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Environmental
Change:

time-scale
matters



HOURS
DAYS

SEASONS

YEARS

DECADES

CENTURIES

MILLENNIA

Paleoenvironmental data spans millenia

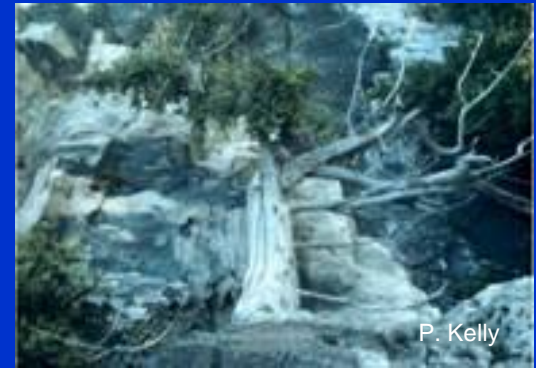
Ice cores



Marine cores

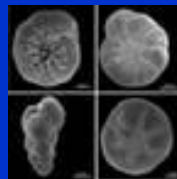


Tree rings



Proxy:

$\delta^{18}\text{O}$, e.g. $[\text{CH}_4]$,
 $[\text{CO}_2]$, pH



$\delta^{18}\text{O}$

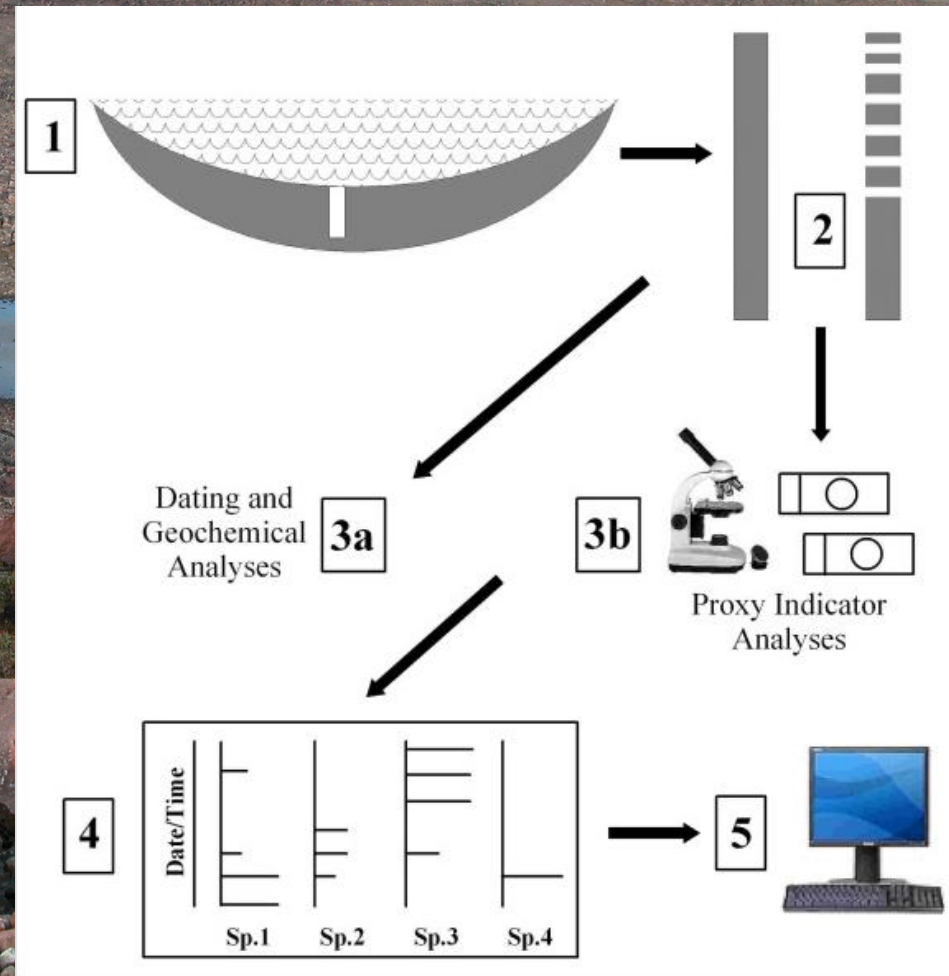
mud composition,
etc.

Tree ring width

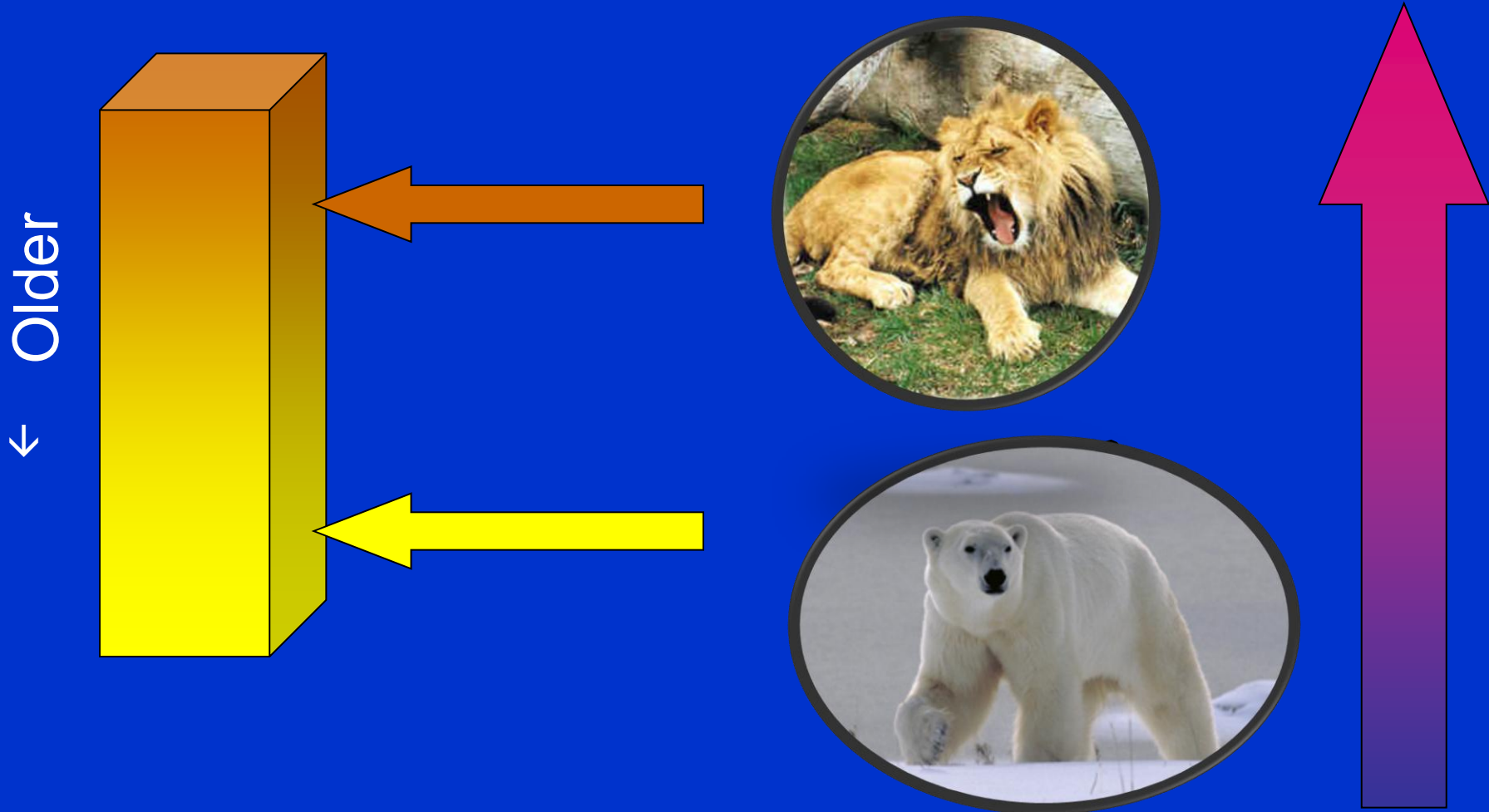
... many more!

Three lectures ...

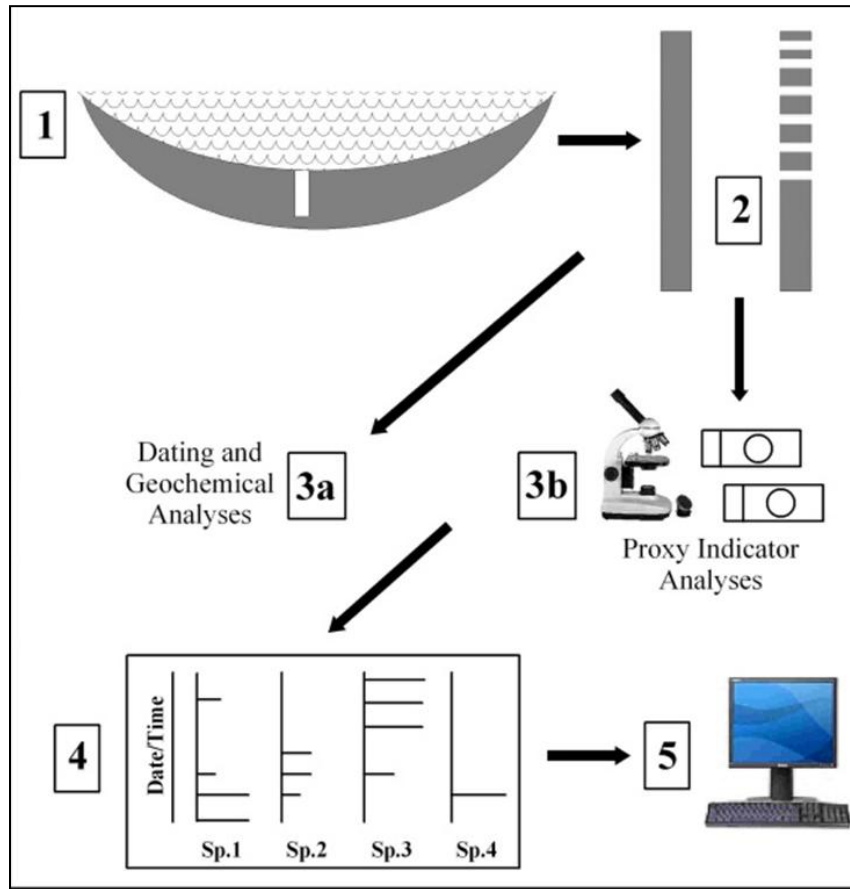
- Polar limnology
- Polar paleolimnology
- Environmental change



