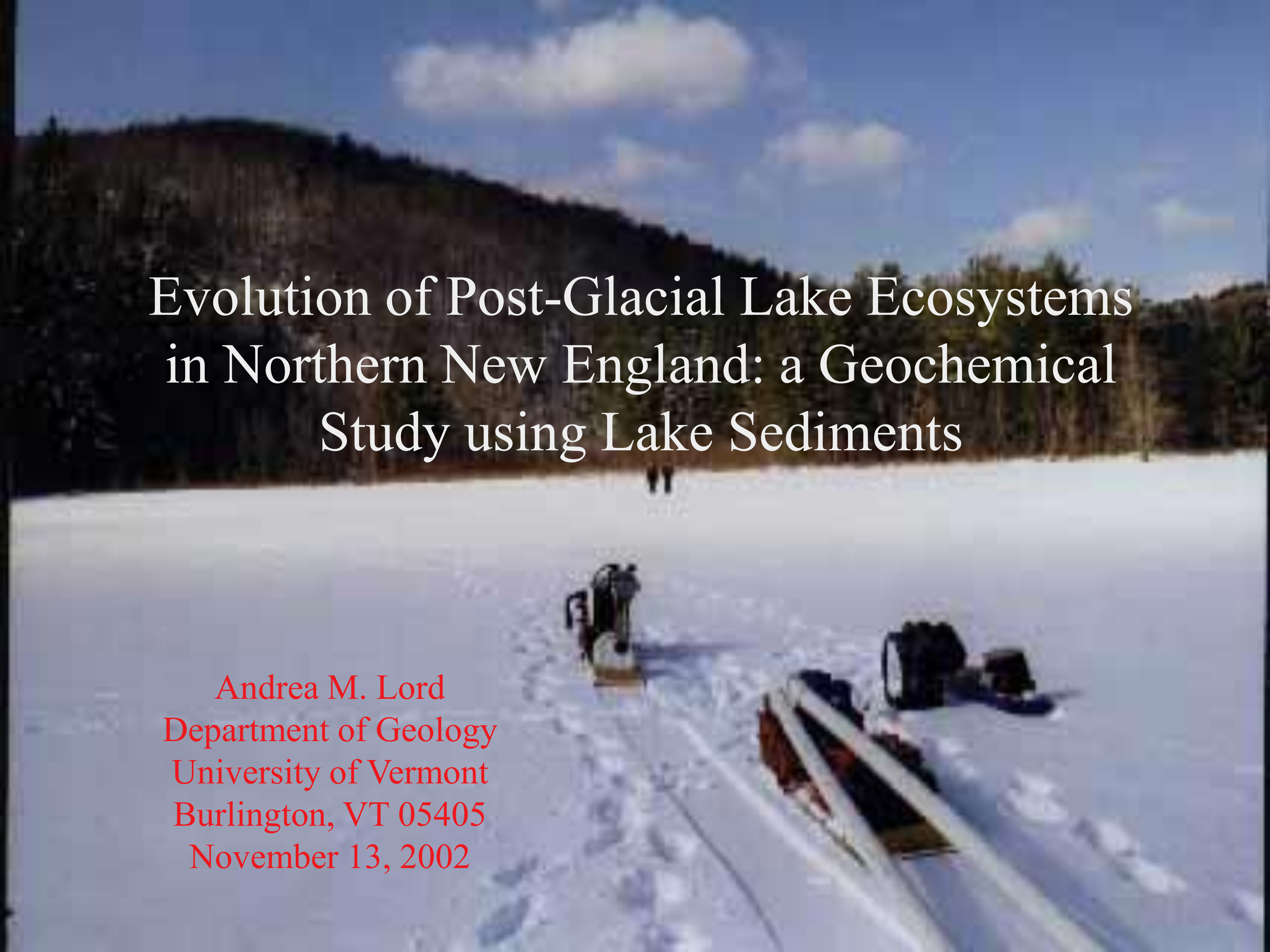

Evolution of Post-Glacial Lake Ecosystems in Northern New England: a Geochemical Study using Lake Sediments

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Outline

- Significance of Study, Objectives
- Study Area
- Methods
- Results and Interpretations
- Comparisons across northern New England
- Summary

Significance of study

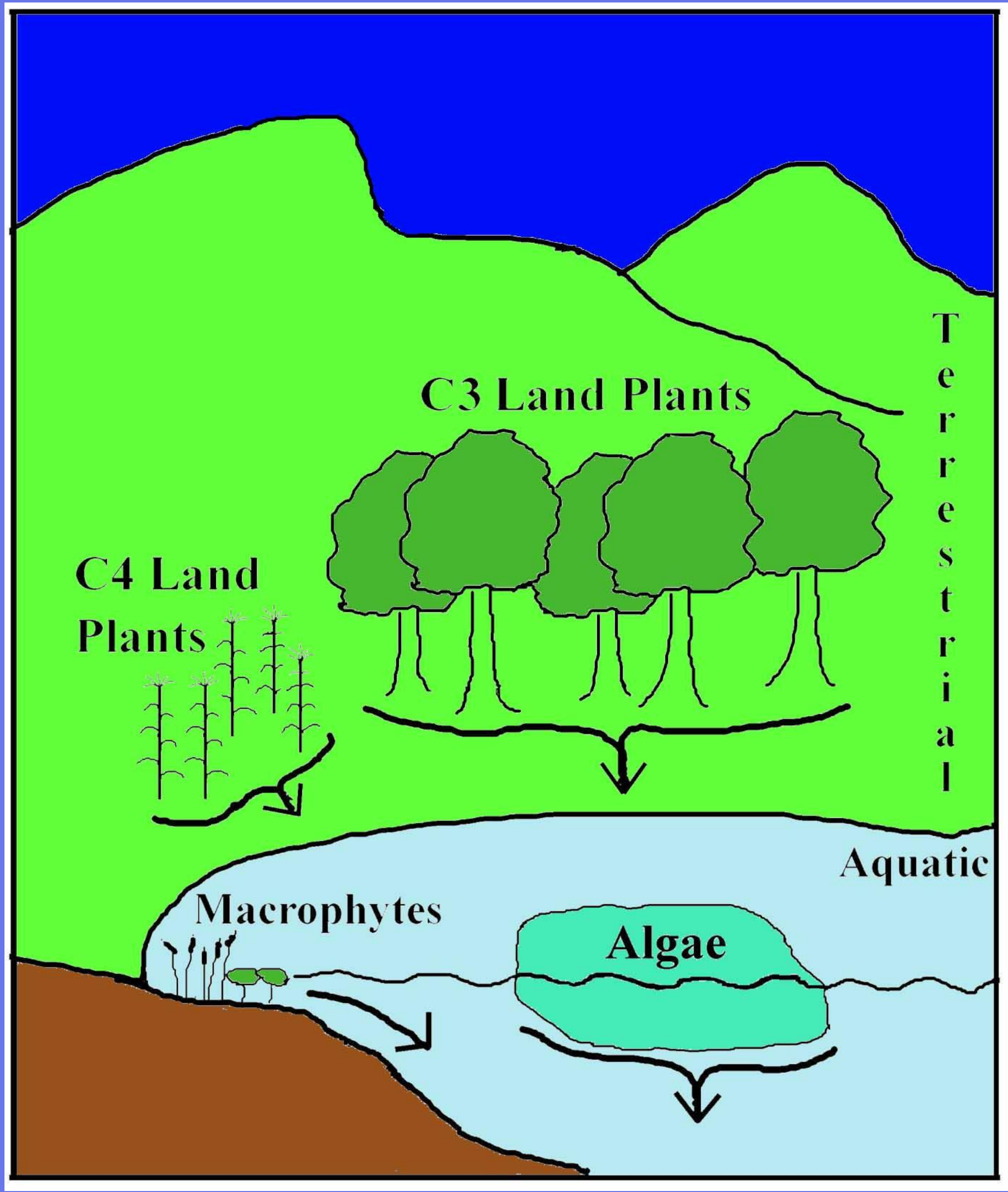
- Extreme climatic events impact ecological communities in and around lakes
- Lake sediments record changes in surface and lacustrine processes
- This study will examine establishment of ecosystems in newly created lakes in barren, nutrient-poor watersheds

Objectives

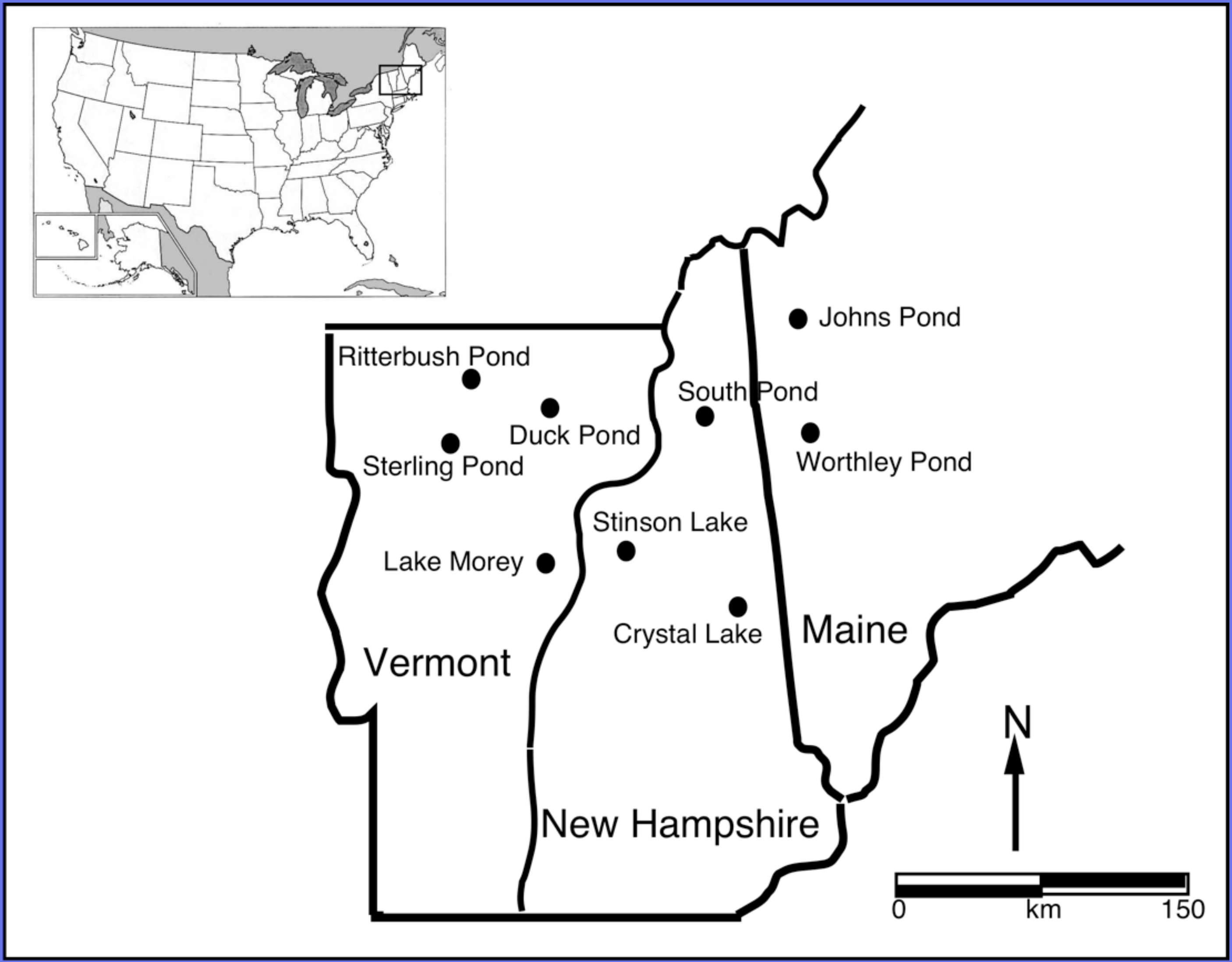
- To investigate the onset of primary productivity in newly formed, post-glacial lakes in northern New England
- To determine and compare the ecosystem development rates in different lakes
- To investigate which parameters influence the rate at which a lake ecosystem develops

Sources of sedimentary organic matter

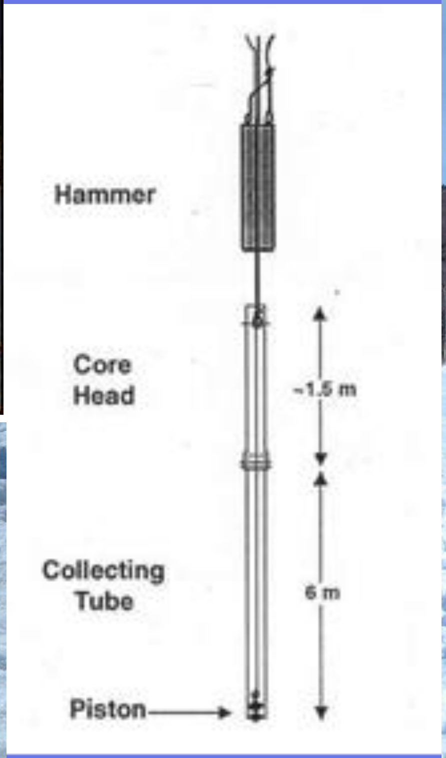
- Terrestrial sources
  (C$_3$ and C$_4$ plants)
- Aquatic sources
  (macrophytes and algae)
- Eolian sources
  (wind-blown, minimal)



