# Source characterization and temporal variation of methane seepage from thermokarst lakes on the Alaska North Slope in response to Arctic climate change

Principal Investigators:
Matthew Wooller (UAF PI), Katey Walter (UAF Co-PI),
Mary Beth Leigh (UAF Co-PI),
John Pohlman (USGS Co-PI) and Carolyn Ruppel
(USGS Co-PI)

# Presentation structure

- Introductions to our collaborative group
- Relevant background for the project
- Objectives
- Description of the work to be performed
- Expected impact of the project
- Project schedule and milestones

Introductions to our collaborative group

Principal Investigators:

Matthew Wooller (UAF PI), Katey Walter (UAF Co-PI), Mary Beth Leigh (UAF Co-PI), John Pohlman (USGS Co-PI) and Carolyn Ruppel (USGS Co-PI)

**My background:**

- Associate Professor (stable isotope biogeochemistry) in the Institute of Marine Science/School of Fisheries and Ocean Science and the Water and Environmental Research Center in the Institute of Northern Engineering at the University of Alaska Fairbanks.
- Director of the Alaska Stable Isotope Facility - a state-of-the-art laboratory for analyzing the stable isotope composition of a range of materials.

# Introductions to our collaborative group

**Mary Beth Leigh (co-PI),** Assistant Professor (microbial ecology and stable isotope probing) in the Institute of Arctic Biology and has established and manages a state-of-the-art laboratory for stable isotope probing.

Mary Beth with PhD student La'Ona DeWilde

**Katey Walter (co-PI),** Assistant Professor in the Water and Environmental Research Center. Dr. Walter has considerable experience as a biogeochemist, limnologist and methane expert, with 12 years of experience in studying arctic lakes.

# Introductions to our collaborative group

**John Pohlman (co-PI):** Mendenhall Postdoctoral Fellow at the United States Geological Survey. Specialization in studying deep marine gas hydrate systems and methane seeps and analysis of pore fluid geochemistry. He has developed and adapted laboratory instrumentation for preparation of samples for radiocarbon analysis and reconfigured IRMS systems for analysis of complex gas mixtures and dissolved organic carbon (DOC).

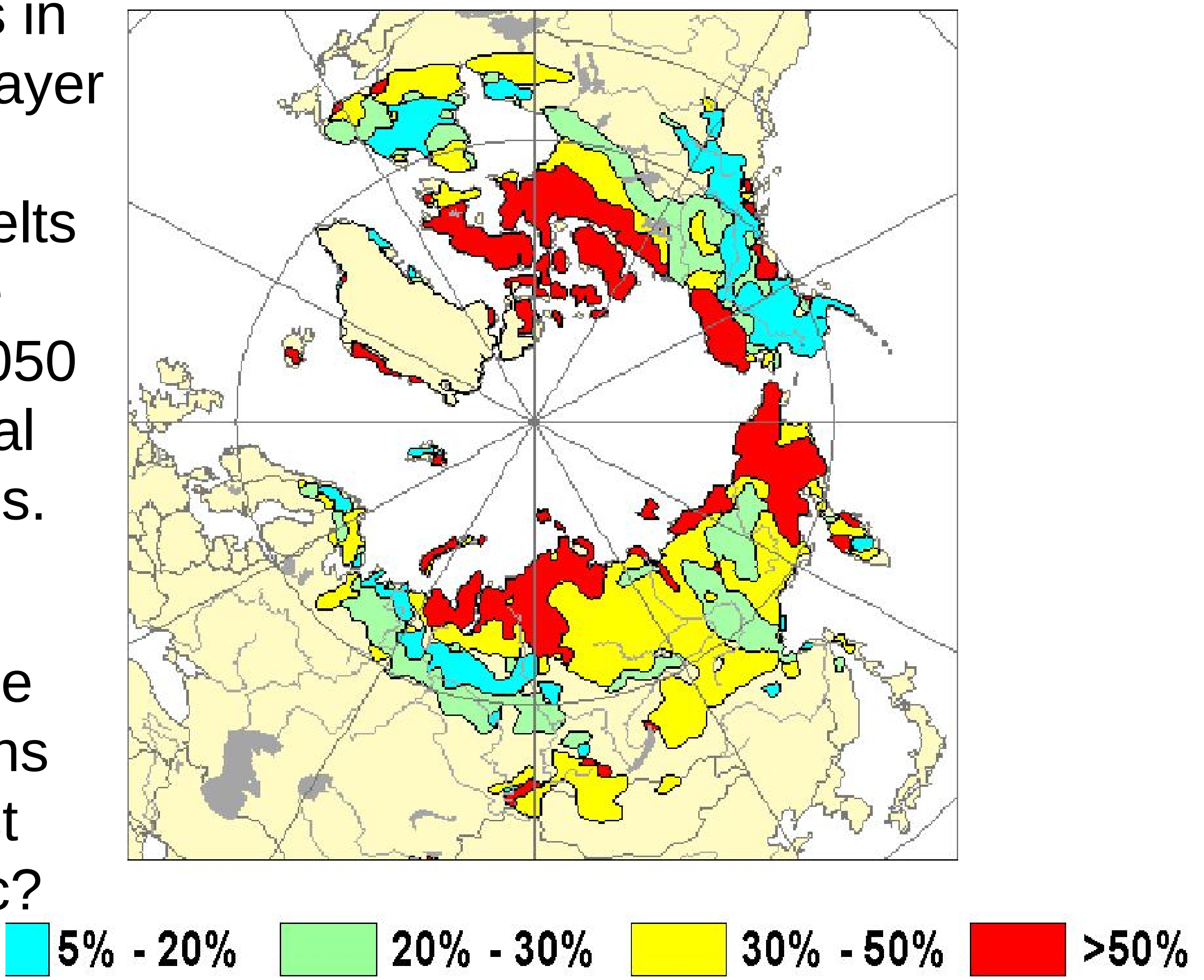
**Carolyn Ruppel (co-PI):** senior scientist (geophysicist) in the methane hydrates group at the USGS and a Visiting Scientist at the Earth Resources Laboratory at MIT. Ruppel's expertise is in hydrate systems from a geologic perspective, hydrogeophysics (shallow exploration geophysics), thermal geophysics, and numerical modeling of fluid systems, biogeochemical processes, and thermal processes.