Paleoecological Inferences



Paleolimnological Method

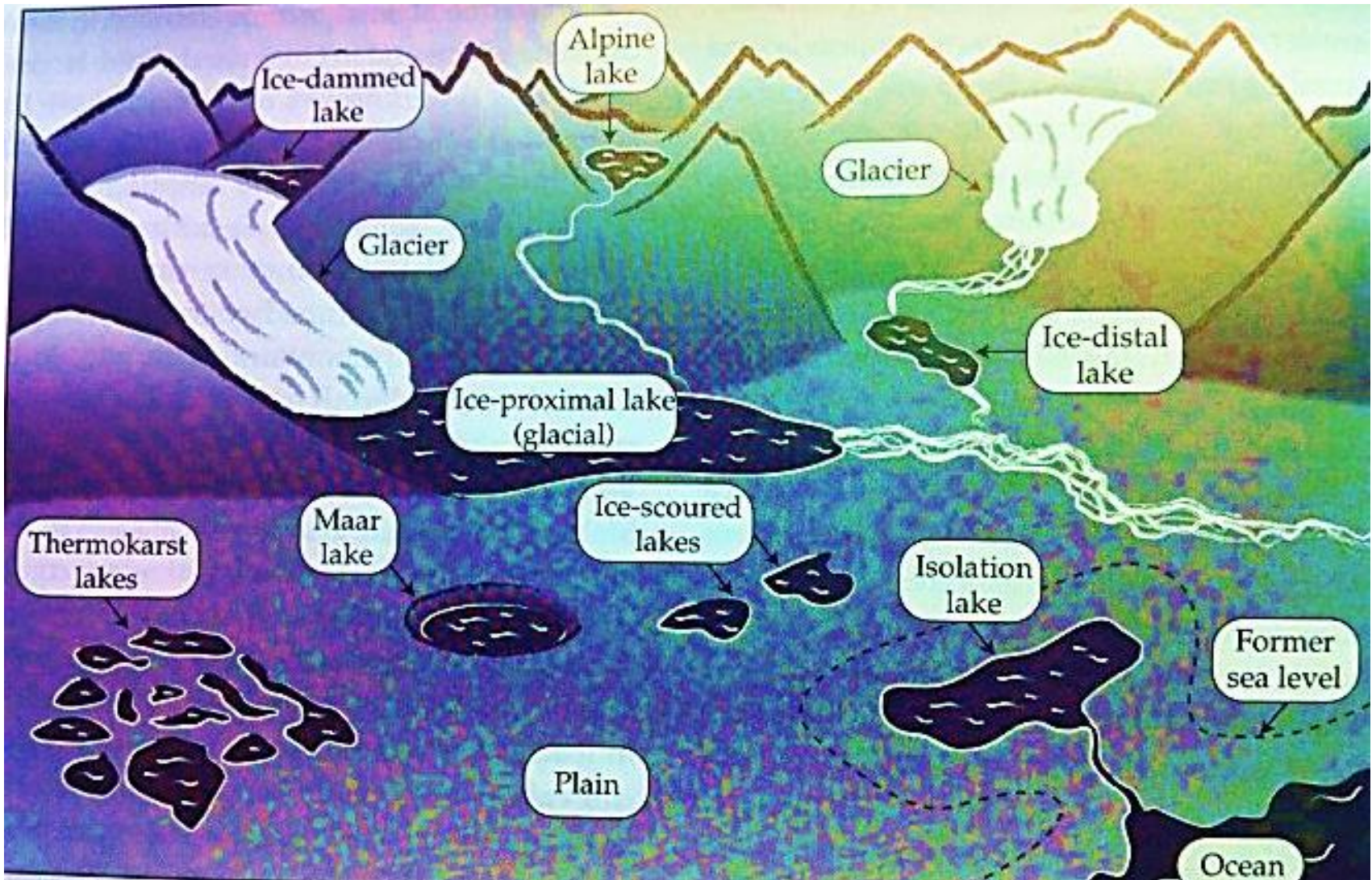


1-2 Coring techniques

3a,b Dating and geochemical analyses

4-5 Proxy indicators and interpretation

Coring method depends upon lake type and time period investigated



Modified from Pienitz et al. 2008

Surface sediment gravity coring

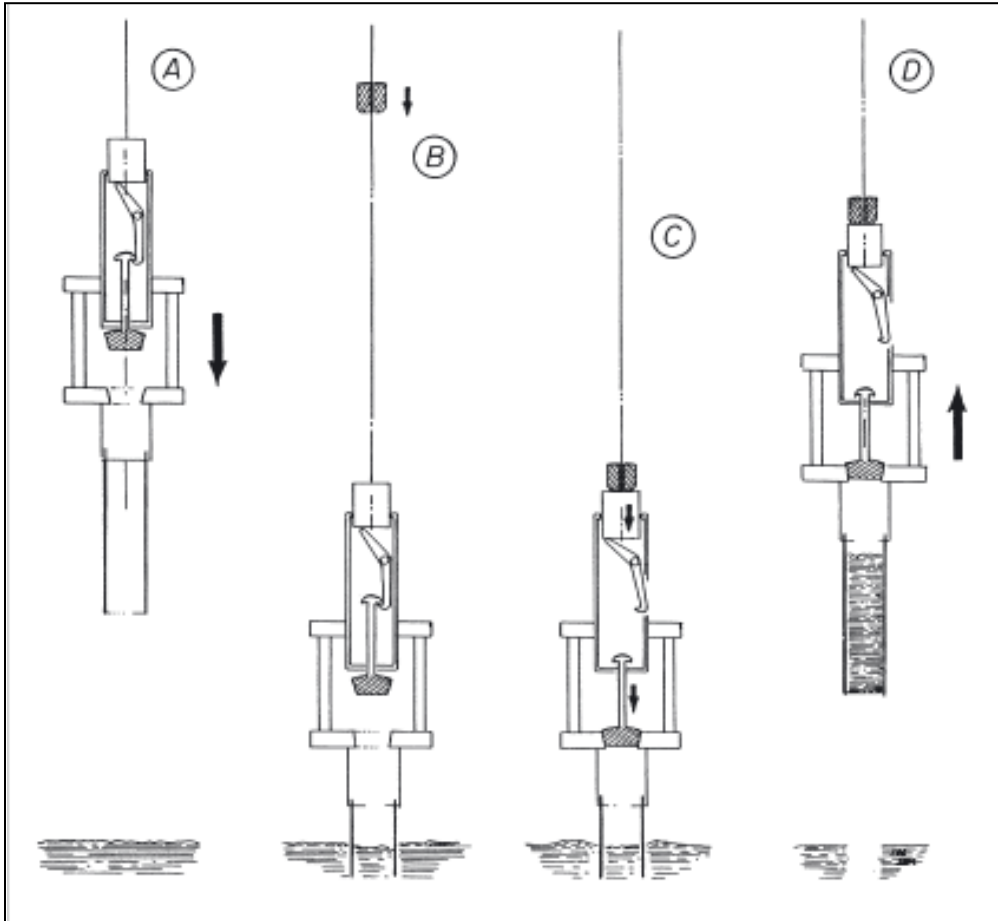
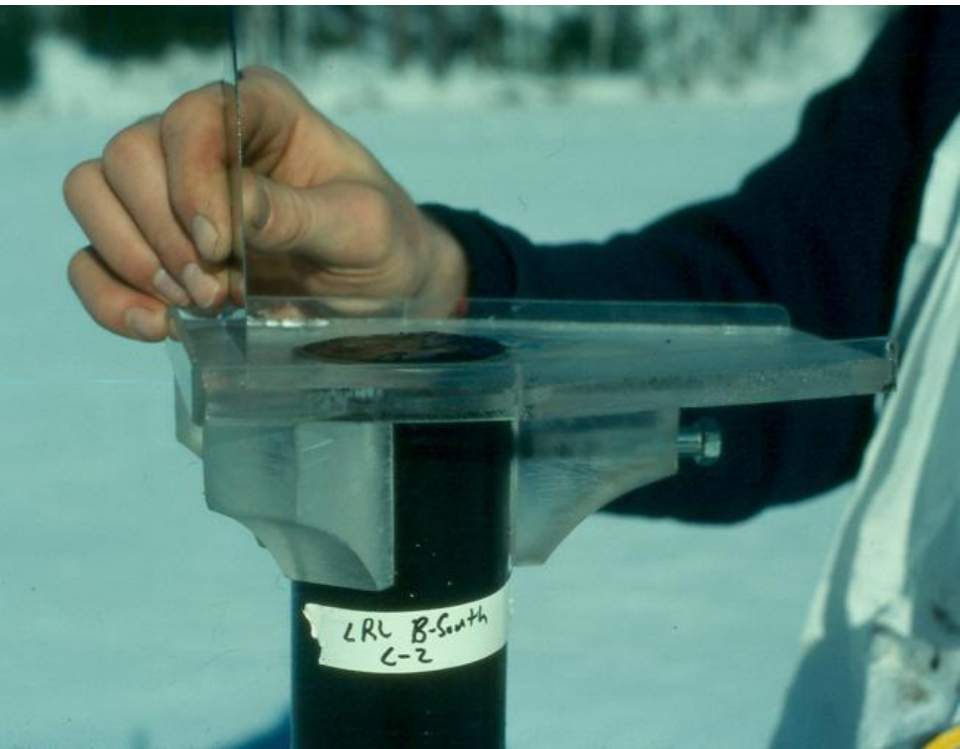


Figure 4.2 in Smol (2008)



Close-Interval Sectioning



Photos: JP Smol

Freeze coring

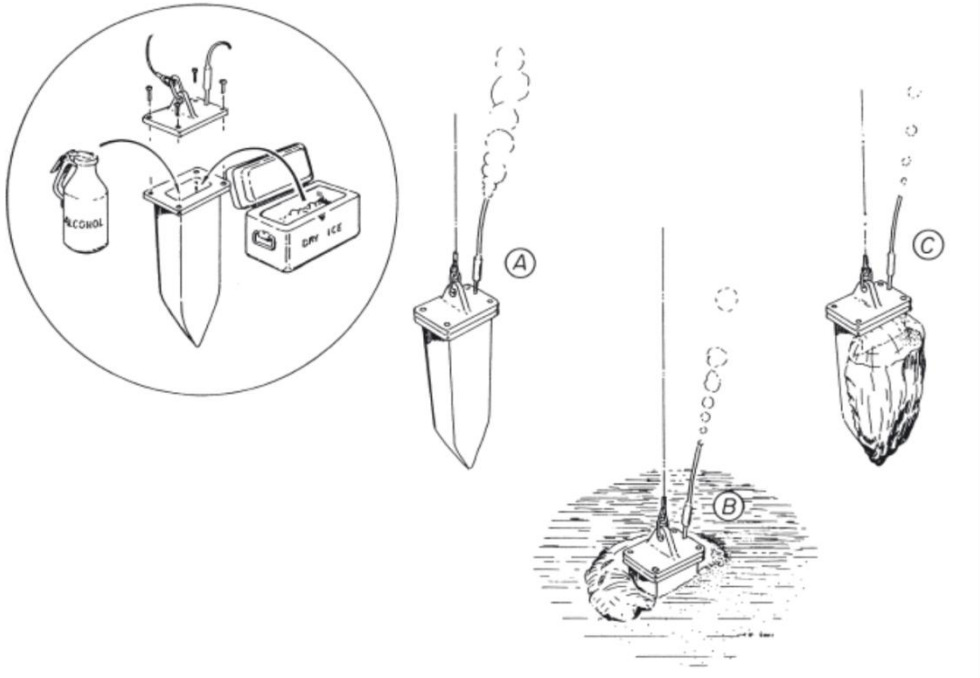


Figure 4.3 in Smol (2008)



Photo: P. Leavitt

Piston coring

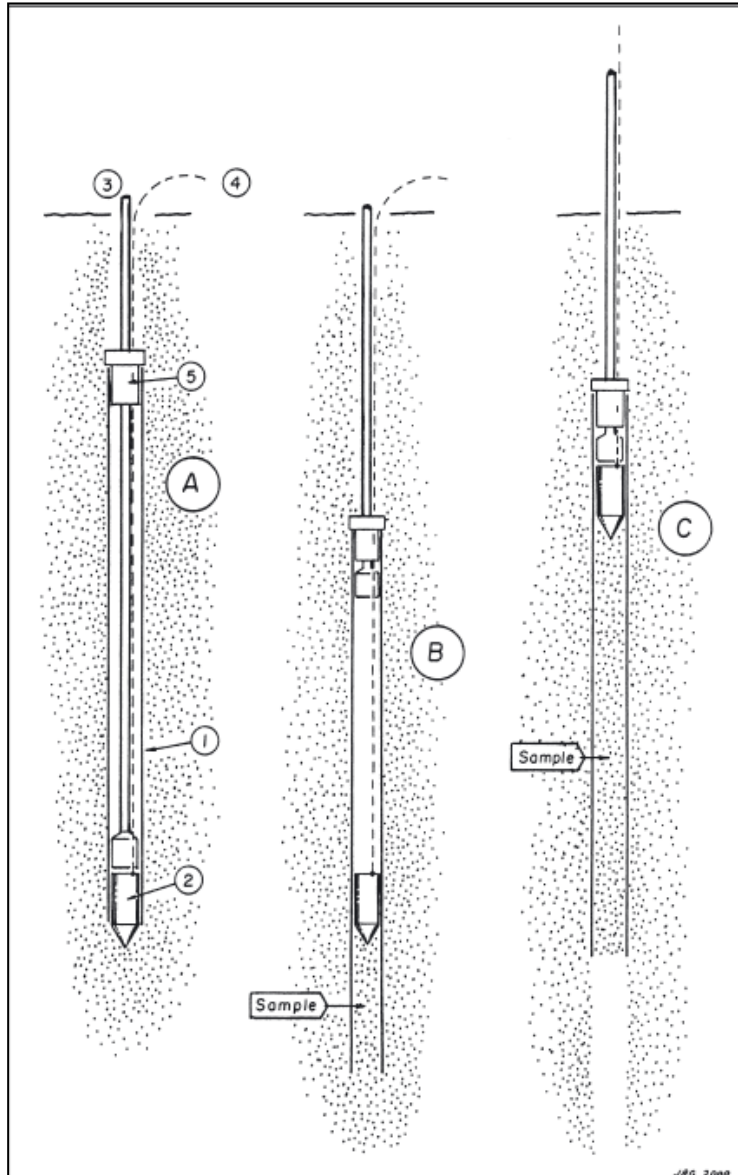


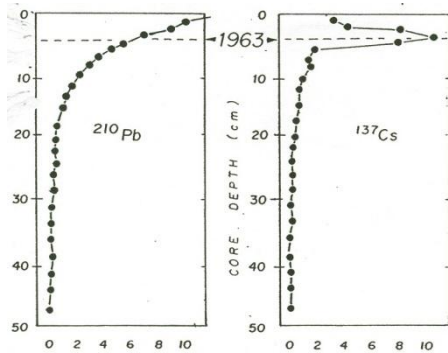
Photo: I. Walker

Figure 4.5 in Smol (2008)