Locations of studied lakes



Field methods - winter



Modified Reasoner Coring Device

Field methods - summer

- Biological Sampling

  - Watershed Plants
  - Macrophytes
  - Phytoplankton filtering

Field methods - summer

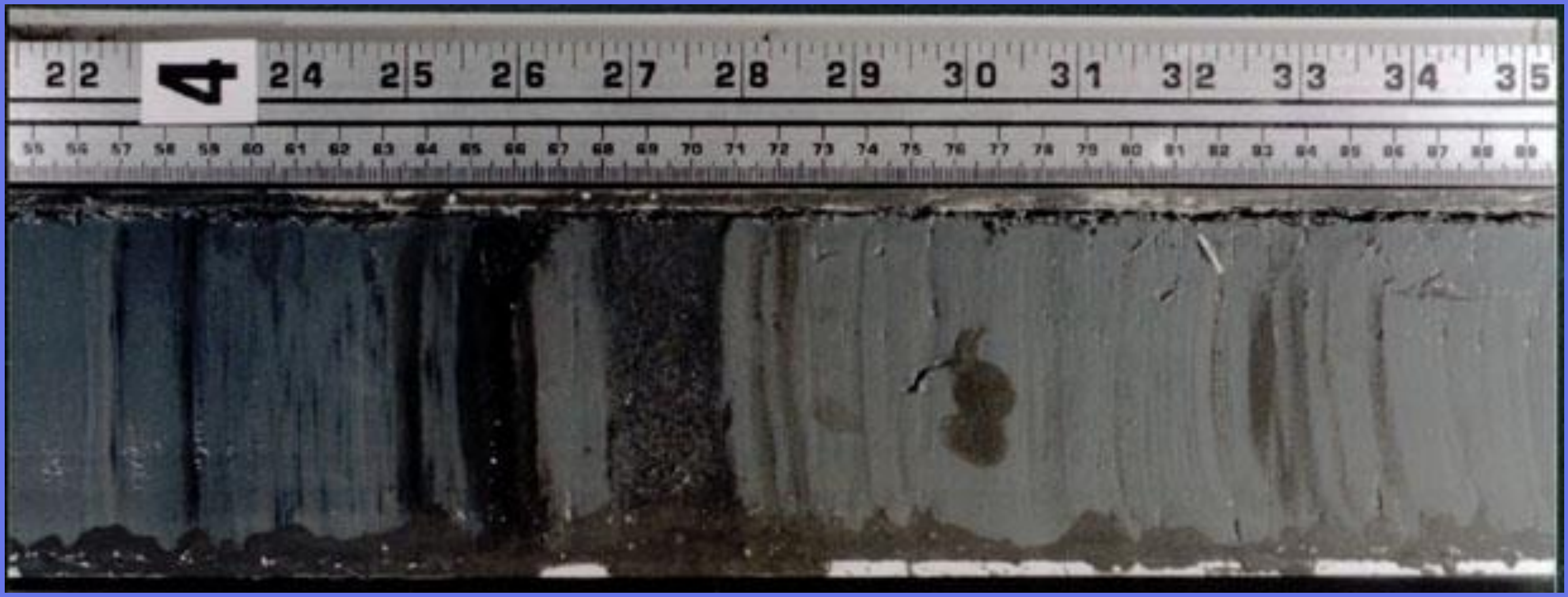
- Glew gravity coring

  Recent sediments

  (top 20 - 40 cm)

Lab methods

- Collect Cores → Photograph → Visual Log
- Visual Log → Sample at 1-cm Resolution
- Sample at 1-cm Resolution → Freeze Dry
- Sample at 1-cm Resolution → Remove any macrofossils → Radiocarbon Dating



Lab methods - continued

Freeze dried sample

% carbon

% nitrogen

C/N ratio

Carbon isotope analysis

Rock-Eval pyrolysis

$\delta^{13}C$ and C/N analysis on phytoplankton, macrophytes, and watershed plants

Tools

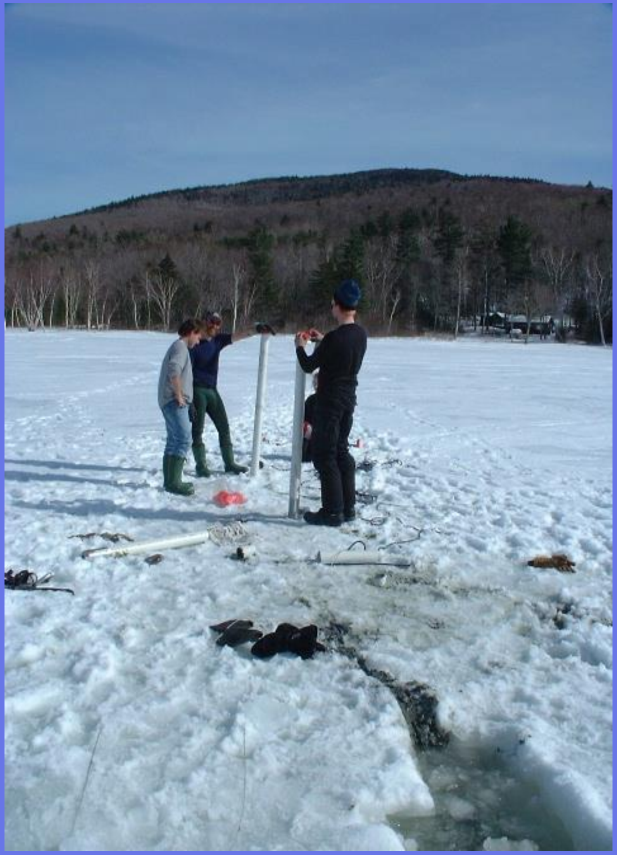
- %C - organic matter content
- C/N - carbon/nitrogen ratio
- $\delta^{13}C$ - stable carbon isotopes
- Rock-Eval pyrolysis - HI, OI
- Radiocarbon Dating

Tools (continued)

Stable carbon isotopes

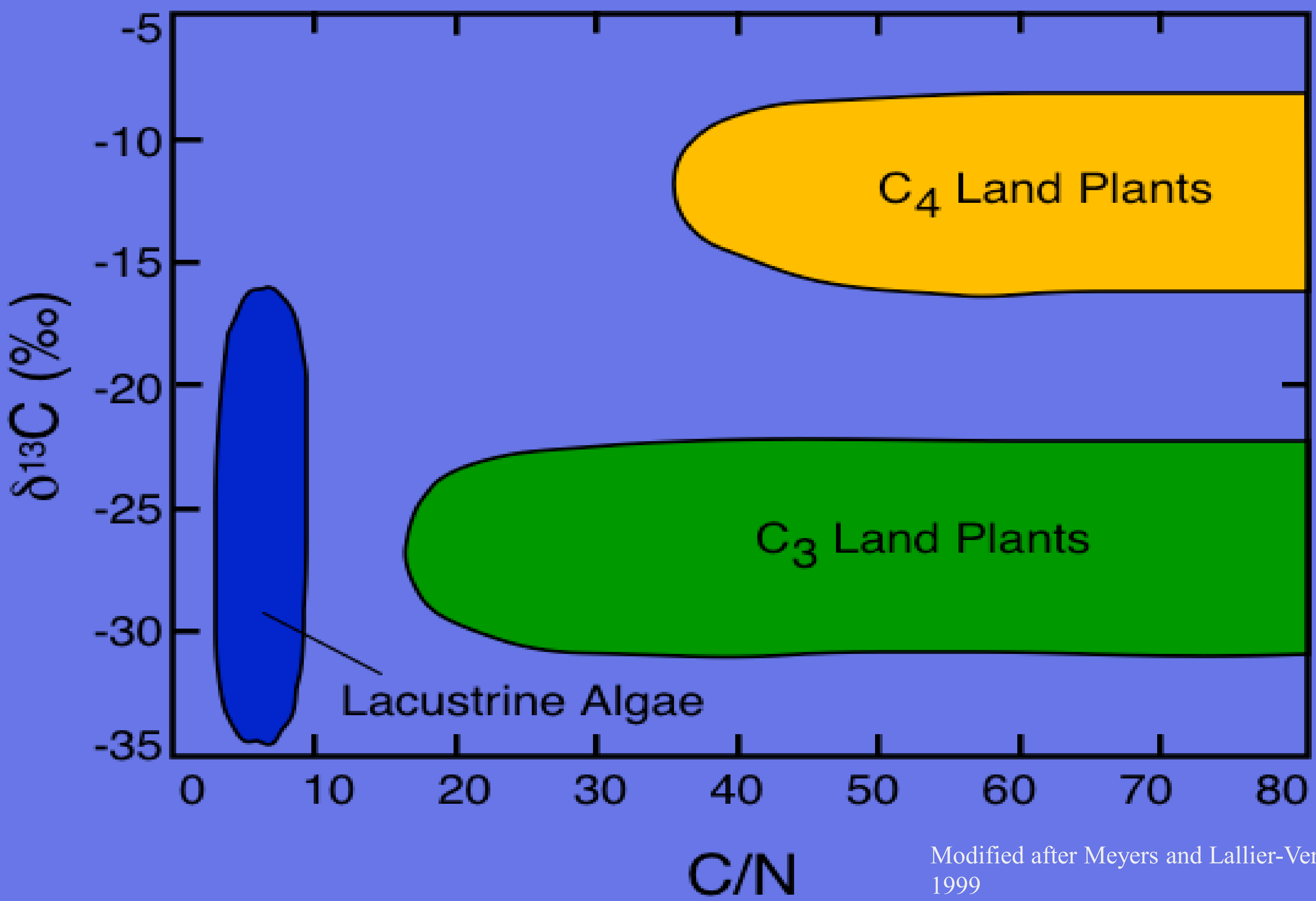
$\delta^{13}C(‰) = (R_{sample} / R_{standard}) * 1000$

- R is the ratio of $^{13}C/^{12}C$
- VPDB Standard
- Negative values (ex. -27‰)