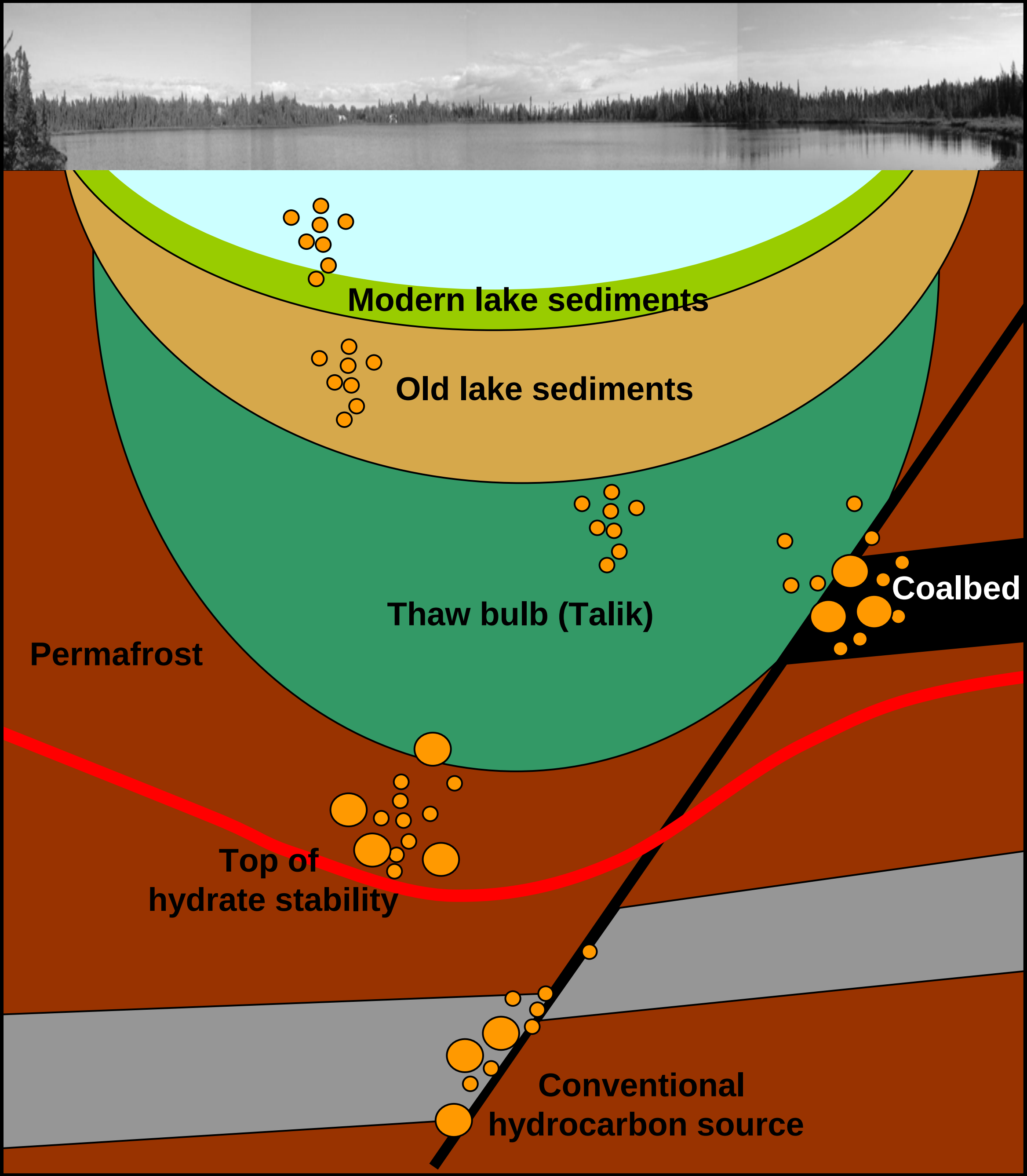
# Relevant background for the project:

# methane in the context of climate change in the Arctic

Predicted changes in thickness of active layer (the soil above permafrost, that melts each year in the summer sun) by 2050 under some global warming scenarios.