Geochronology: Dating sediments

Older sediments : ^{14}C radiocarbon dating

Recent sediments : ^{210}Pb , ^{137}Cs



Varves: annual couplets of sediment

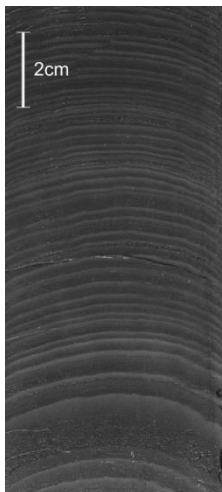
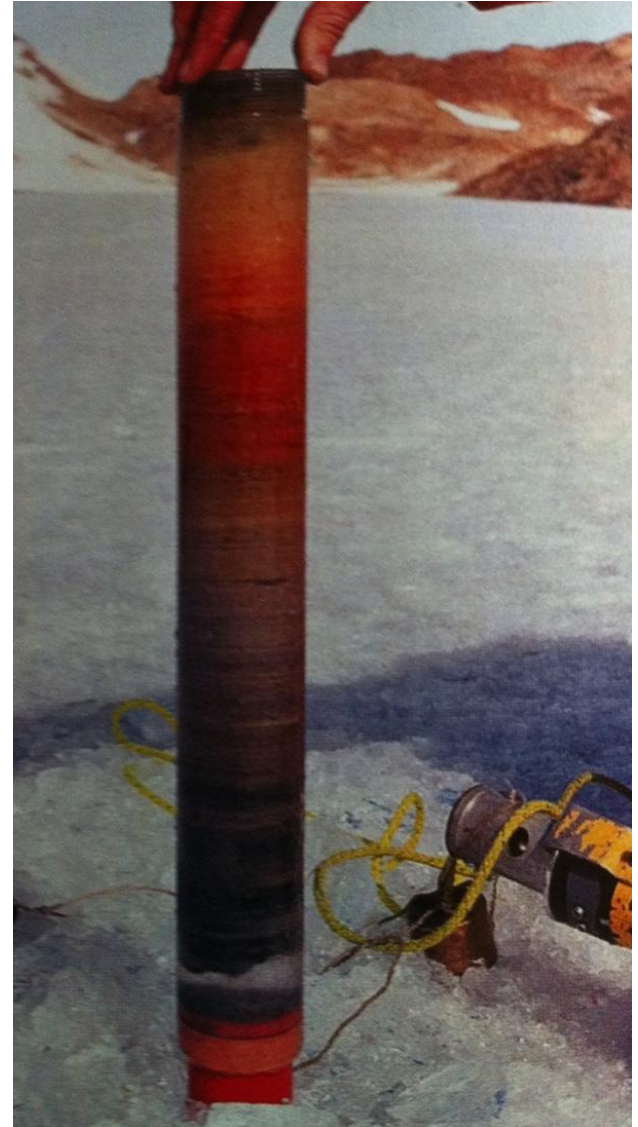
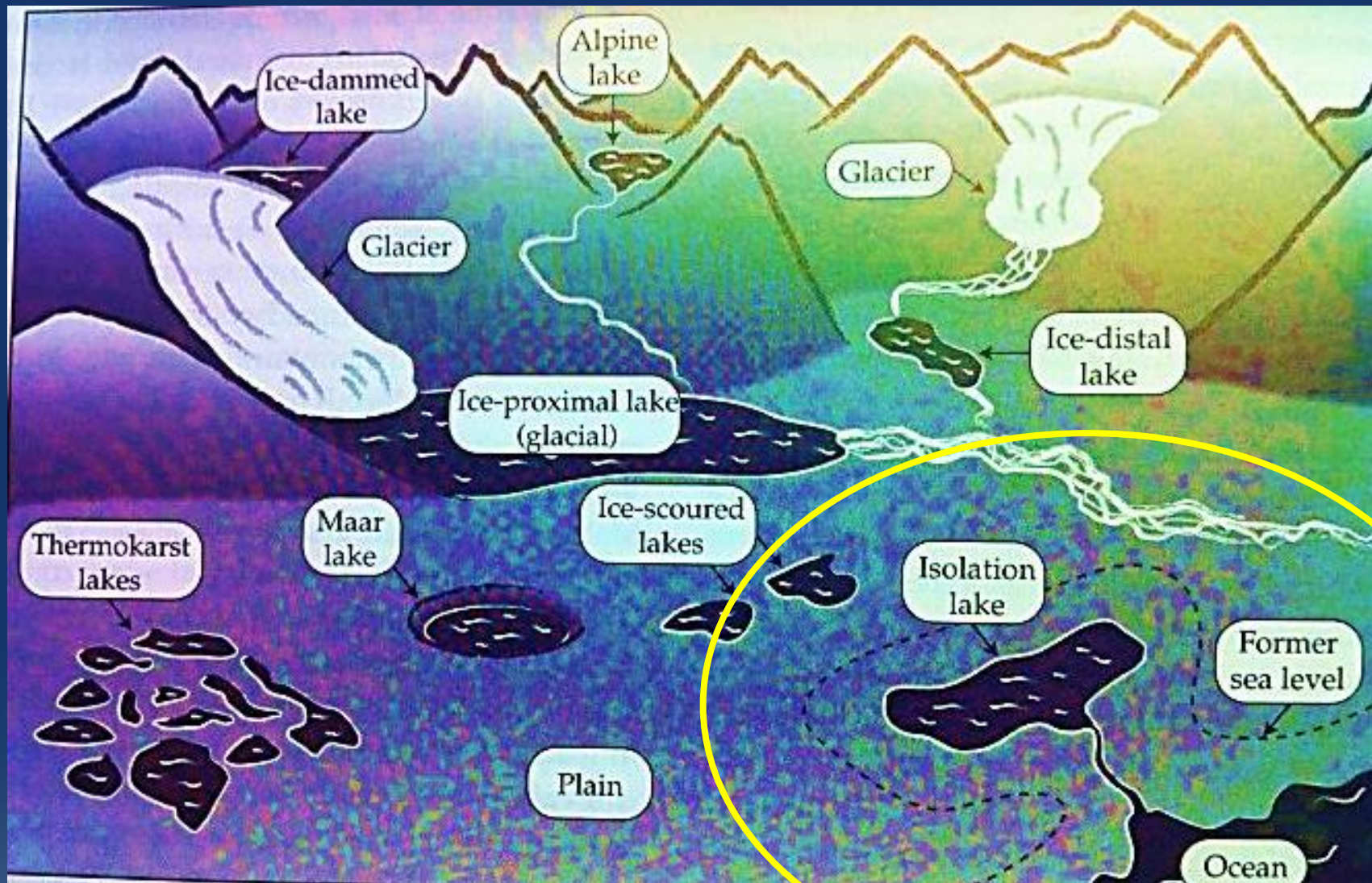


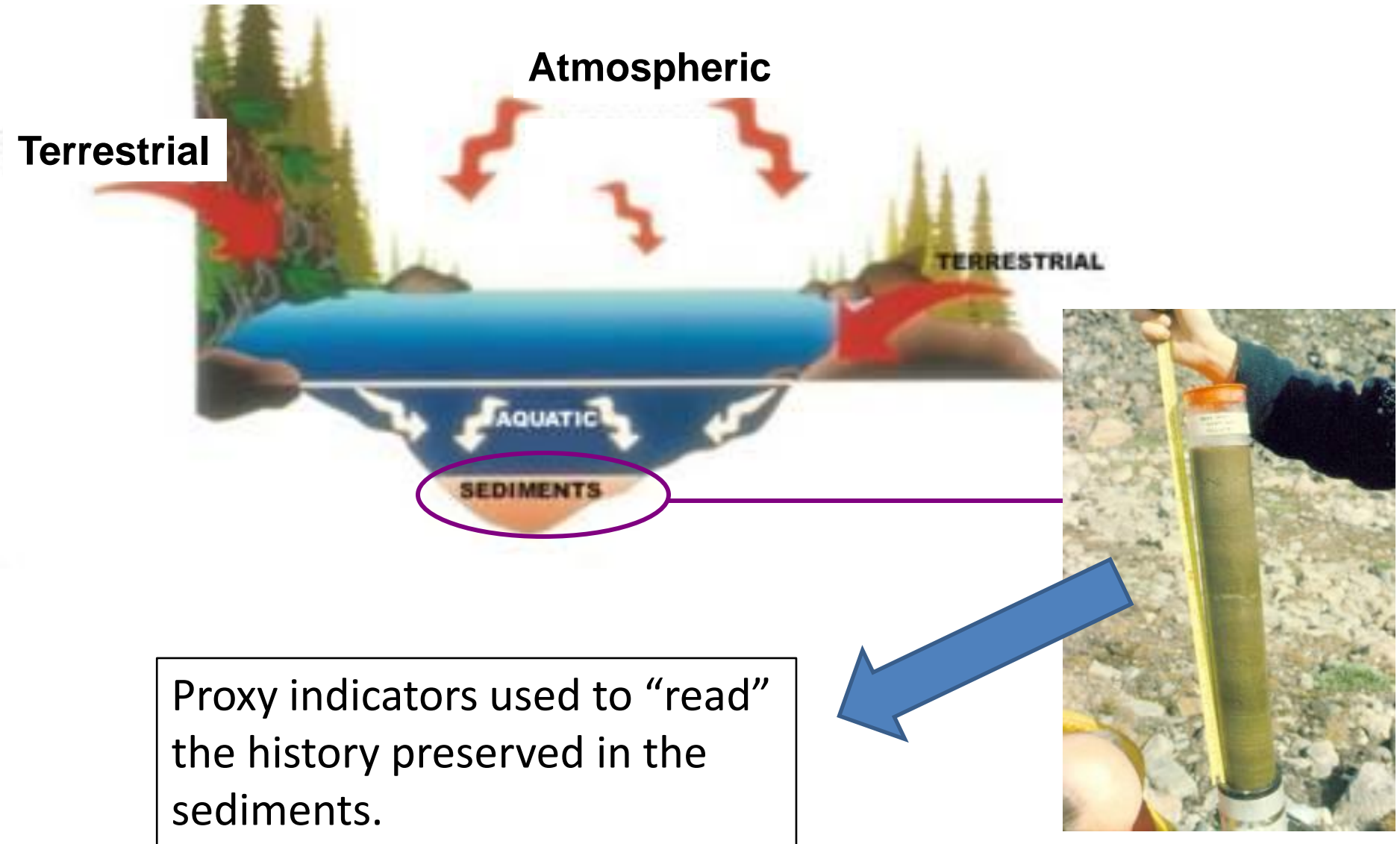
Photo: S. Lamoureux; Figure 4.9 in Smol (2008)