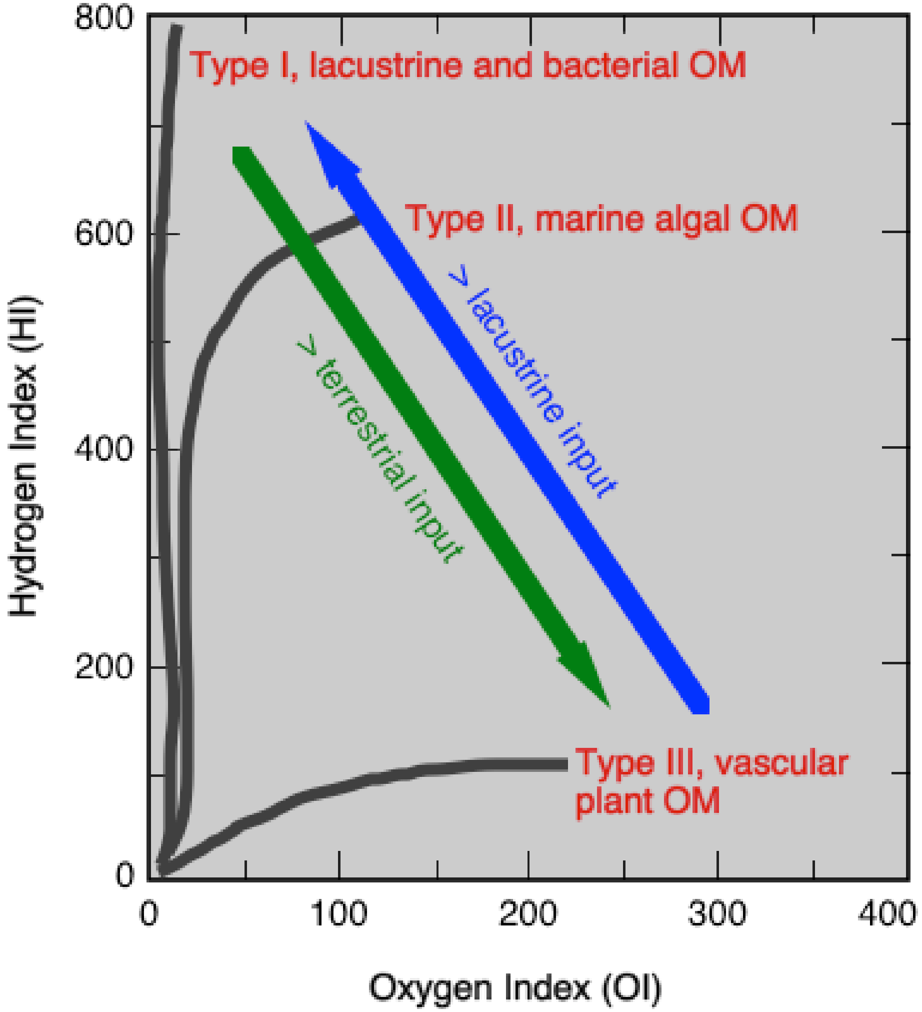
C/N Ratios

- Terrestrial plants - higher C/N
- Aquatic plants - lower C/N



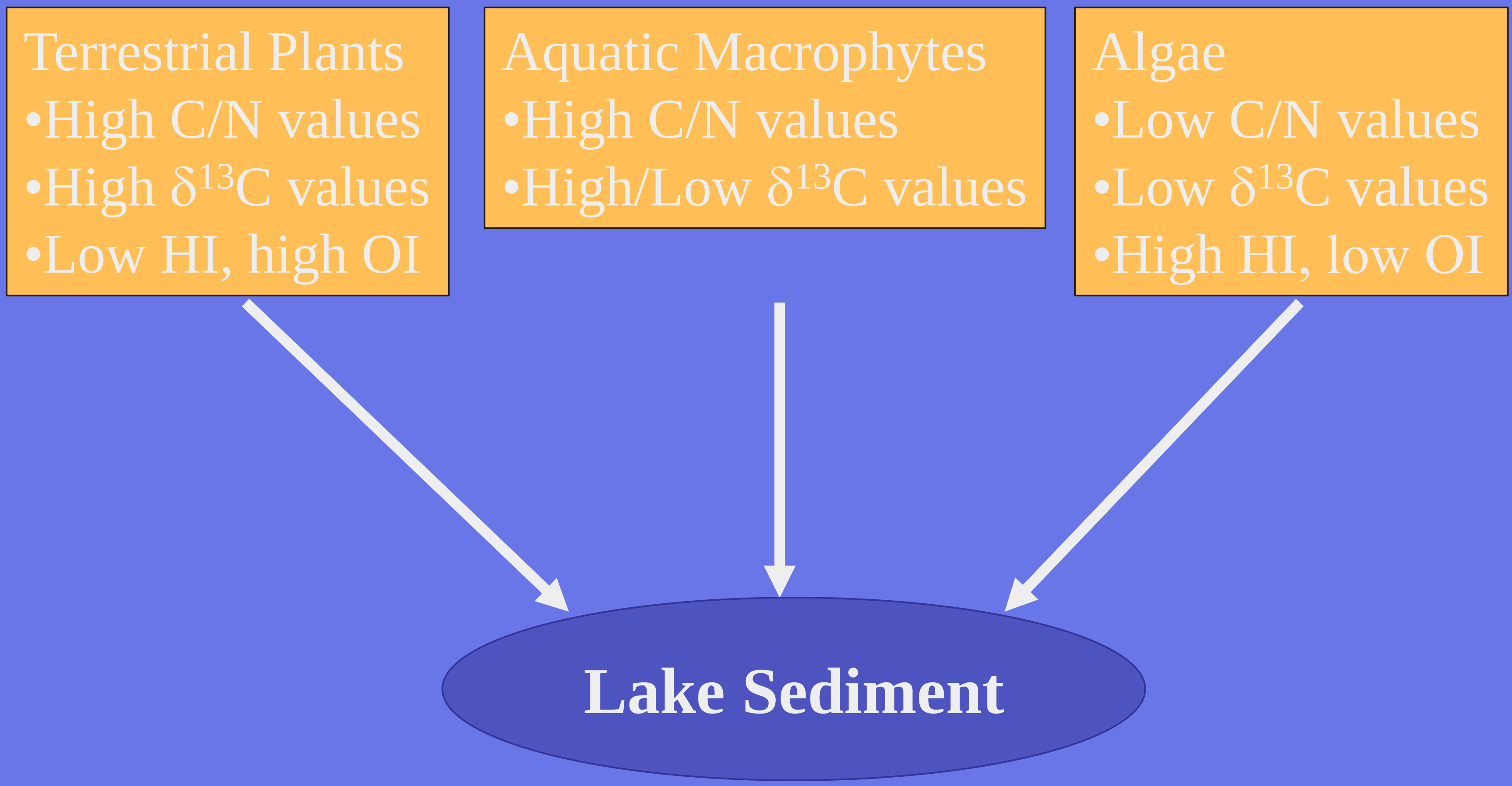
Modified after Meyers and Lallier-Verges, 1999

Rock-Eval pyrolysis

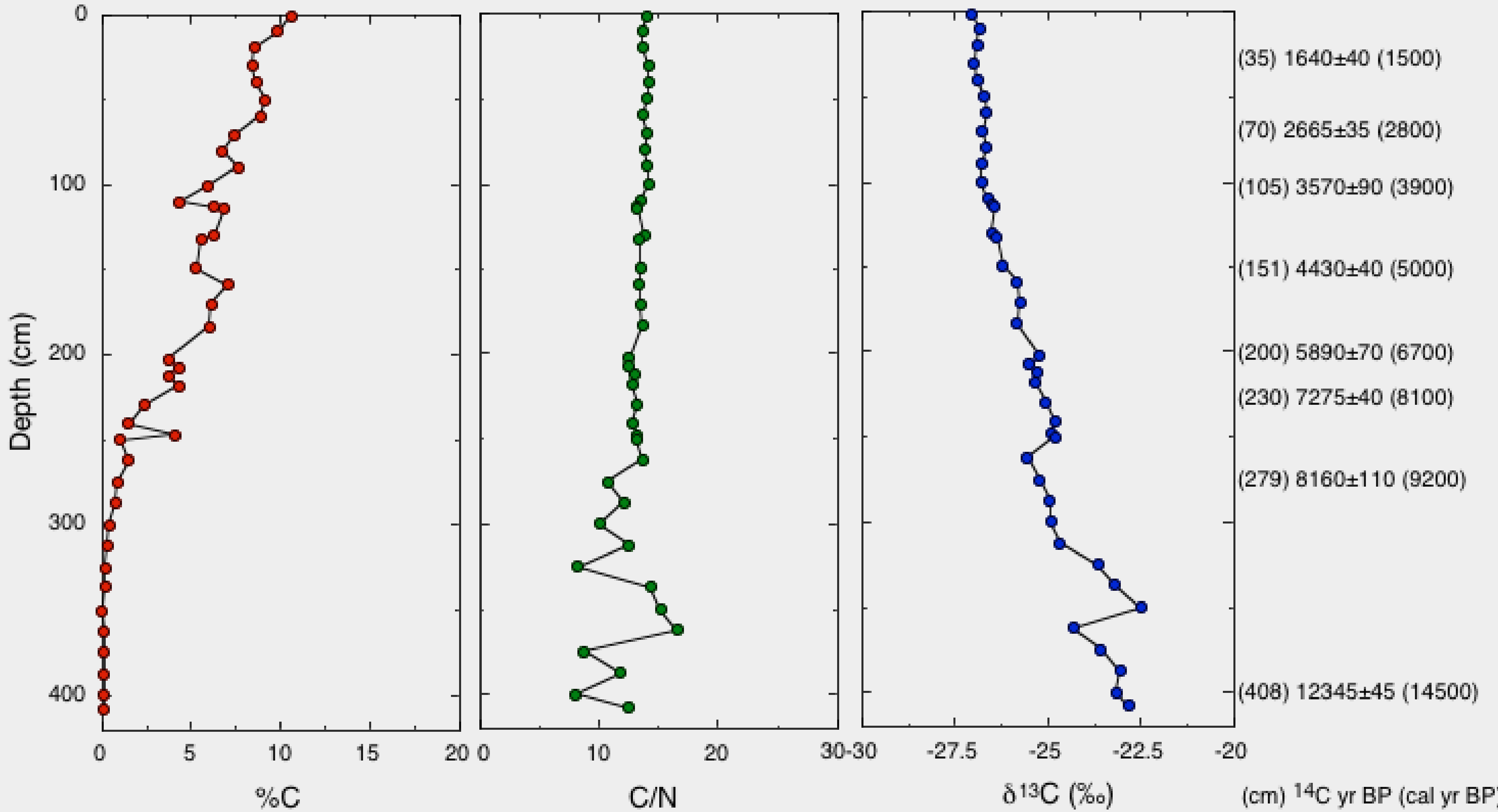


HI~H/C, hydrocarbon potential in mg HC g^{-1} TOC
OI~O/C, oxygen amount in mg CO_2 g^{-1} TOC

