <i>Carex panicea</i> , <i>Viola palustris</i> , <i>Filipendula</i>	<i>Najas</i> , <i>Potamogeton</i> , <i>Ceratophyllum demersum</i> , <i>Typha natans</i>	<i>Najas marina</i> , <i>Najas</i> , <i>Nymphaea</i> , <i>Typha natans</i> , <i>Potamogeton natans</i> , <i>Ceratophyllum demersum</i>
interpretation:	fen	shallow pools	open water



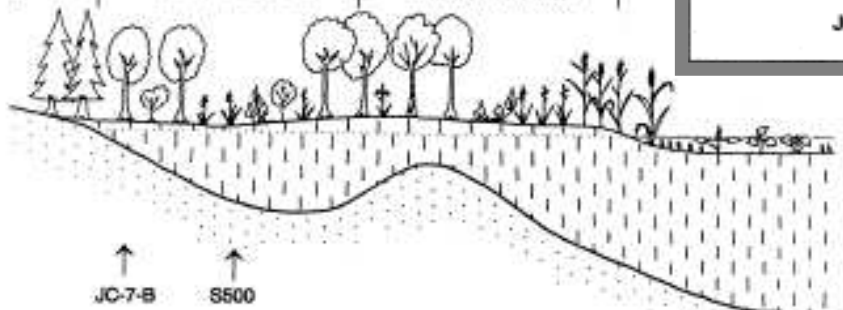
**E** zone S7 - second half, about 4,500 BP

location (core label):	JC-7-B	S500	"main profile"
characteristic taxa:	<i>Mnium</i> , <i>Potentilla palustris</i> , <i>Sphagnum</i>	?	<i>Potentilla palustris</i> , <i>Carex lasiocarpa</i> , <i>C. chondrofolia</i> , <i>Mnium trifoliatum</i> , <i>Andromeda polifolia</i> , <i>Sphagnum</i>
interpretation:	Sphagnum bog	Sphagnum bog (?)	Sphagnum bog



**C** zone S6 - second half, about 6,000 BP

location (core label):	JC-7-B	S500	"main profile"
characteristic taxa:	<i>Alnus glutinosa</i> , <i>Betula pubescens</i> , <i>Fraxinus alnus</i> , <i>Carex vesicaria</i> , <i>C. panicea</i> , <i>C. pseudocyperus</i> , <i>Calla palustris</i>	<i>Alnus glutinosa</i> , <i>Betula pubescens</i> , <i>Fraxinus alnus</i> , <i>Carex rostrata</i> , <i>C. sect. nigros</i> , <i>C. pseudocyperus</i> , <i>Calla palustris</i> , <i>Eleocharis</i> , <i>Solanum dulcamara</i> , <i>Lycopus europaeus</i>	<i>Potamogeton</i> , <i>Ceratophyllum demersum</i> , <i>Chara</i> , <i>Chara</i>
interpretation:	Carex fen / alder car	Carex fen / alder car	



**D** zone S7 - first half, about 5,200 BP

location (core label):	S500	"main profile"
characteristic taxa:	?	<i>Carex rostrata</i> , <i>C. lasiocarpa</i> , <i>Scheuchzeria palustris</i> , <i>Potentilla palustris</i> , <i>Sphagnum</i>
interpretation:	shaded fen / bog (?)	Sphagnum bog