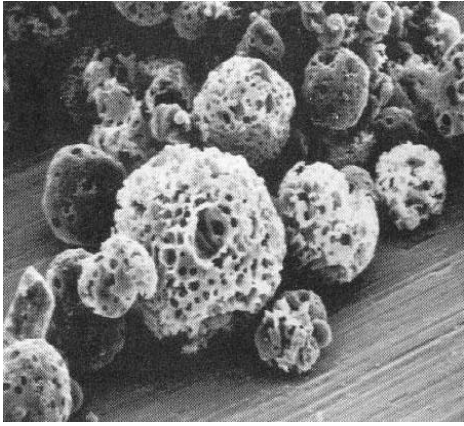


Modified from Pienitz et al. 2008

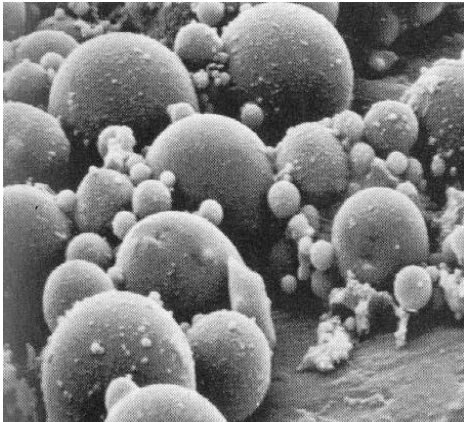
Lake sediments contain useful indicators



FROM THE ATMOSPHERE



carbon particles
from carbon
combustion



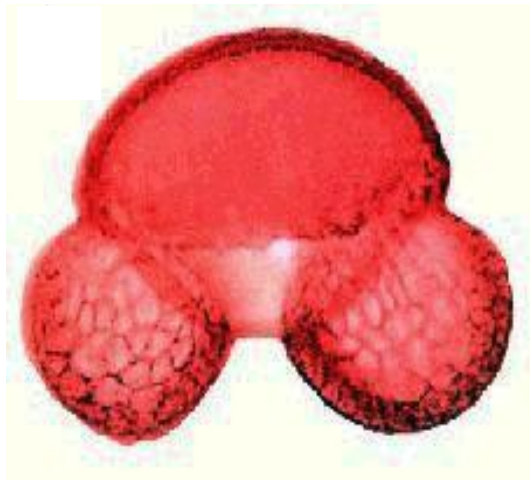
fly ash from coal
combustion

metals and other
pollutants from
industry



FROM THE CATCHMENT

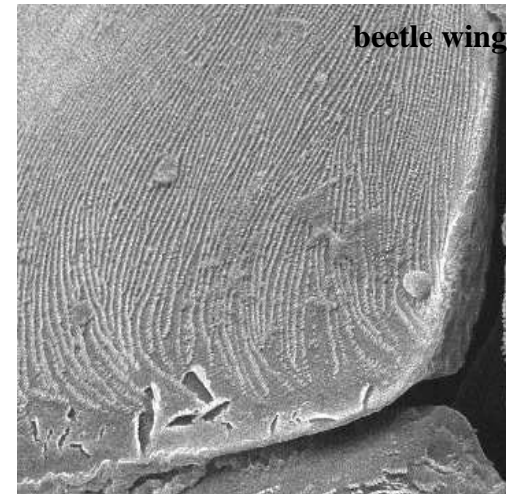
pollen



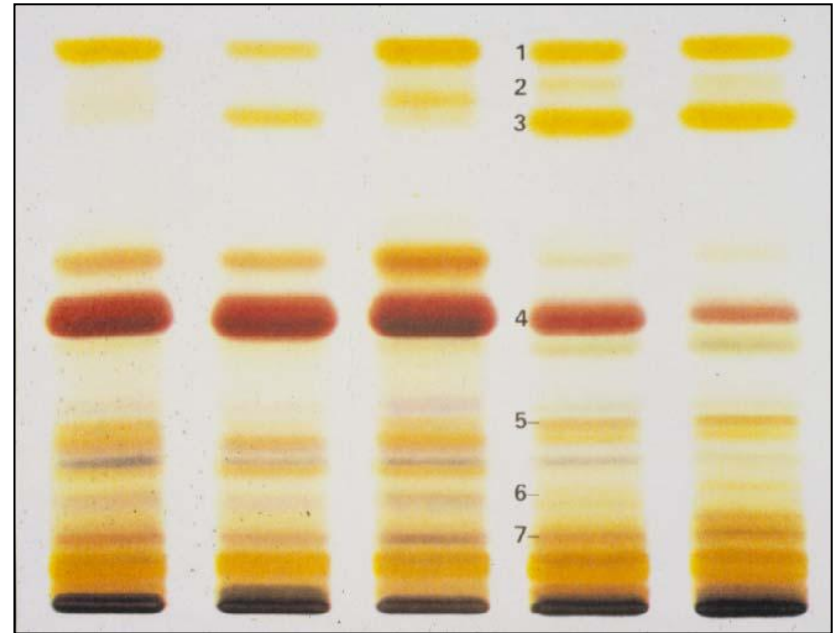
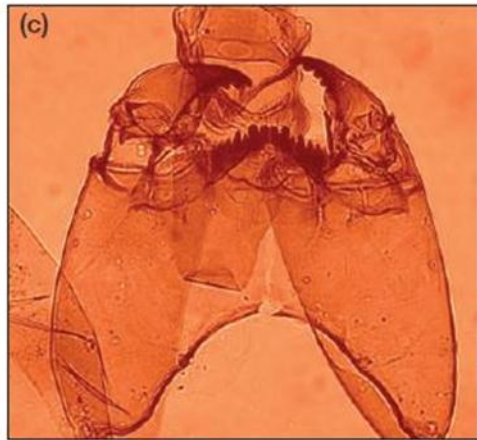
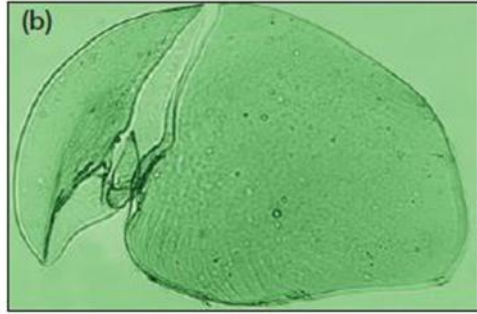
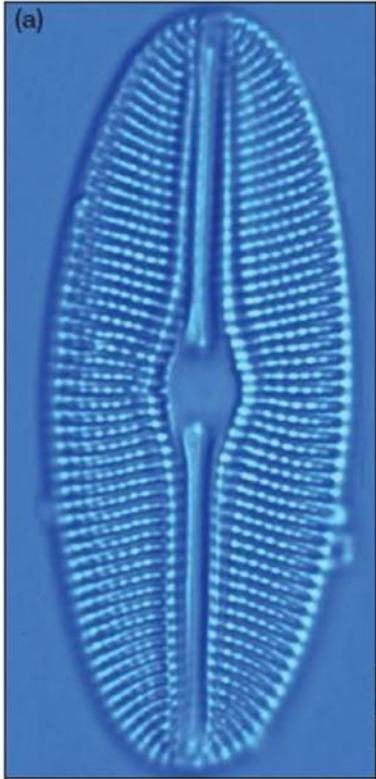
mineral
particles