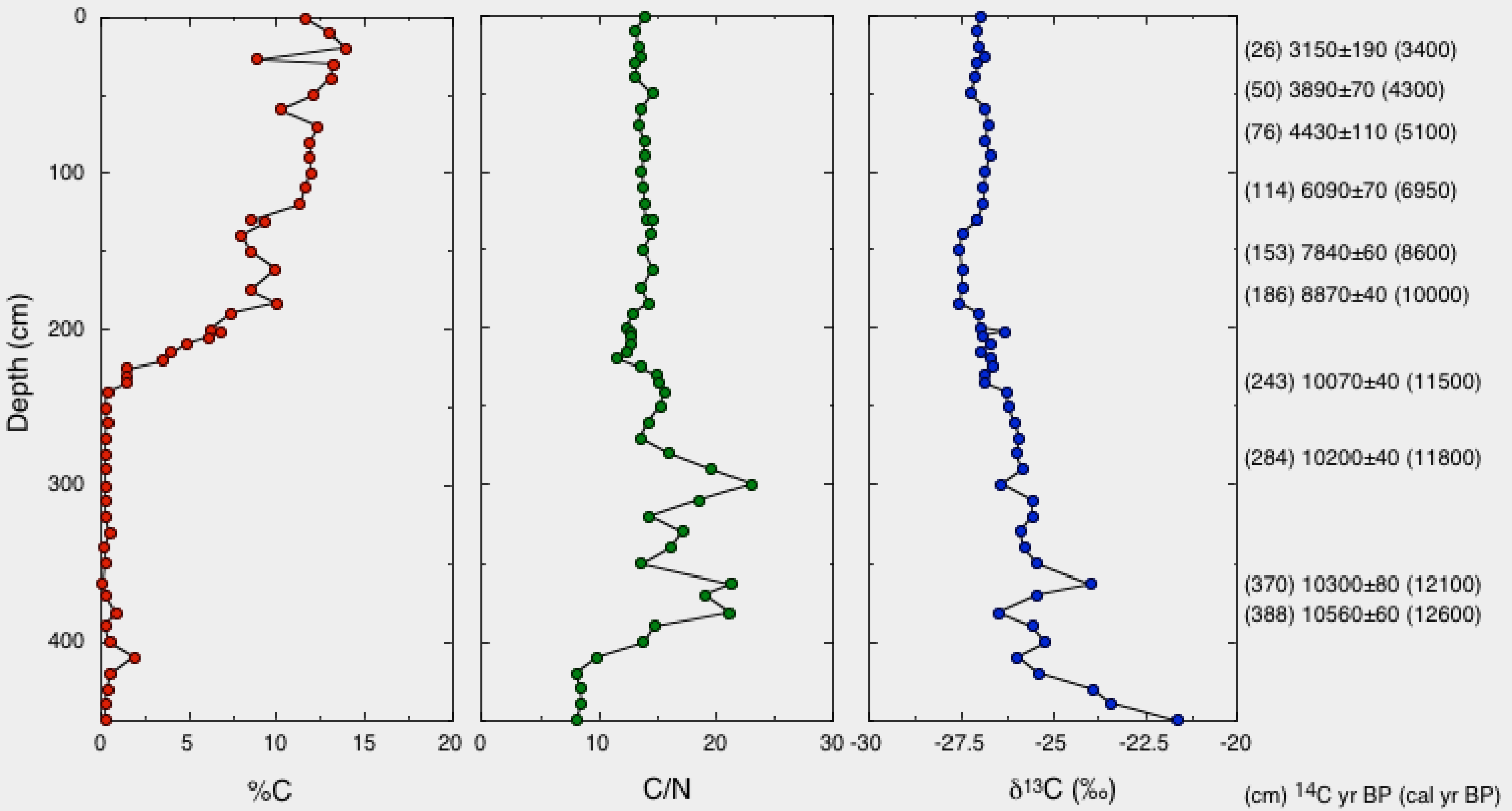
Composition of organic matter sources



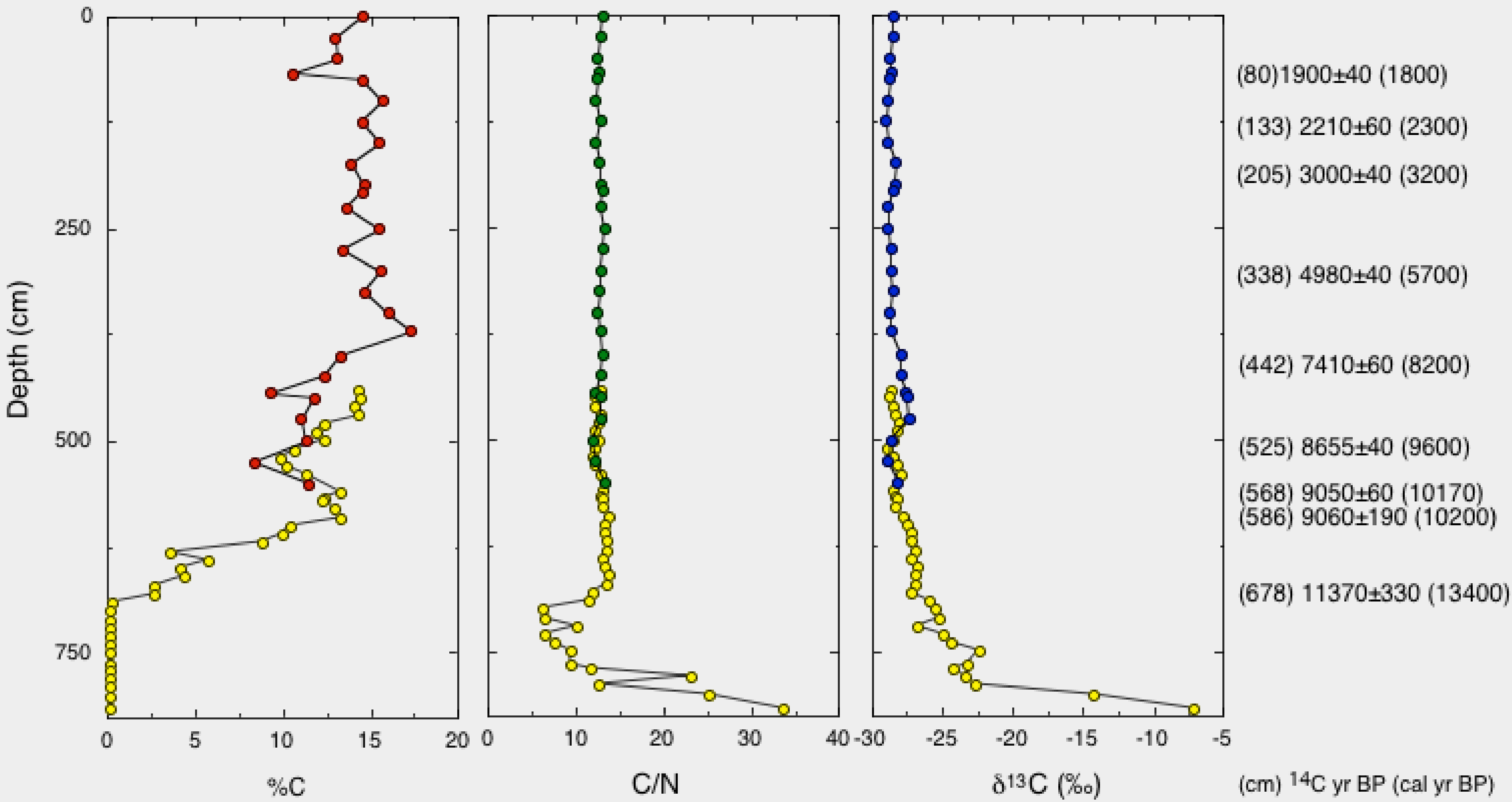
Stinson Lake, NH



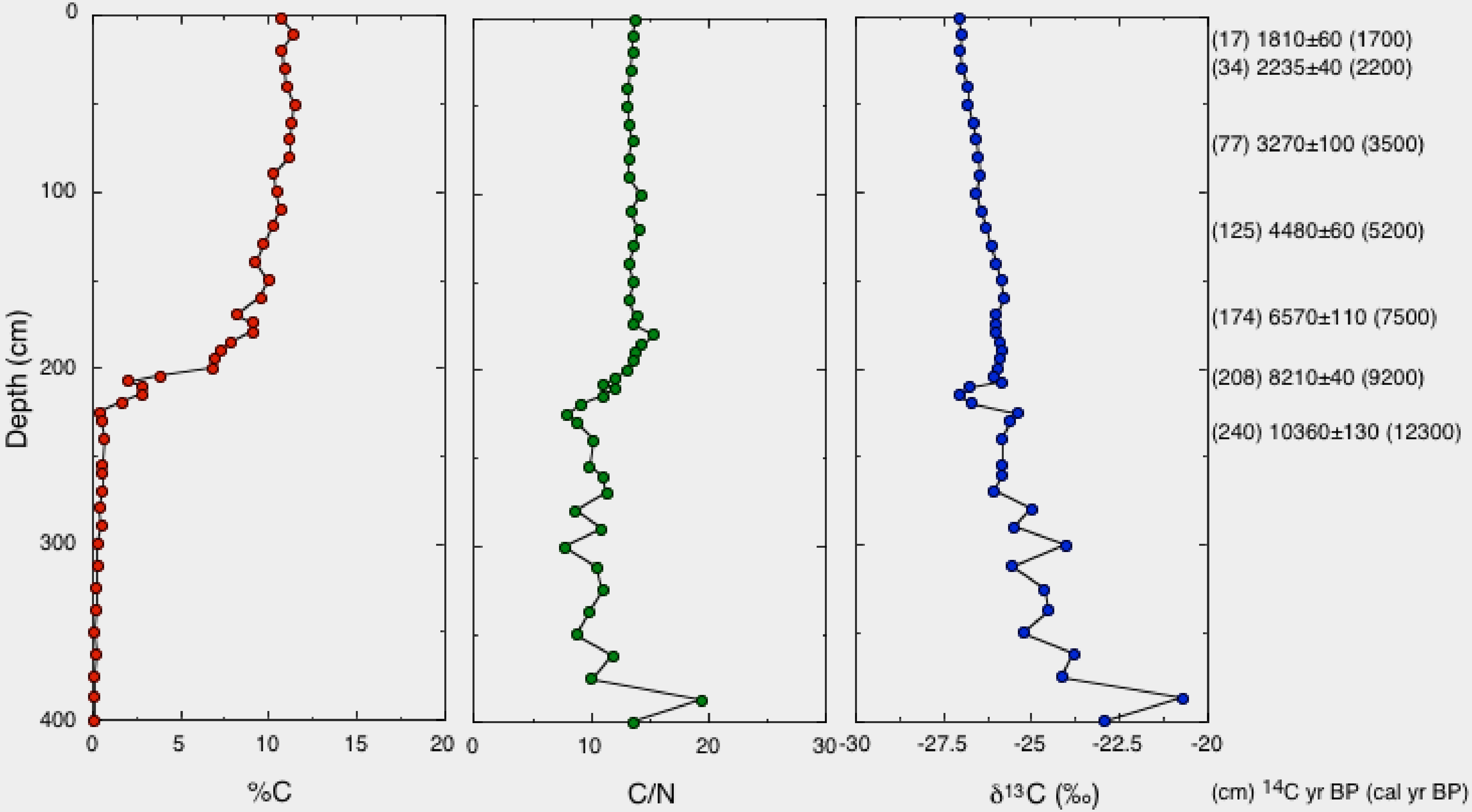
South Pond, NH



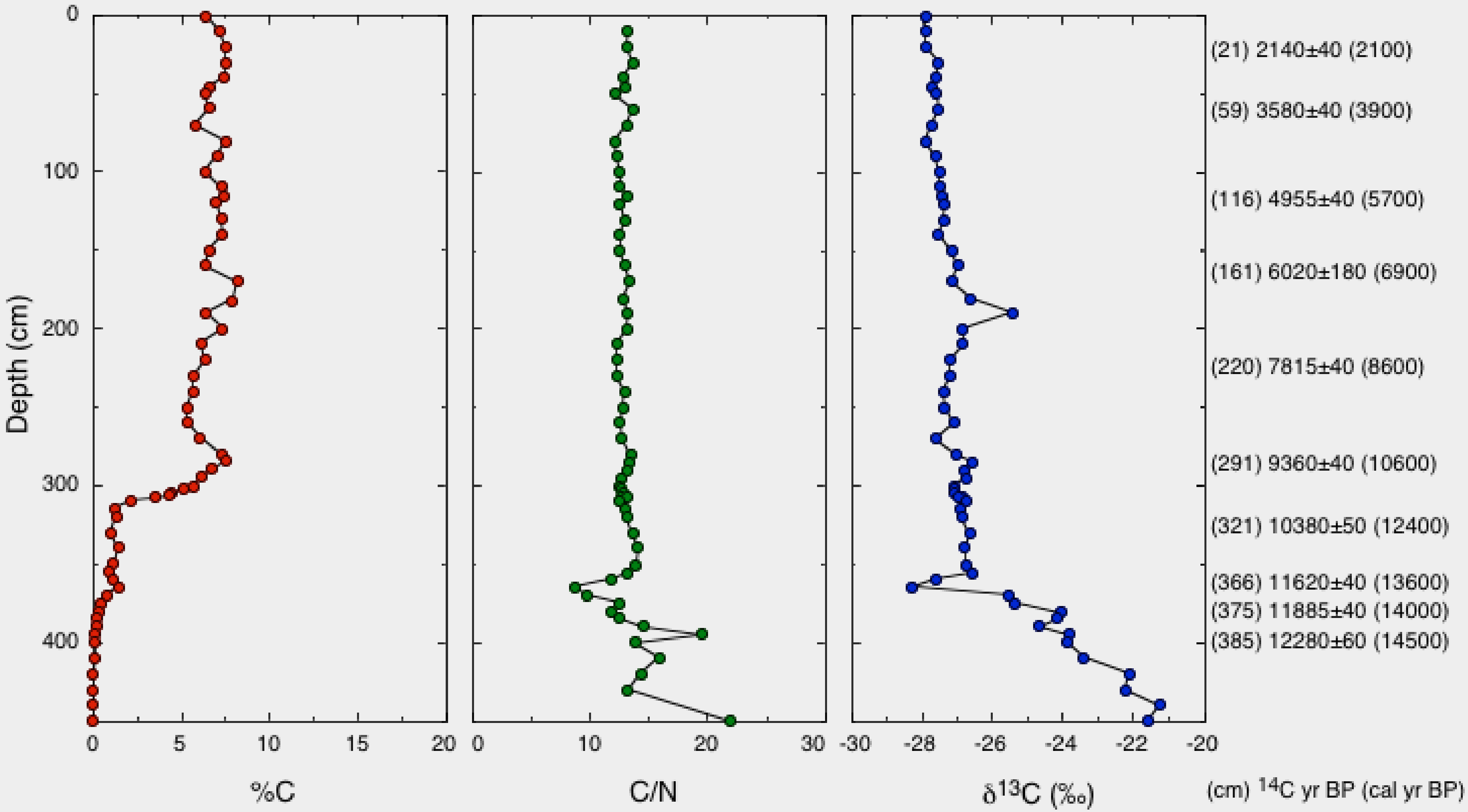
Crystal Lake, NH



Johns Pond, ME



Worthley Pond, ME

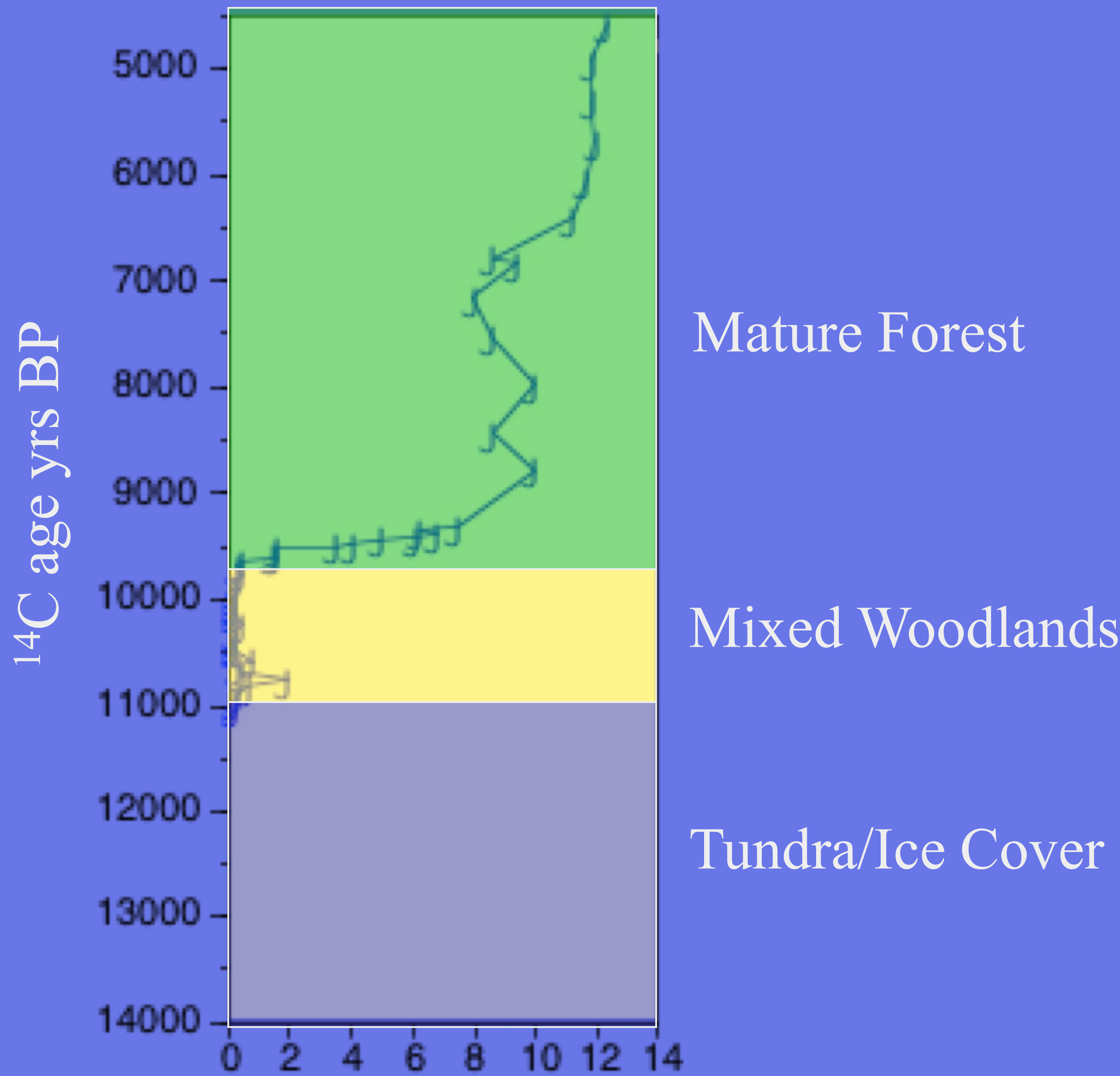


General trends in %C

- Increase in %C is observed in all cores
  - correlates with primary succession of vegetation in watershed