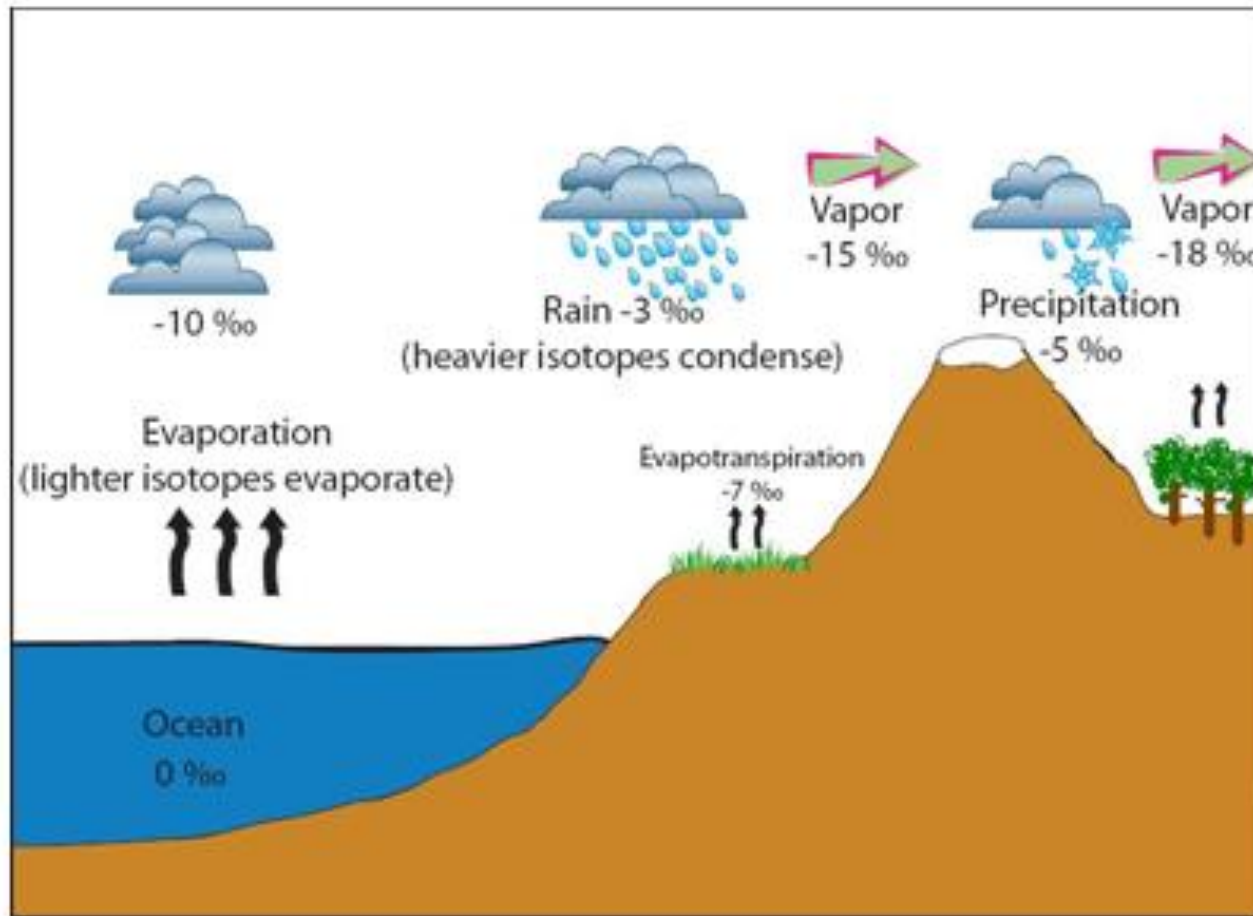
insect
remains



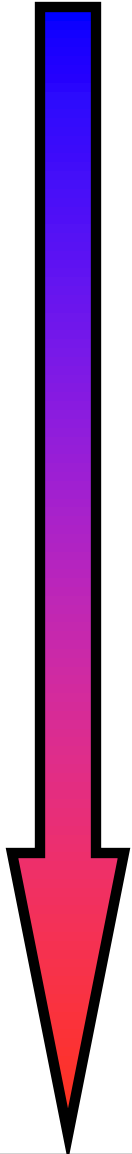
FROM THE AQUATIC SYSTEM



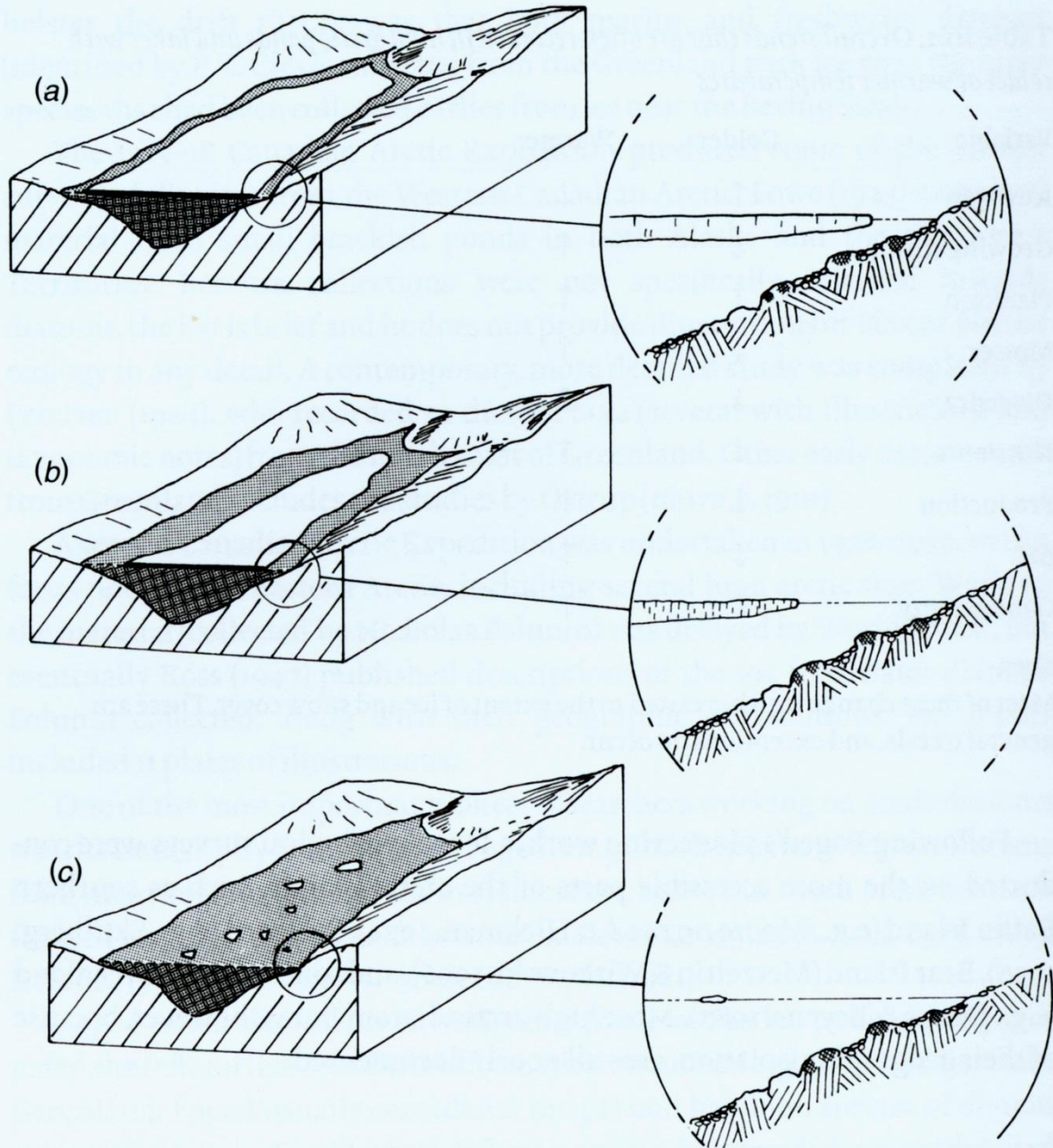
Stable isotopes, eg O, C, N



Cooler temperatures

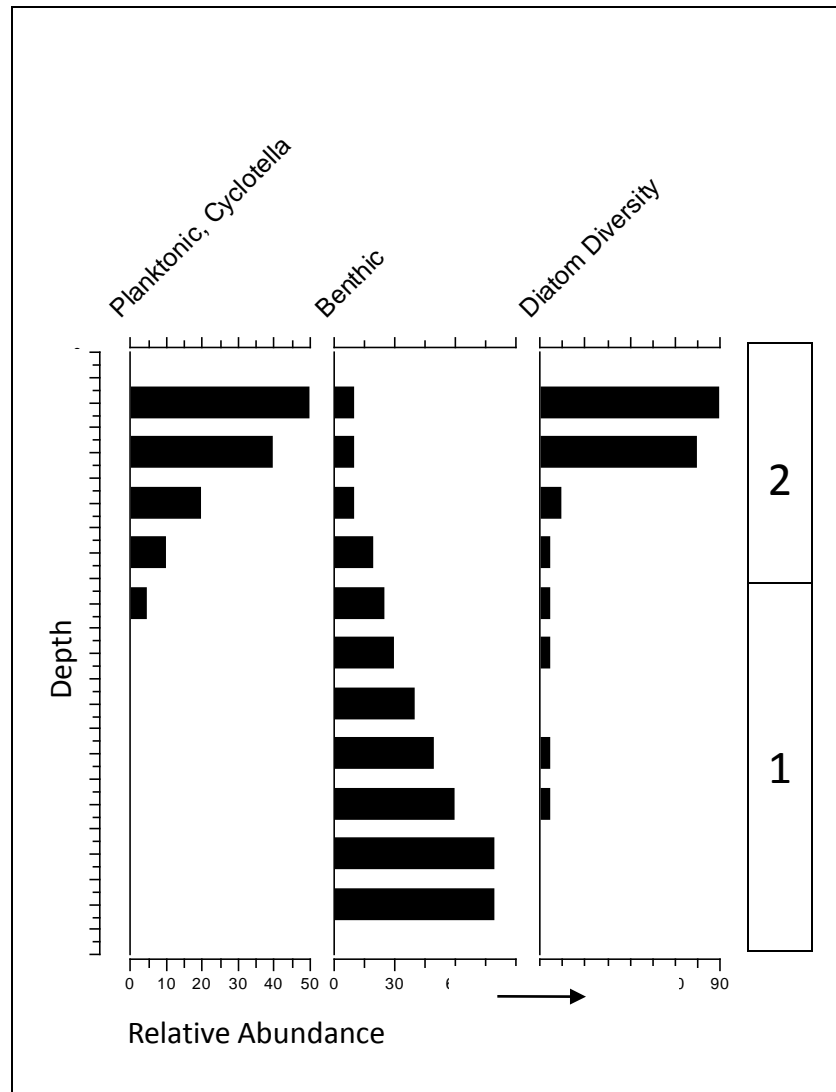
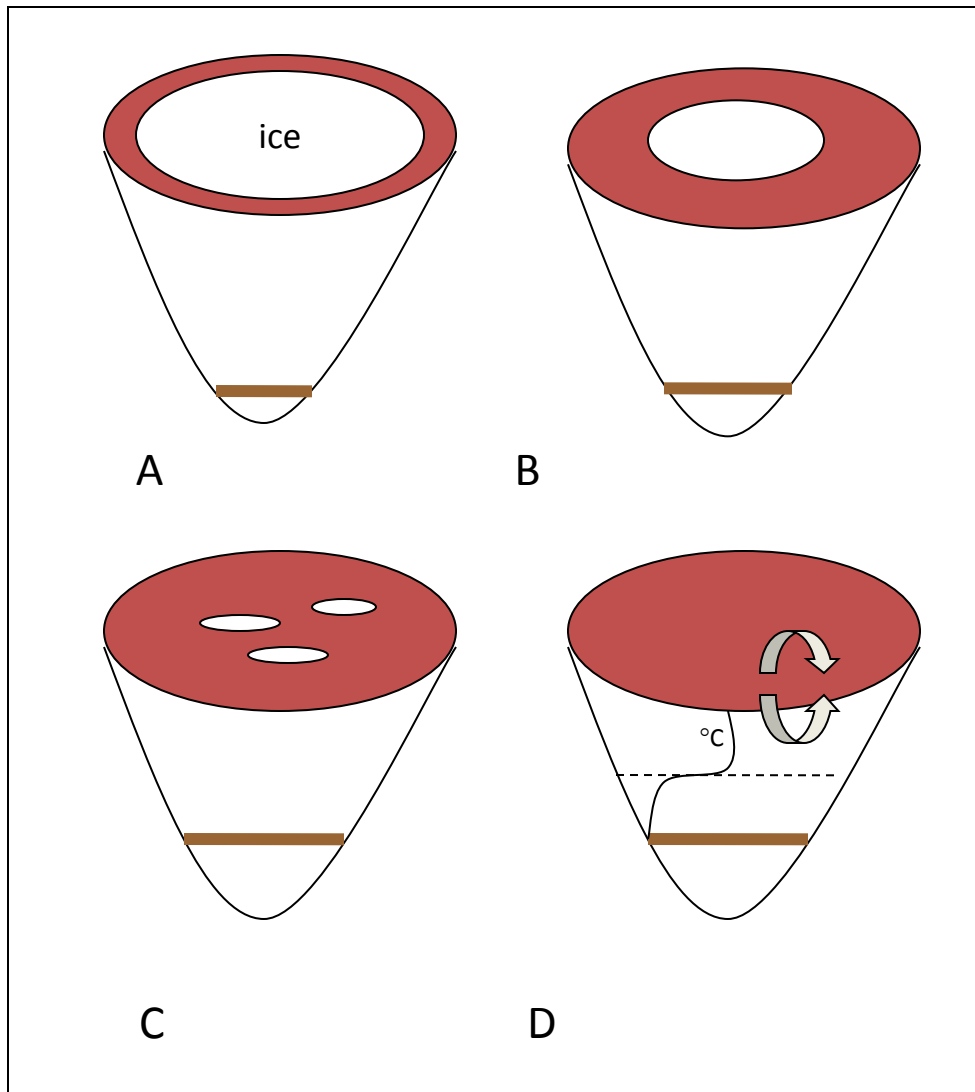


Warmer Temperatures

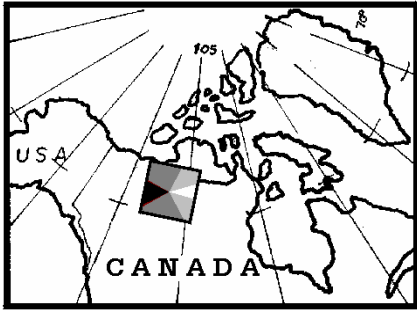


(Smol 1983, 1988)

Ice effects on lakes' habitats, nutrients ...



Slipper Lake, NWT

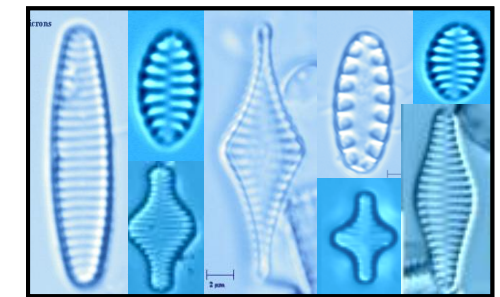
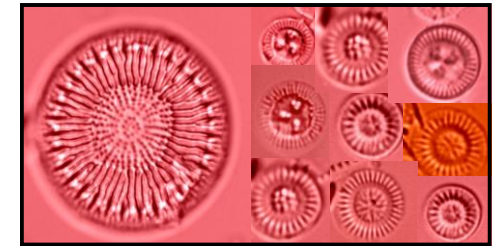
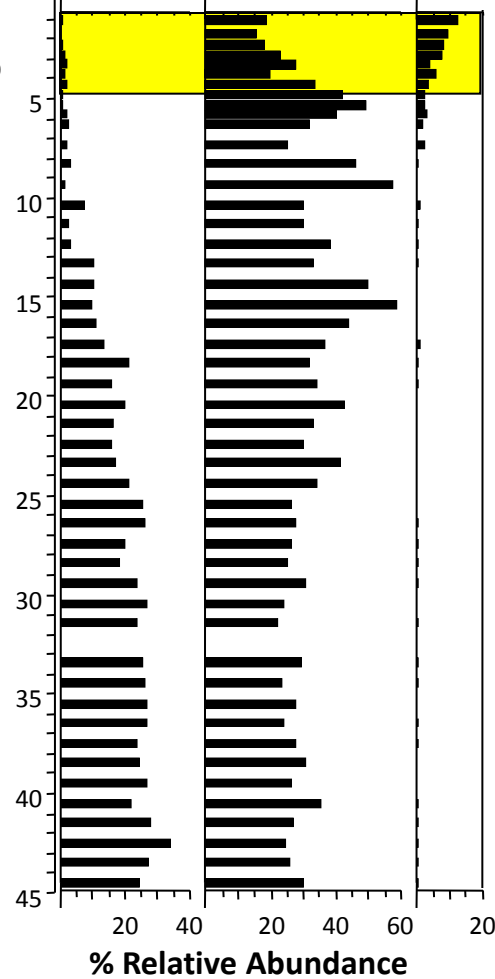


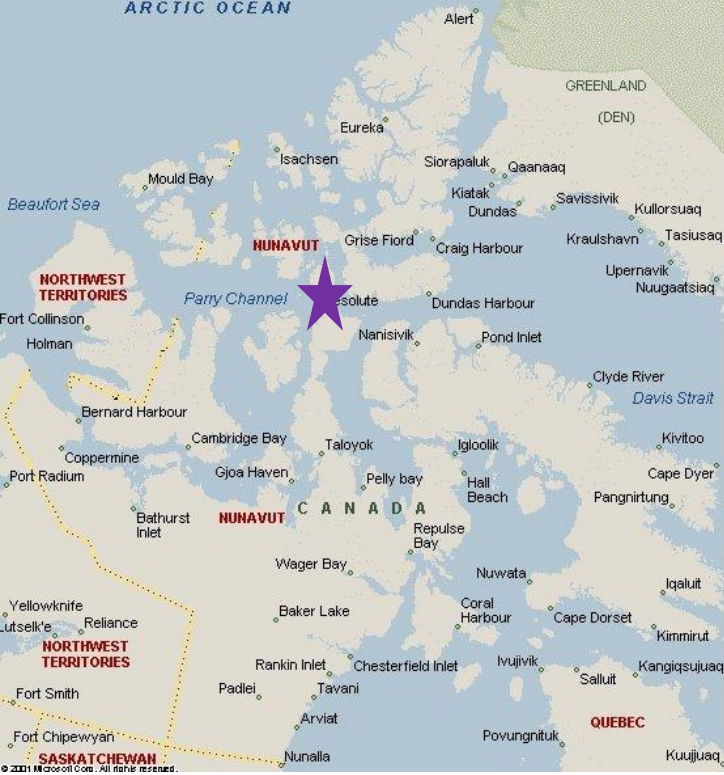
Core Depth (cm)

1997 +/- 2.0
 1937 +/- 6.5
 1886 +/- 29.9
 1837 +/- 60.0
 1804 +/- 74.0

1695-1400 BC

3660-3365 BC





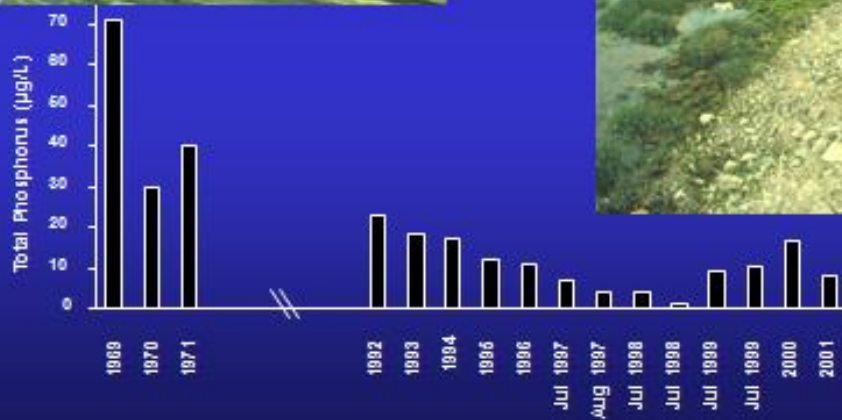
Nutrient additions...
Meretta Lake, Resolute Bay (★),
Cornwallis Island, NU.
IBP study site



August 1970



August 1997



(Douglas and Smol)

Taken July 8 2014
The Meretta Lake “sewage stream” is now a regular High Arctic Stream, as is also Meretta Lake = a typical High Arctic lake.



Meretta Lake
Cornwallis Island, Nunavut

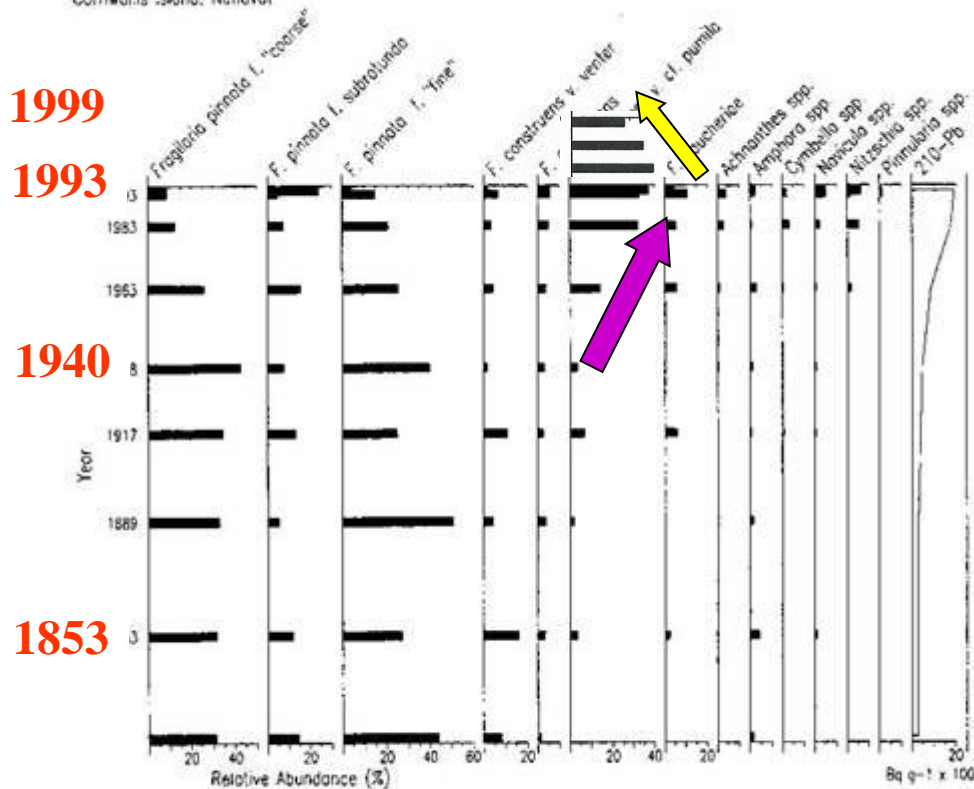


Figure 9. Diatom species composition changes (%) in the Meretta Lake core. ^{210}Pb dates are shown to the left, and activity is shown to the right.

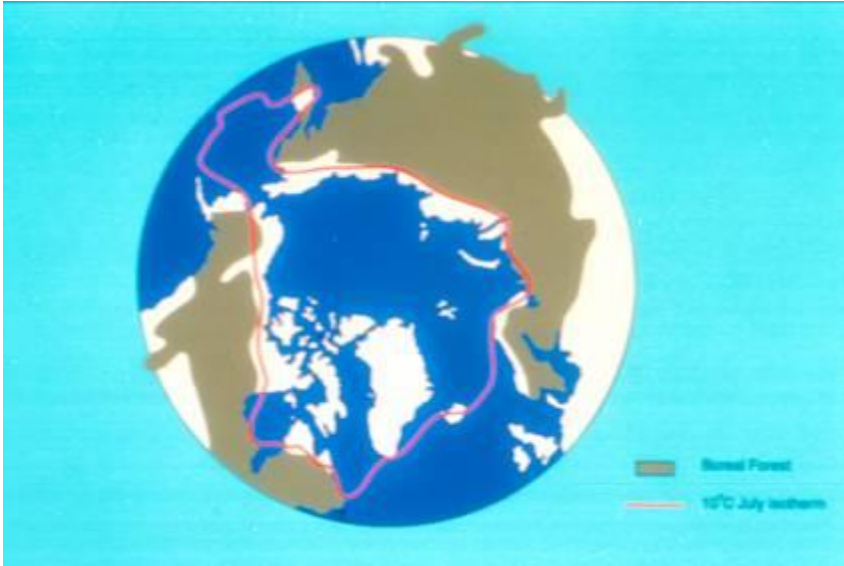
Douglas and Smol 2000, Michelutti et al. 2002a, b

Fragilaria pumila increases rapidly, post 1948.

Recent sampling show that this diatom has decreased, in parallel with decreasing P levels

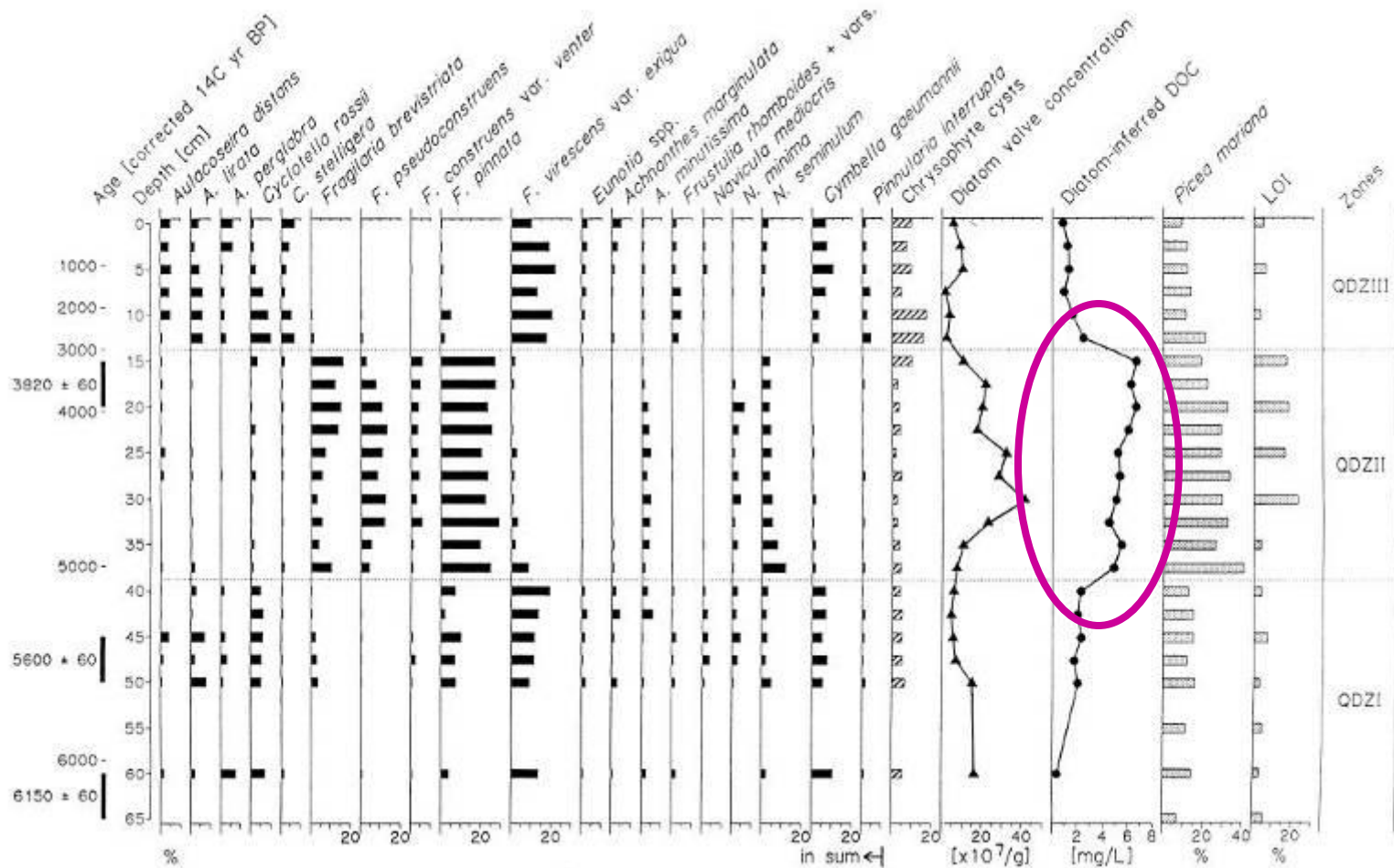


Paleolimnology tracks treeline.



Bioindicators, such as diatoms can be used to track amount of DOC (dissolved organic carbon). Higher amounts are present in the water when there is vegetation present. So, as treeline moves with climate, the water chemistry varies.