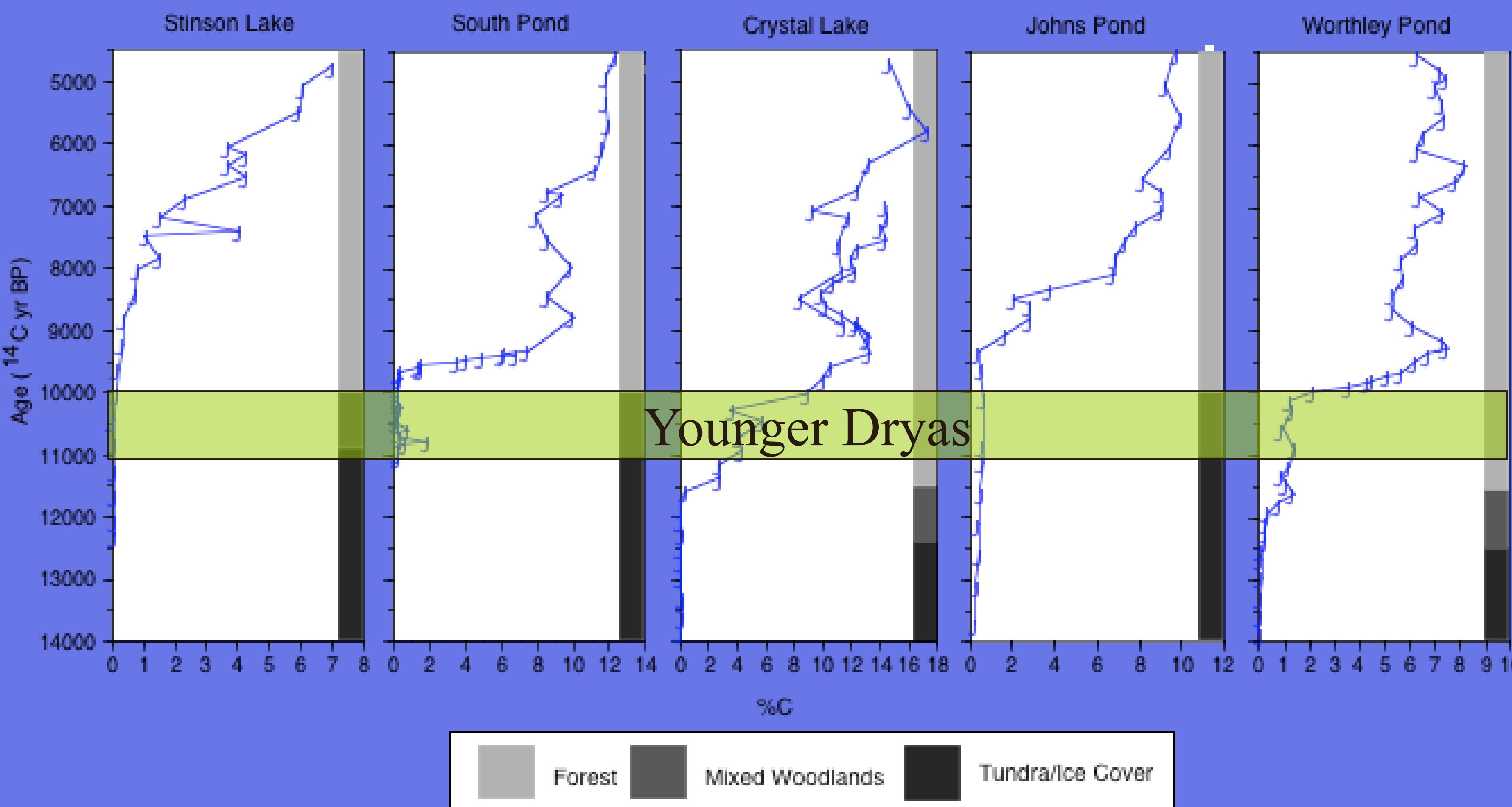
Ice → Tundra → Mixed Woodlands → Mature Forest

South Pond, %C

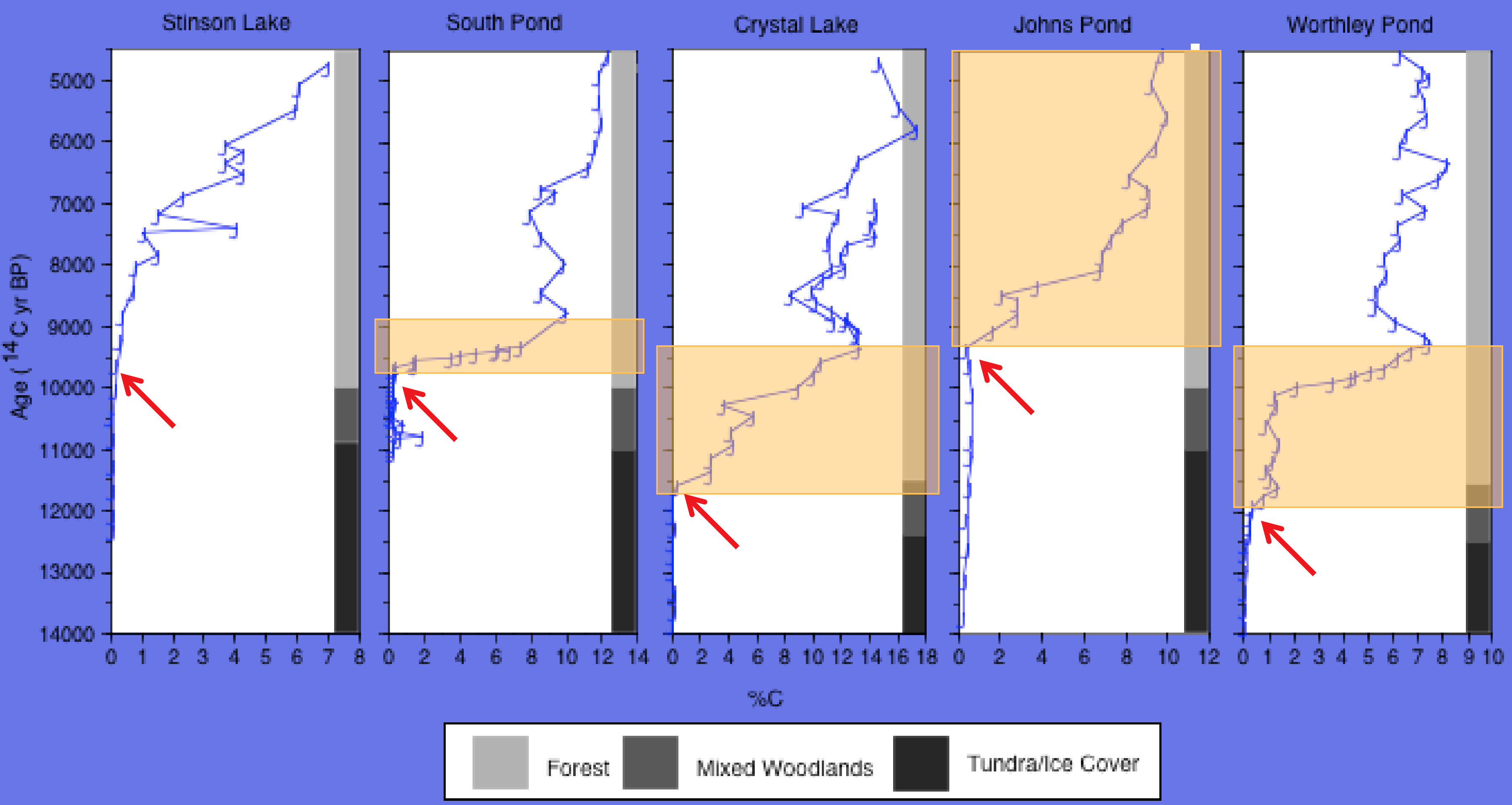


14C age yrs BP
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
0
2
4
6
8
10
12
14
Mature Forest
Mixed Woodlands
Tundra/Ice Cover

Primary succession and %C



Timing and rate of ecosystem establishment



Ecosystem establishment

Timing

- ~ 12,000 ^{14}C yrs BP
  - Crystal Lake
  - Worthley Pond
- 9300 - 10,000 ^{14}C yrs BP
  - Stinson Lake
  - South Pond
  - Johns Pond

Duration/Rate

- South Pond
  - 800 ^{14}C years
- Johns Pond
  - 5200 ^{14}C years

Differences in timing and rates of ecosystem establishment due to:

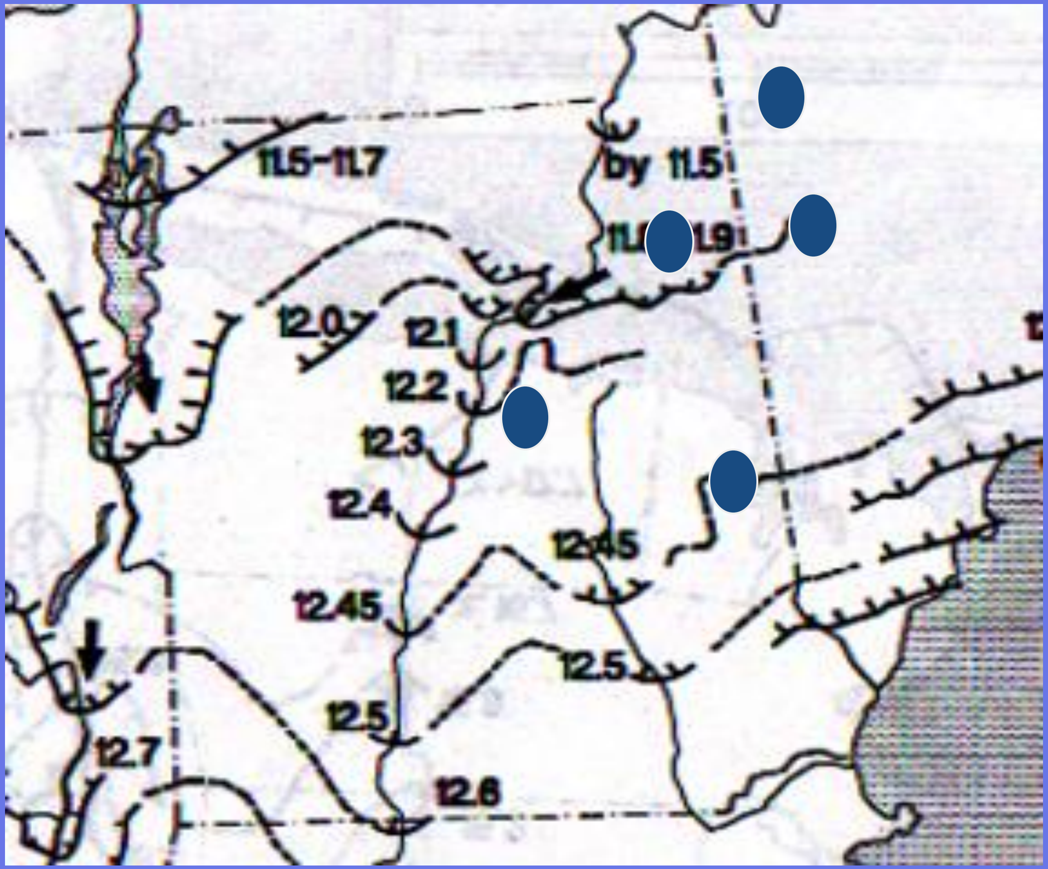
- Elevation
- Timing of deglaciation
- Frequency and magnitude of terrigenous inputs