Shifting tree-line as inferred from diatom-inferred DOC



“Queen’s Lake”, 64°N 110°W, NWT

MacDonald et al. 1993

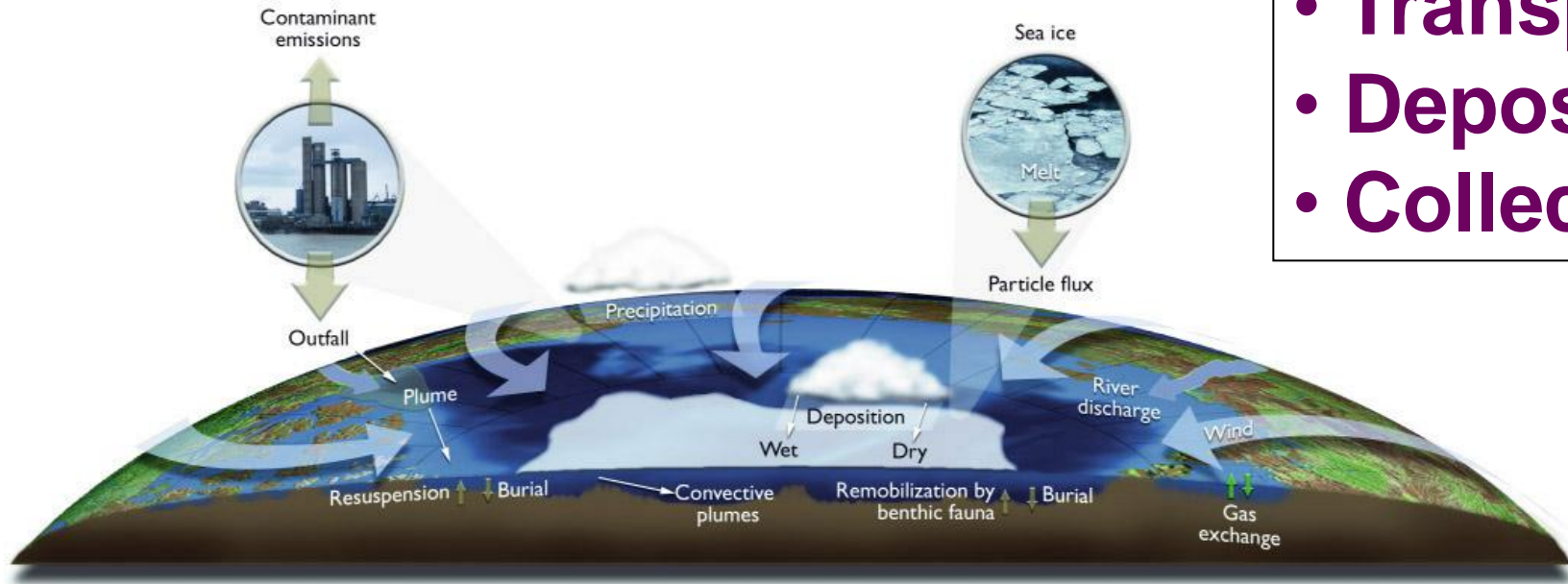
Projected Vegetation, 2090-2100



Seabirds as vectors for nutrients and contaminants

Marine to terrestrial environments

- Transport
- Deposition
- Collection

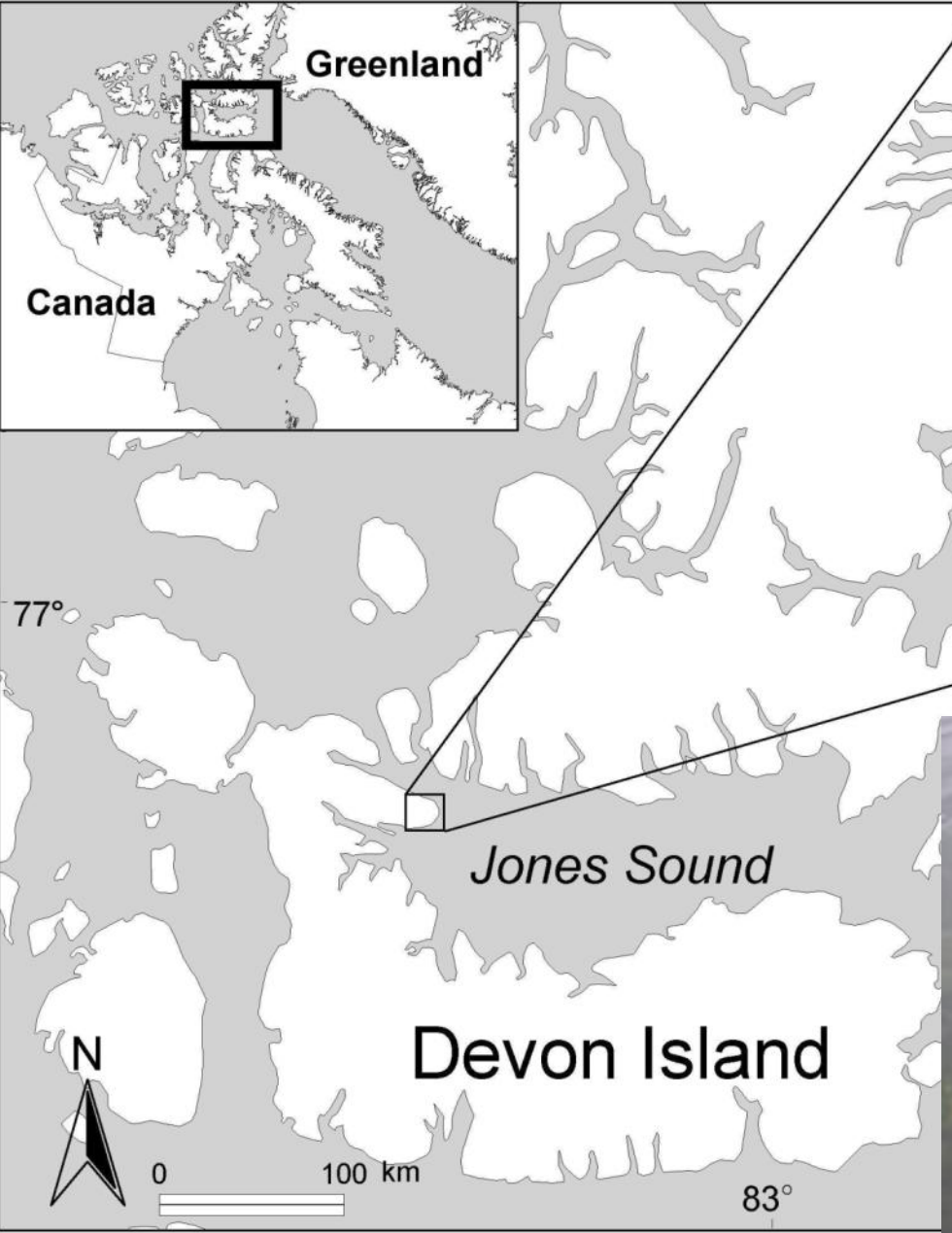


Seabirds

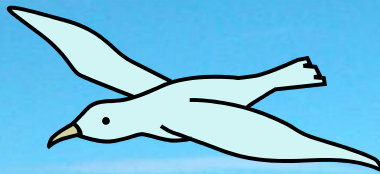
- Found on every continent
- Nesting sites can number in the millions
- Focus nutrients and contaminants



76°15'N, 89°15'W



Cape Vera, Devon Island



Main colony

Abandoned colony ?