  (nutrient input)

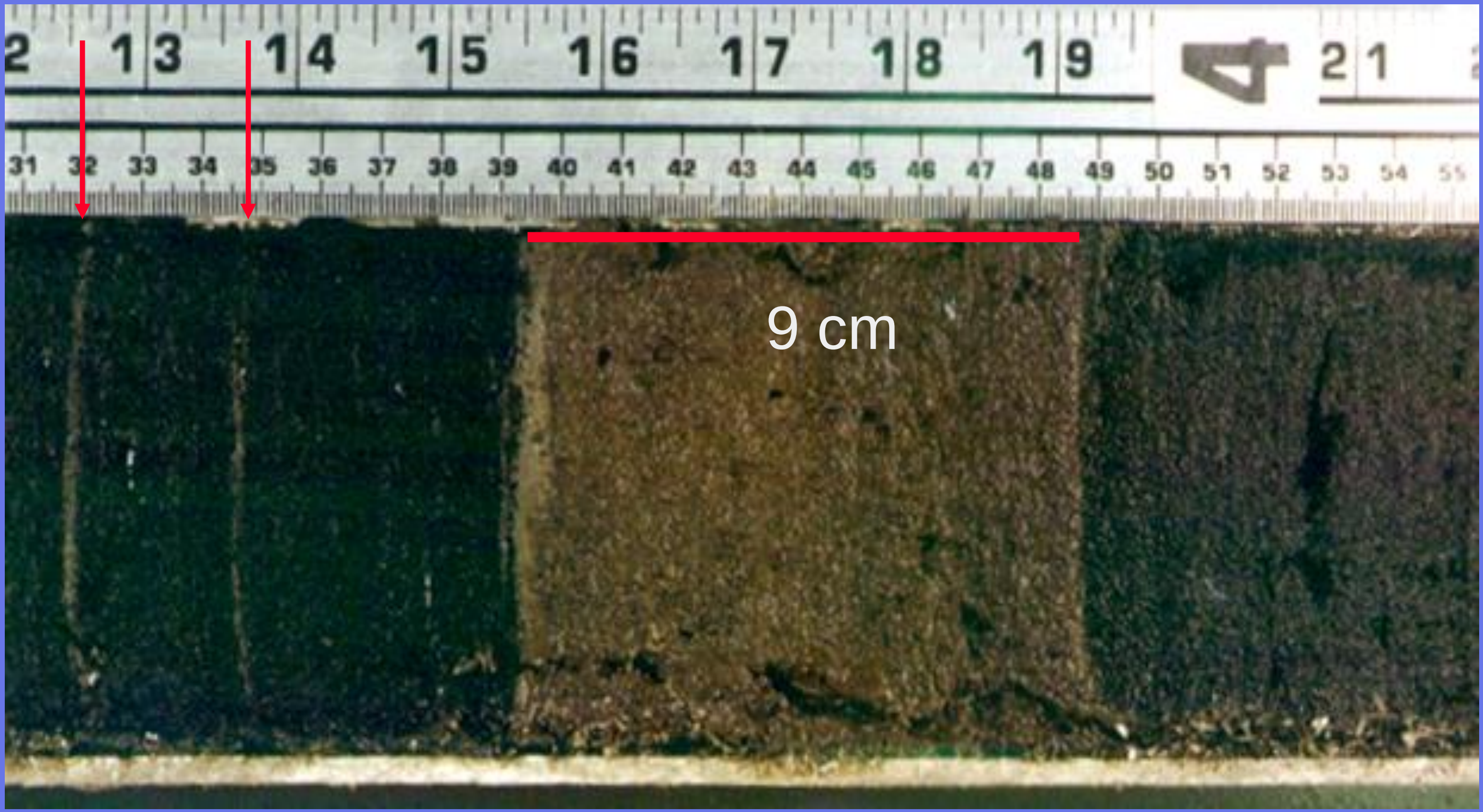
Physiographic characteristics of the study lakes

Lake Name	Surface Area (km^2)	Maximum Depth (m)	Elevation (m)	Drainage Basin Area (km^2)	Drainage Basin Relief (m)	Latitude	Longitude
New Hampshire:							
Crystal Lake	0.38	18	146	150	353	N 43°54'	W 71°05'
Stinson Lake	1.40	22	396	207	655	N 43°52'	W 71°48'
South Pond	0.70	26	340	7.4	427	N 44°36'	W 71°22'
Maine:							
Johns Pond	1.08	15	533	182	384	N 45°04'	W 70°46'
Worthley Pond	1.43	15	174	135	344	N 44°24'	W 70°26'
Vermont:							
Duck Pond	0.03	14	520	0.7	290	N 44°42'	W 72°04'
Lake Morey	2.22	13	127	207	414	N 43°55'	W 72°09'
Ritterbush Pond	0.05	14	317	2.2	293	N 44°45'	W 72°36'
Sterling Pond	0.03	9	917	0.3	40	N 44°33'	W 72°47'

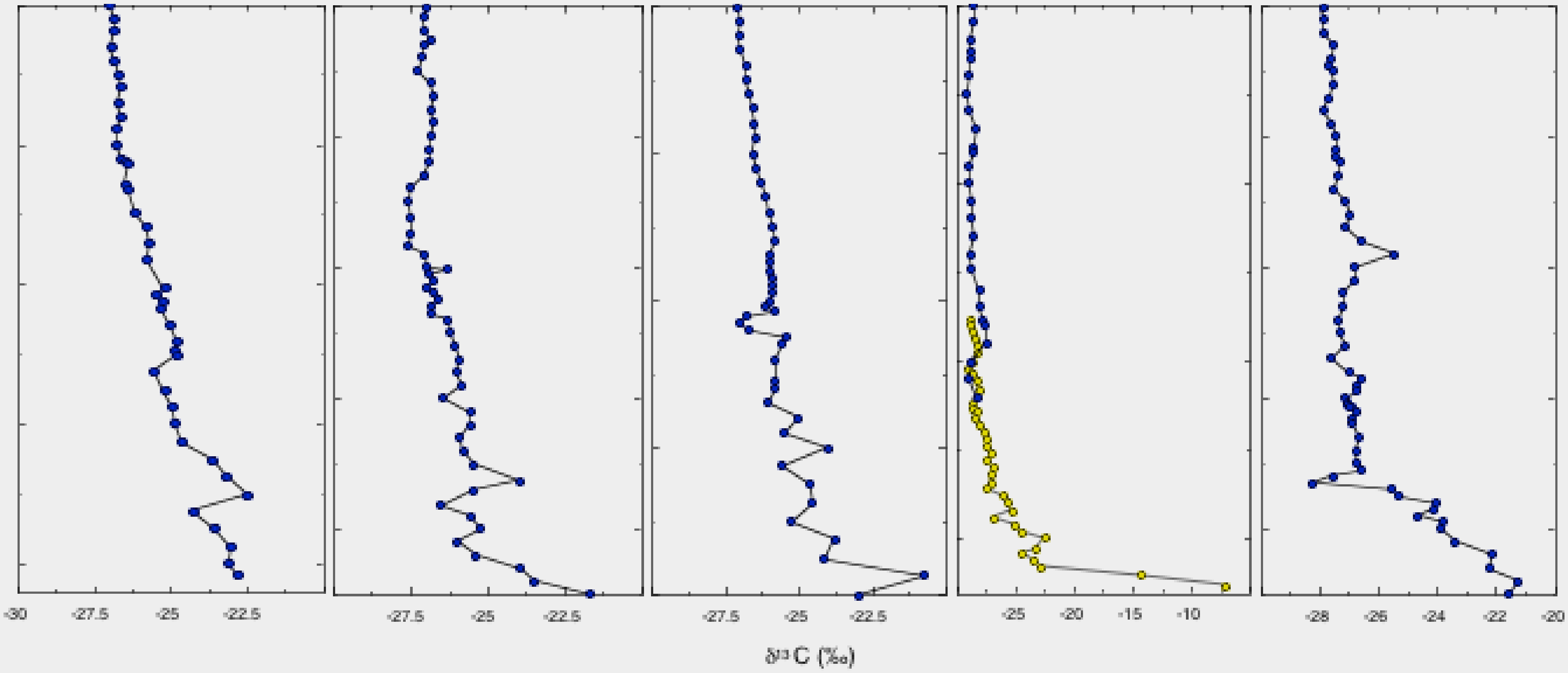
Timing of deglaciation



Terrigenous inputs



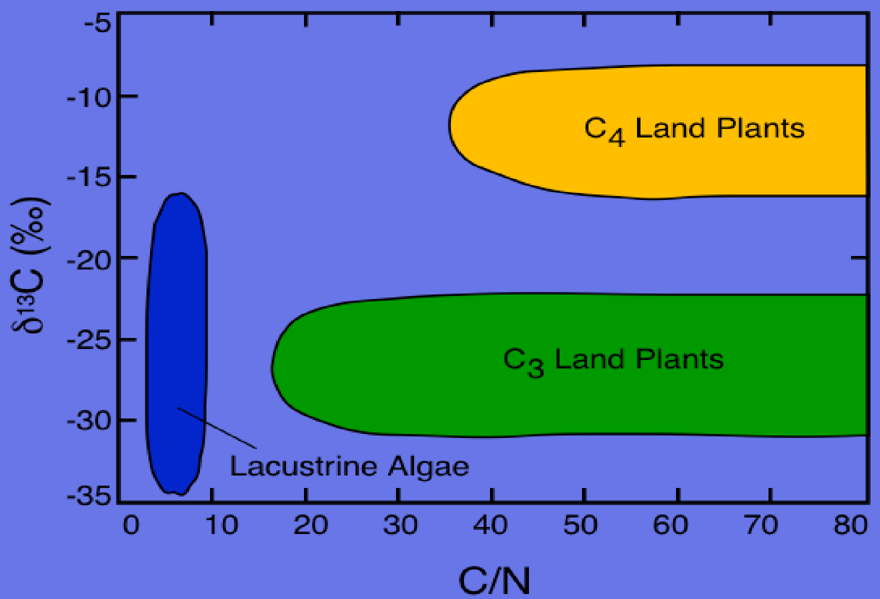
Trends in $\delta^{13}C$ records



Possible causes of the negative shift in $\delta^{13}C$ values

- ✓ Change in the proportion of terrestrial and aquatic organic matter
- ✓ Shift from C_4 (higher $\delta^{13}C$) to C_3 (lower $\delta^{13}C$) vegetation
- Increase in pCO_2 from glacial to post-glacial conditions
- Isotopically depleted DIC entering lake from watershed (soils and dissolution of metamorphic bedrock)
- Diagenesis (less common in shallow oligotrophic lakes)