CV 16, 17, 18

CV-10

CV 9a

CV-9

CV 8

CV 12

CV 20

CV-7

CV 13

CV14

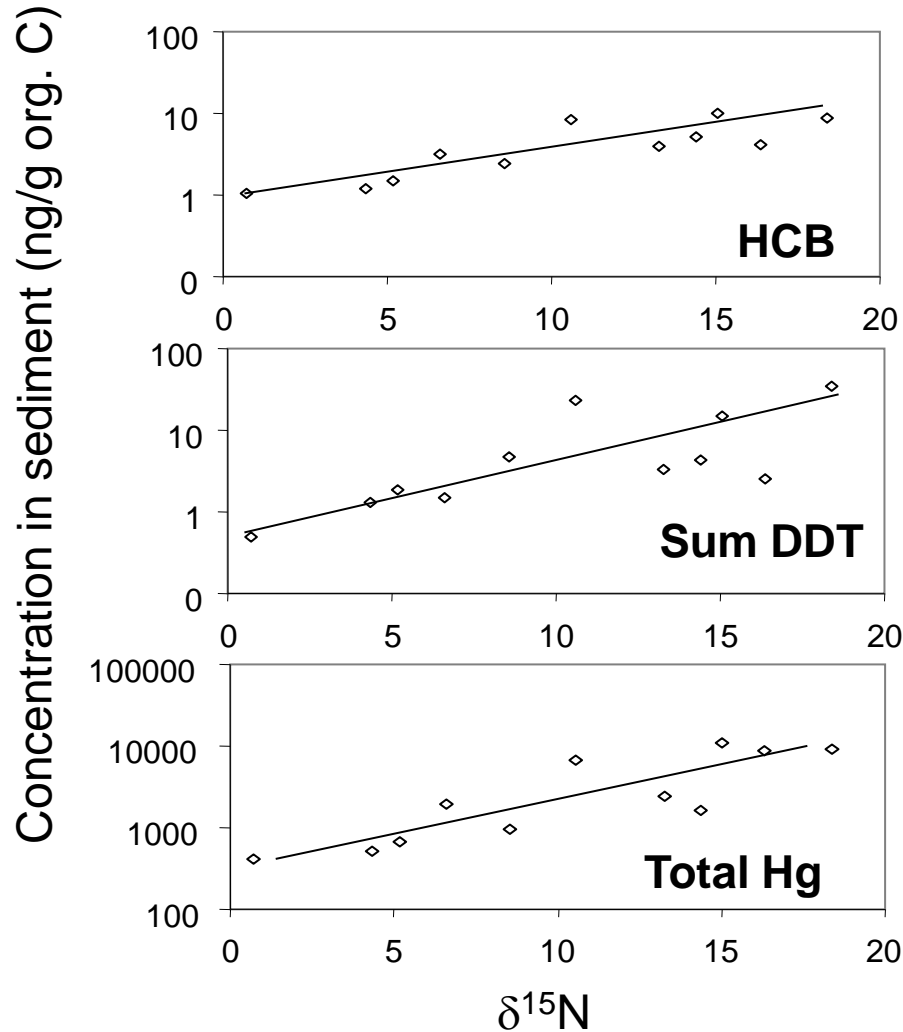
CV15

CV-6

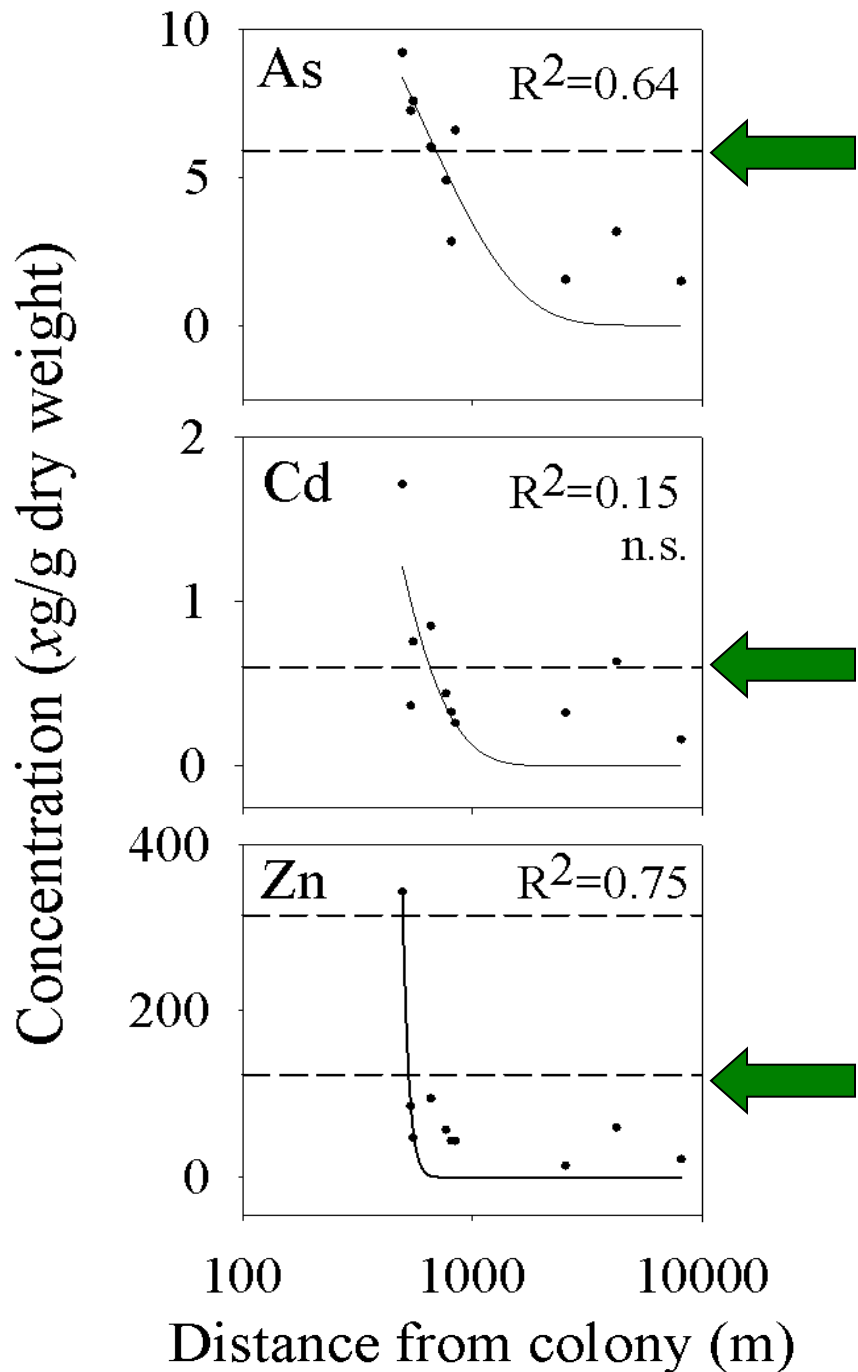
CV-5



Increasing bird influence = more contaminants



(Blais, et al, 2005, *Science*)



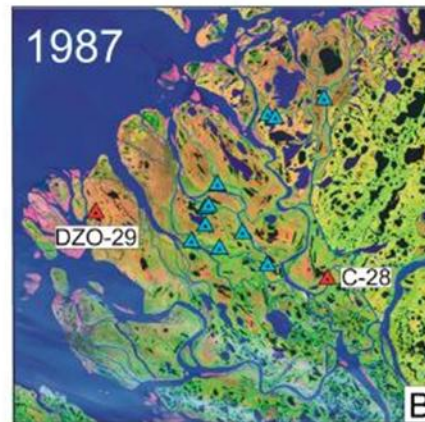
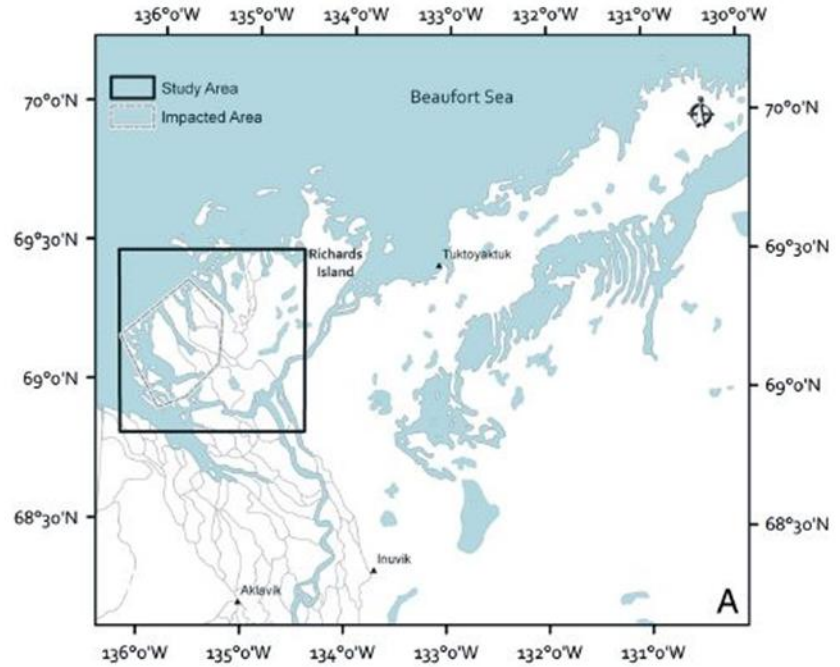
Surface sediment concentrations of some metals plotted against distance from the main colony at Cape Vera

Brimble *et al.* (2009) *Env. Toxicol. Chem.*

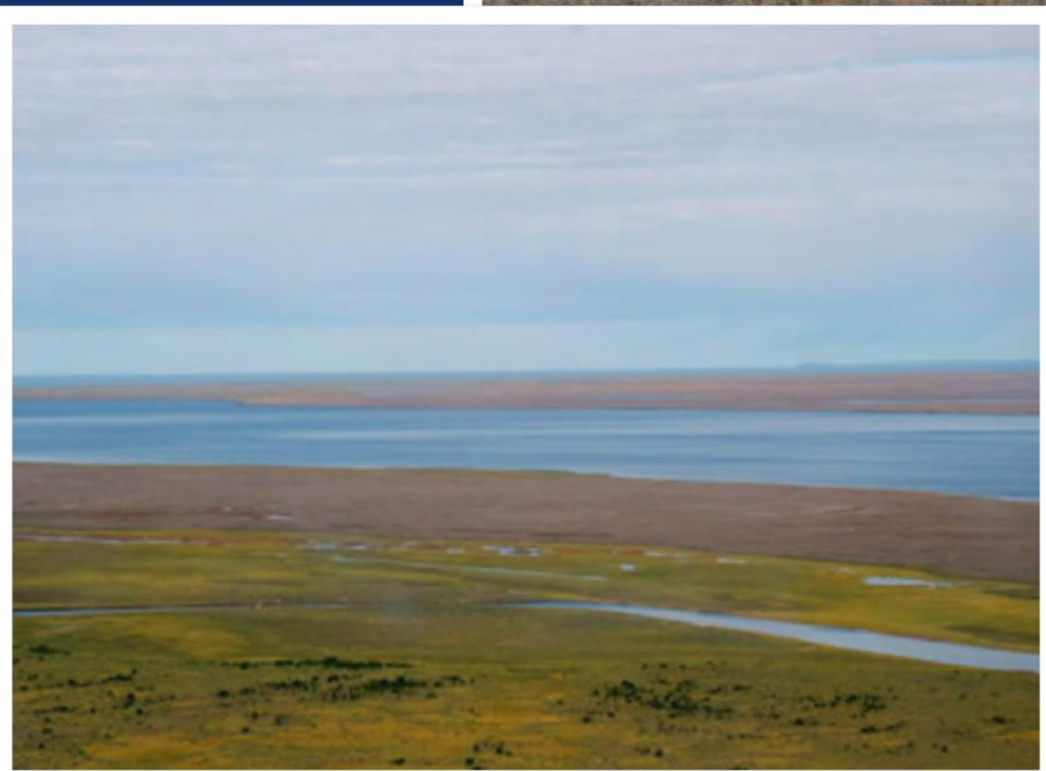
Canadian Sediment Quality Guidelines for the Protection of Aquatic Life

SALT!

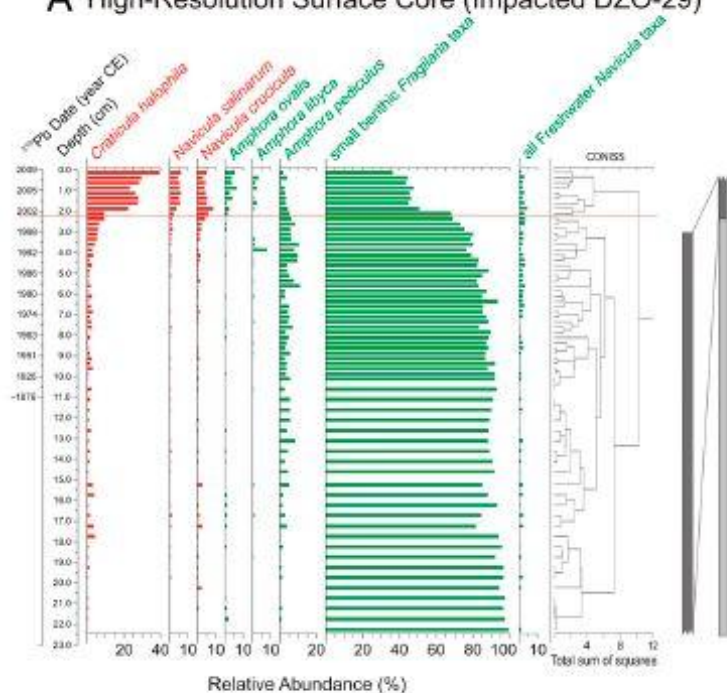
Storm surge 1999



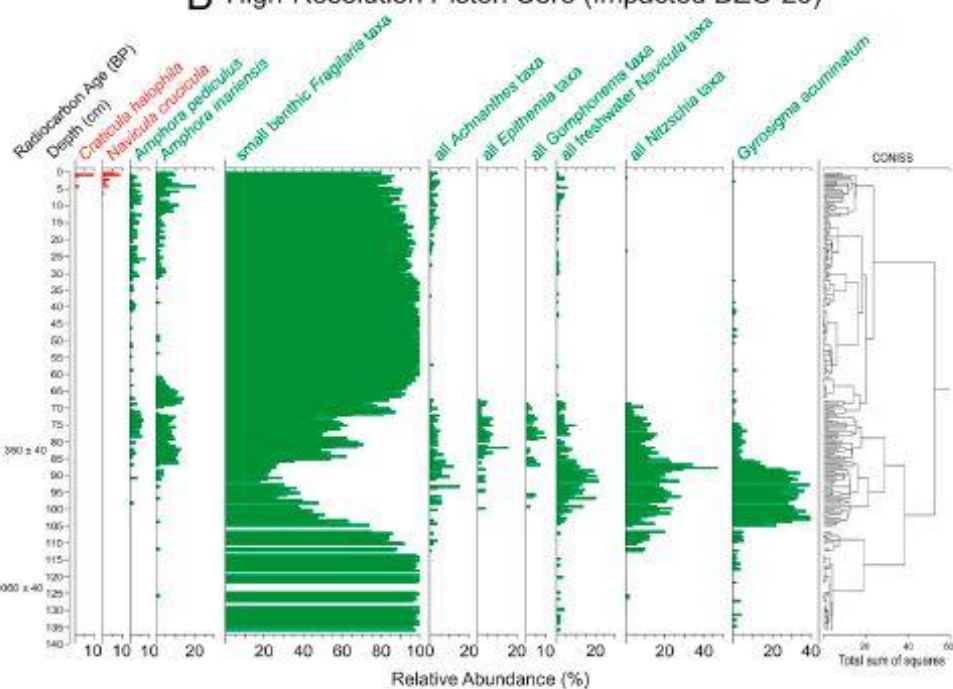
Pisaric et al PNAS 2011



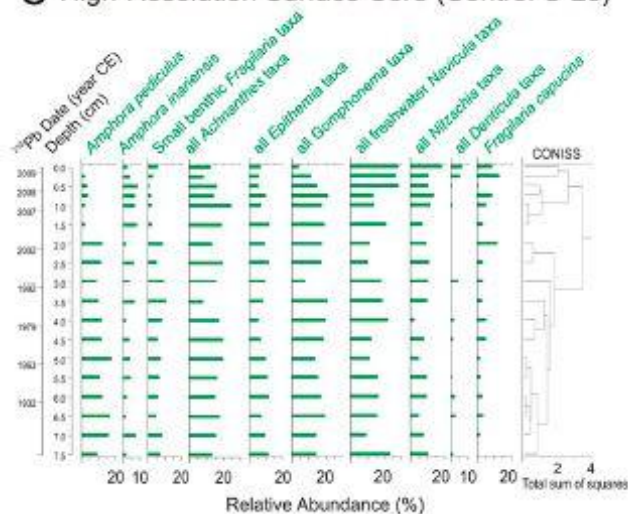
A High-Resolution Surface Core (Impacted DZO-29)



B High-Resolution Piston Core (Impacted DZO-29)



C High-Resolution Surface Core (Control C-28)





Thank you!