- Terrestrial ecosystem established first, followed by aquatic ecosystem



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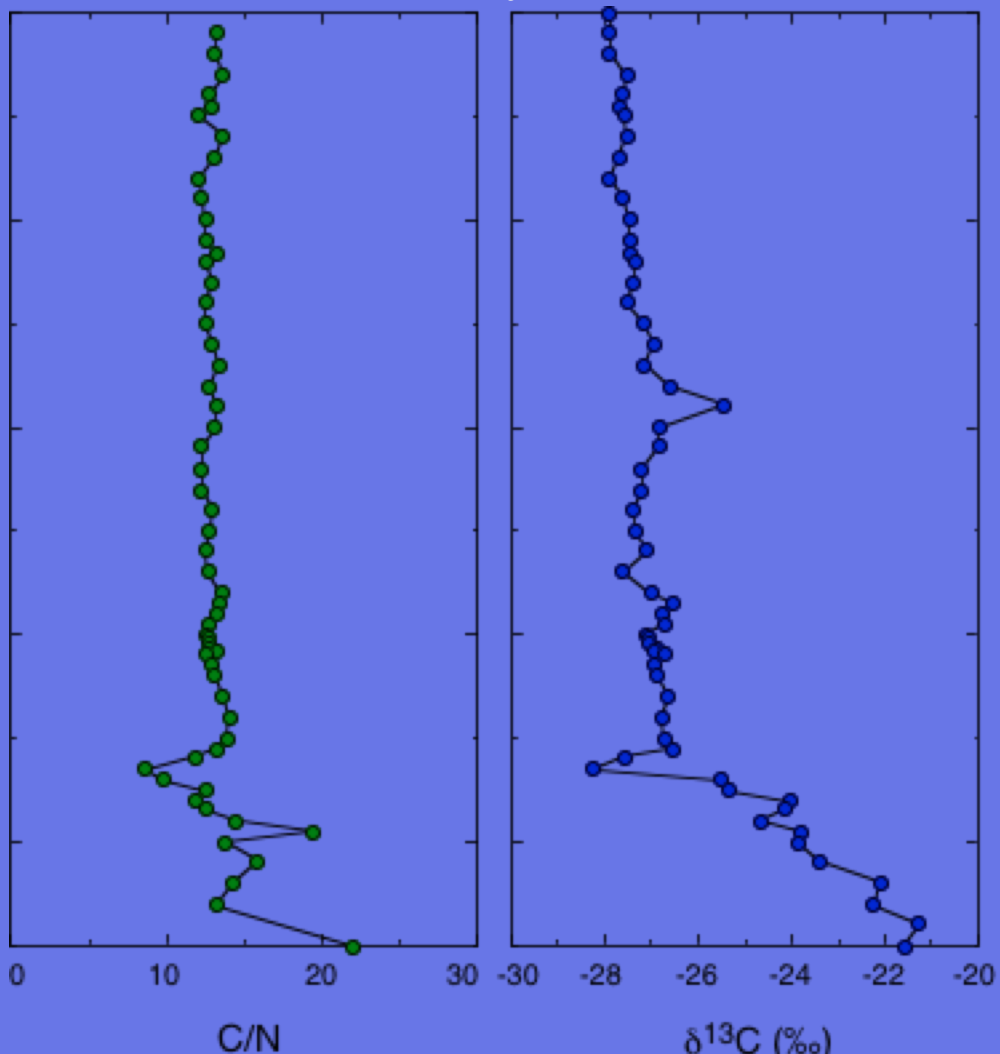
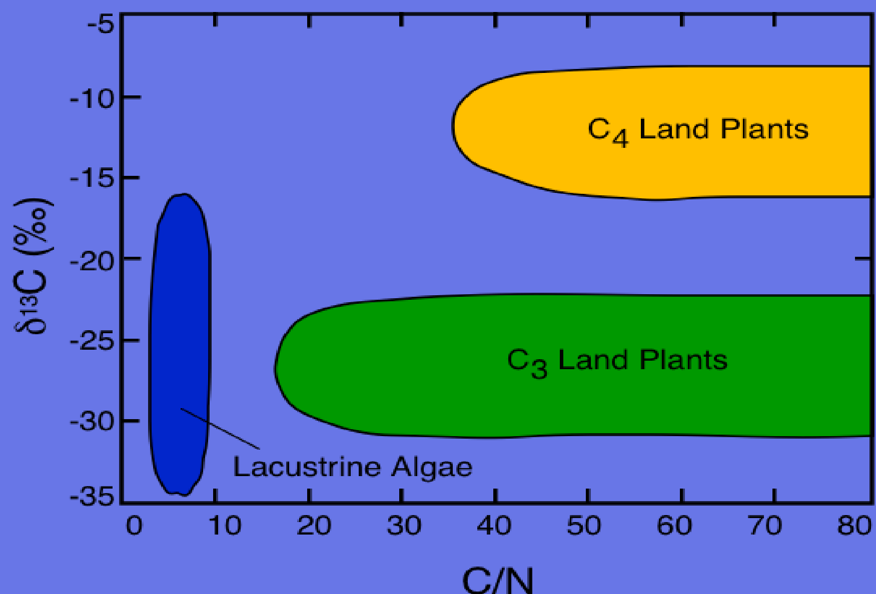
Worthley Pond

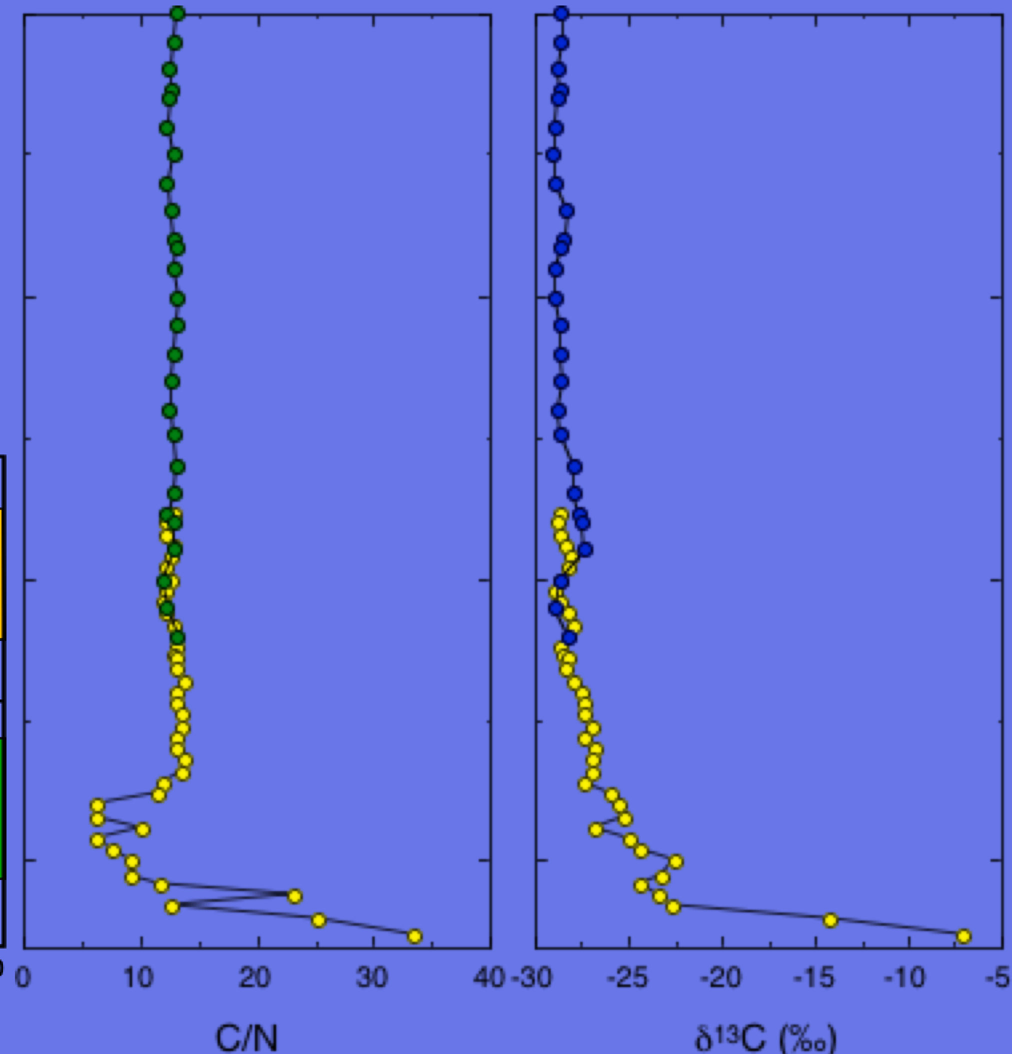


Crystal Lake

- Change from C_4 and C_3 tundra plants to primarily C_3 woodland plants



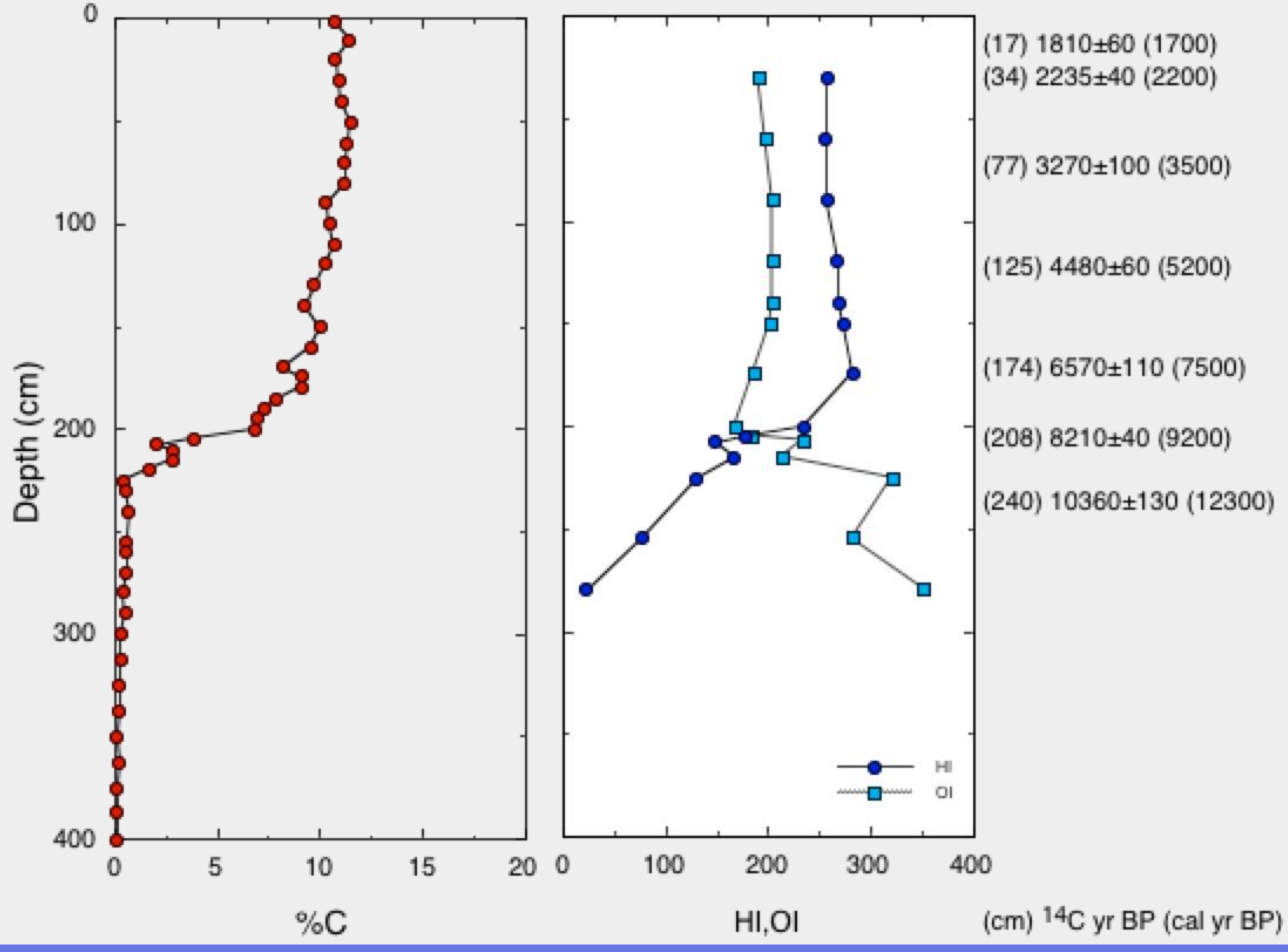
modif. after Meyers, 1998



Rock-Eval records and aquatic productivity

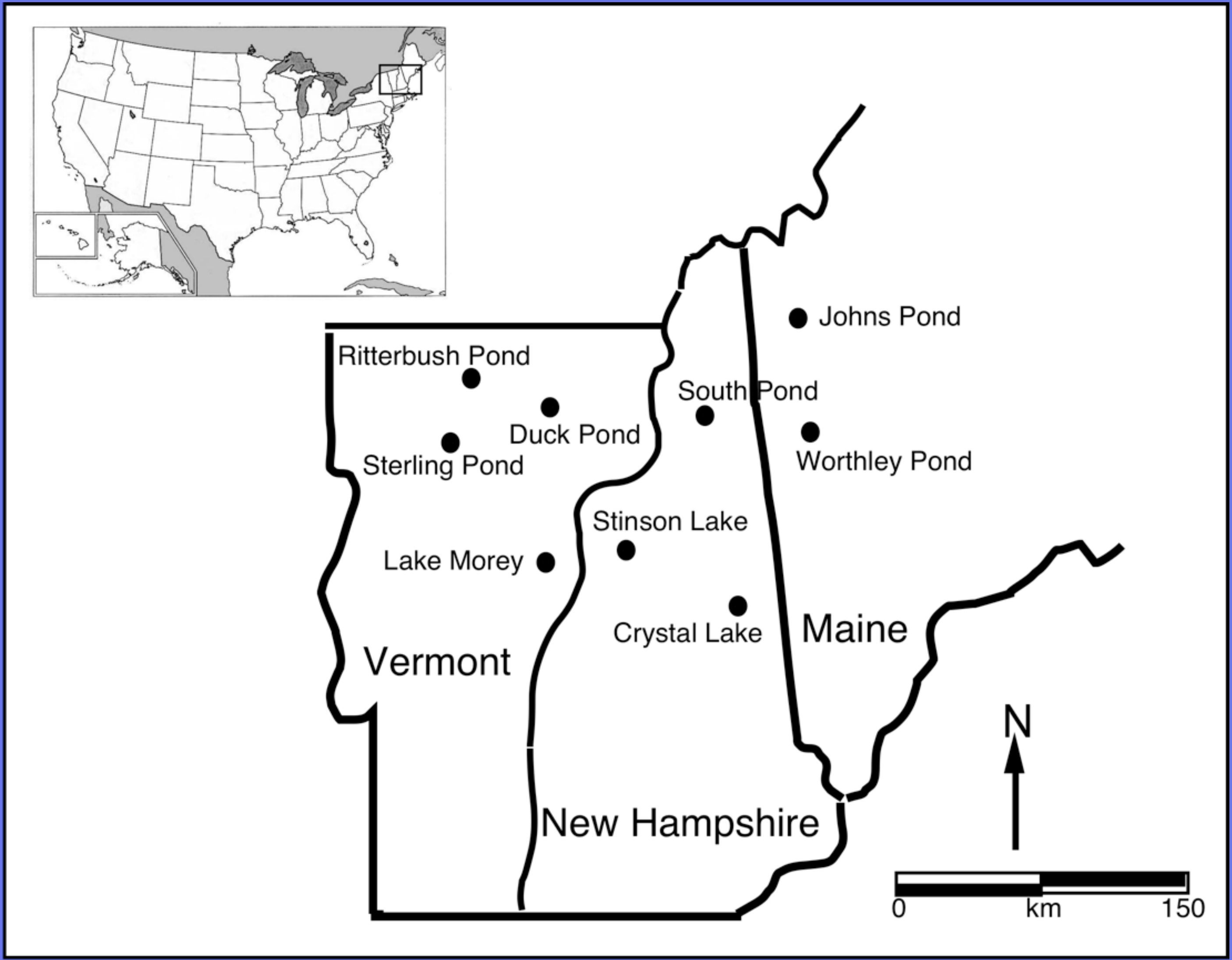
- HI and %C show correlated increases
- Low HI values in older sediments due to highly degraded organic matter, increase with better preservation
- As aquatic productivity increases:
  – Increase in HI values
  – Inverse relationship between OI and HI

Johns Pond



Depth (cm)
0
100
200
300
400
0
5
10
15
20
%C
0
100
200
300
400
HI,OI
HI
OI
(17) 1810±60 (1700)
(34) 2235±40 (2200)
(77) 3270±100 (3500)
(125) 4480±60 (5200)
(174) 6570±110 (7500)
(208) 8210±40 (9200)
(240) 10360±130 (12300)
(cm) 14C yr BP (cal yr BP)

Comparison with lakes in Vermont



%C records from lakes across northern New England

Ecosystem Establishment
11,000 to 12,500 ^{14}C yrs BP

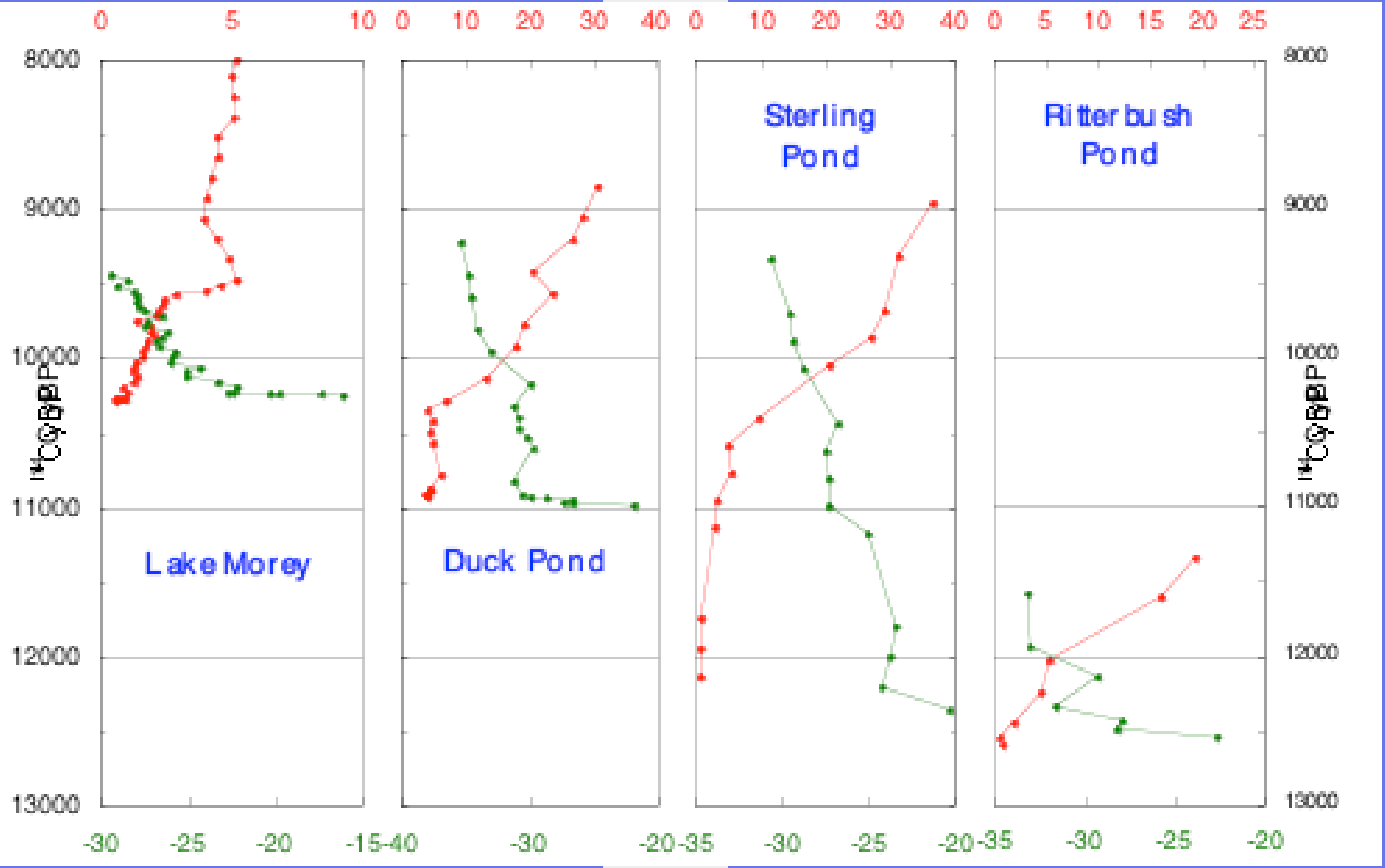
- Ritterbush Pond, VT
- Sterling Pond, VT
- Duck Pond, VT
- Crystal Lake, NH
- Worthley Pond, ME

Ecosystem Establishment
9,000 to 10,000 ^{14}C yrs BP

- Lake Morey, VT
- Stinson Lake, NH
- South Pond, NH
- Johns Pond, ME

Vermont lakes

%C



$\delta^{13}C$

Comparison across northern New England

Vermont

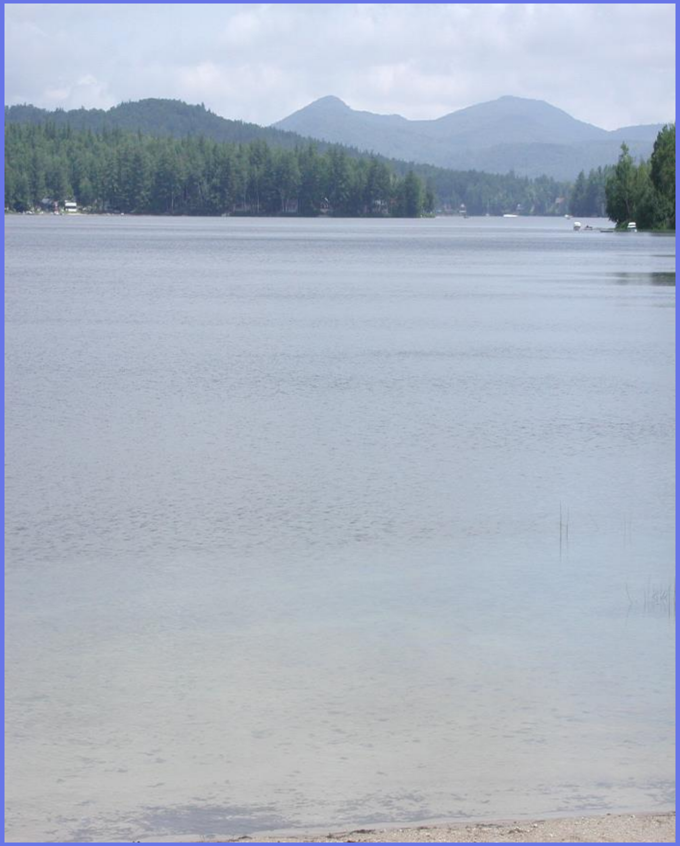
- Maximum %C values
  > 30%

- Minimum $\delta^{13}C$ values
  -29.5 to -35.3 ‰

New Hampshire and Maine

- Maximum %C values
  18%

- Minimum $\delta^{13}C$ values
  -26.8 to -28.5‰



- Lower %C values in NH and ME
  - Proximity to receding glaciers
  - Steeper drainage basins
- More negative $\delta^{13}C$ values in VT
  - Trophic state of lakes
    - VT lakes - greater algal productivity
    - NH and ME lakes - less algal productivity

Oligotrophy Mesotrophy Eutrophy Hypertropl

Amount of organic matter produced within a lake

Unsolved mysteries

- %C increase and negative $\delta^{13}C$ shift are correlated in VT, but are not correlated in NH and ME
- Duration of the $\delta^{13}C$ shift is much longer in NH and ME lakes than in VT lakes

Summary

- Sediments provide detailed records of past conditions in and surrounding lakes
- Timing and rates of post-glacial ecosystem establishment differ across northern New England
- Ecosystem establishment controlled by physiographic characteristics and timing of deglaciation
- Trends in □□□□□□□□□□□□ differ based on source of organic matter and timing of vegetation primary succession

Summary

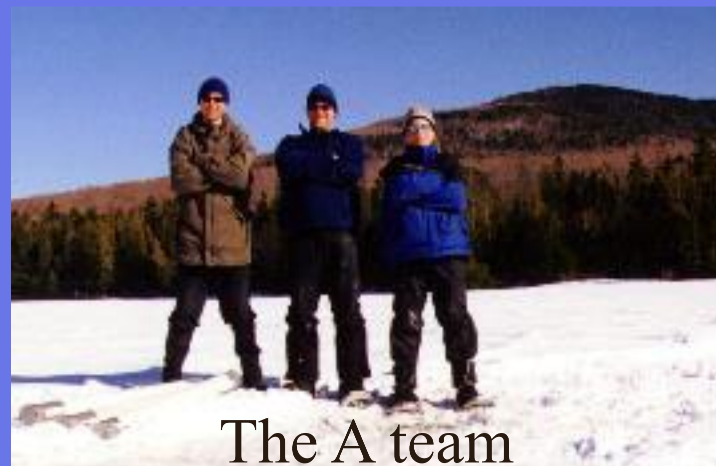
- ✓ The factors that influence ecosystem development need to be known to figure out the effects of climate
- ✓ Response of lakes to climate change differs on even a local scale, and evidence from multiple lakes must be considered when attempting to relate changes in geochemical records to climate

Future work

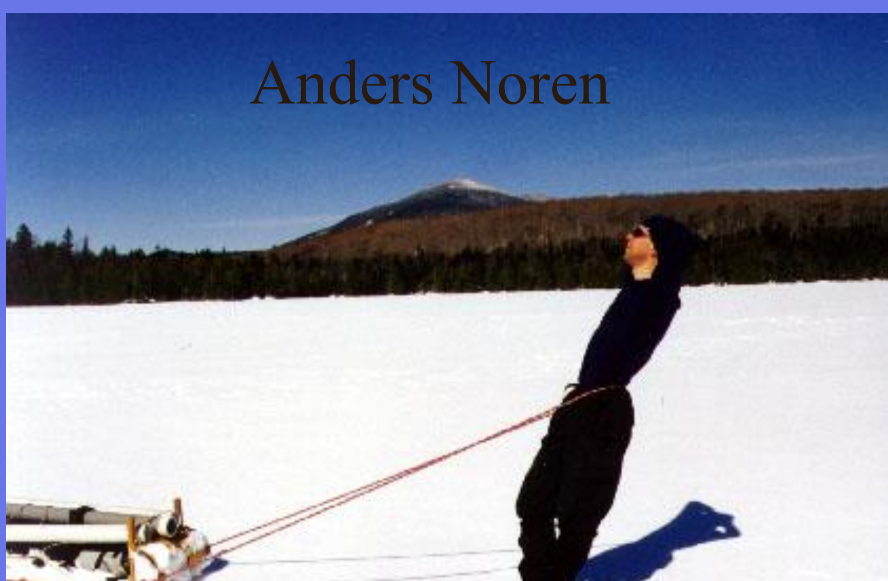
- Continue to expand study area
  - Lakes to the South (earlier deglaciation) and West (compare with Vermont)
  - Lakes at various elevations and with varying physical characteristics
- Take additional cores from each studied lake
- Diatom and pollen analyses on cores

Acknowledgements

Acknowledgements



The A team



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