How will these changes influence methane emissions from thermokarst lakes in the Arctic?






# Introducing thermokarst lakes and possible methane sources


Lake
Qalluuraq

# Goals:

to characterize the source, magnitude and temporal variability of methane seepage from two representative thermokarst lake areas within the Alaskan North Slope gas hydrate province and to assess the vulnerability of these areas to ongoing and future arctic climate change.

# Objectives:

1) measure methane emissions over a range of timescales at thermokarst lakes and use reconnaissance imaging to identify gas source locations.

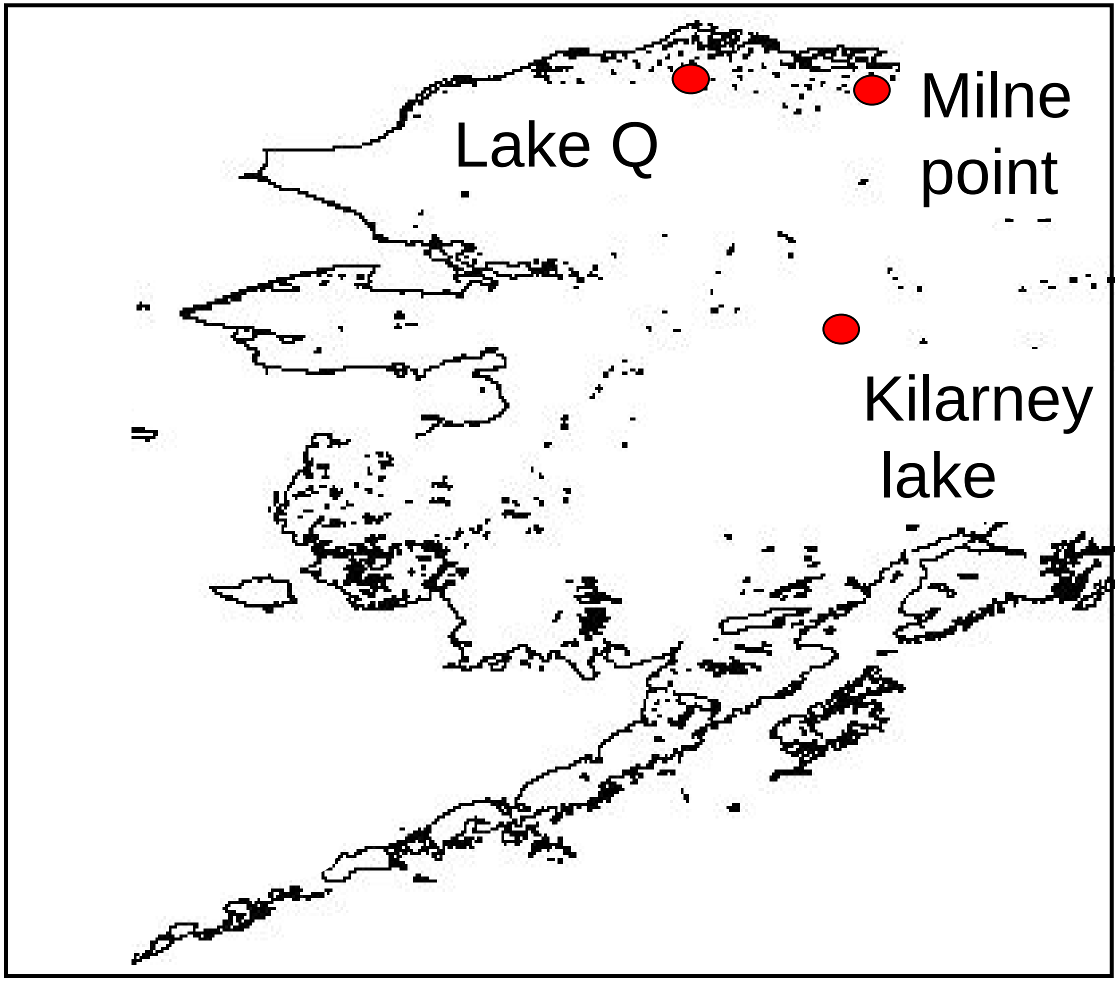
2) determine the methane sources.

3) constrain methane sinks through analysis of methane oxidation pathways in lake water and lake bottom sediments.

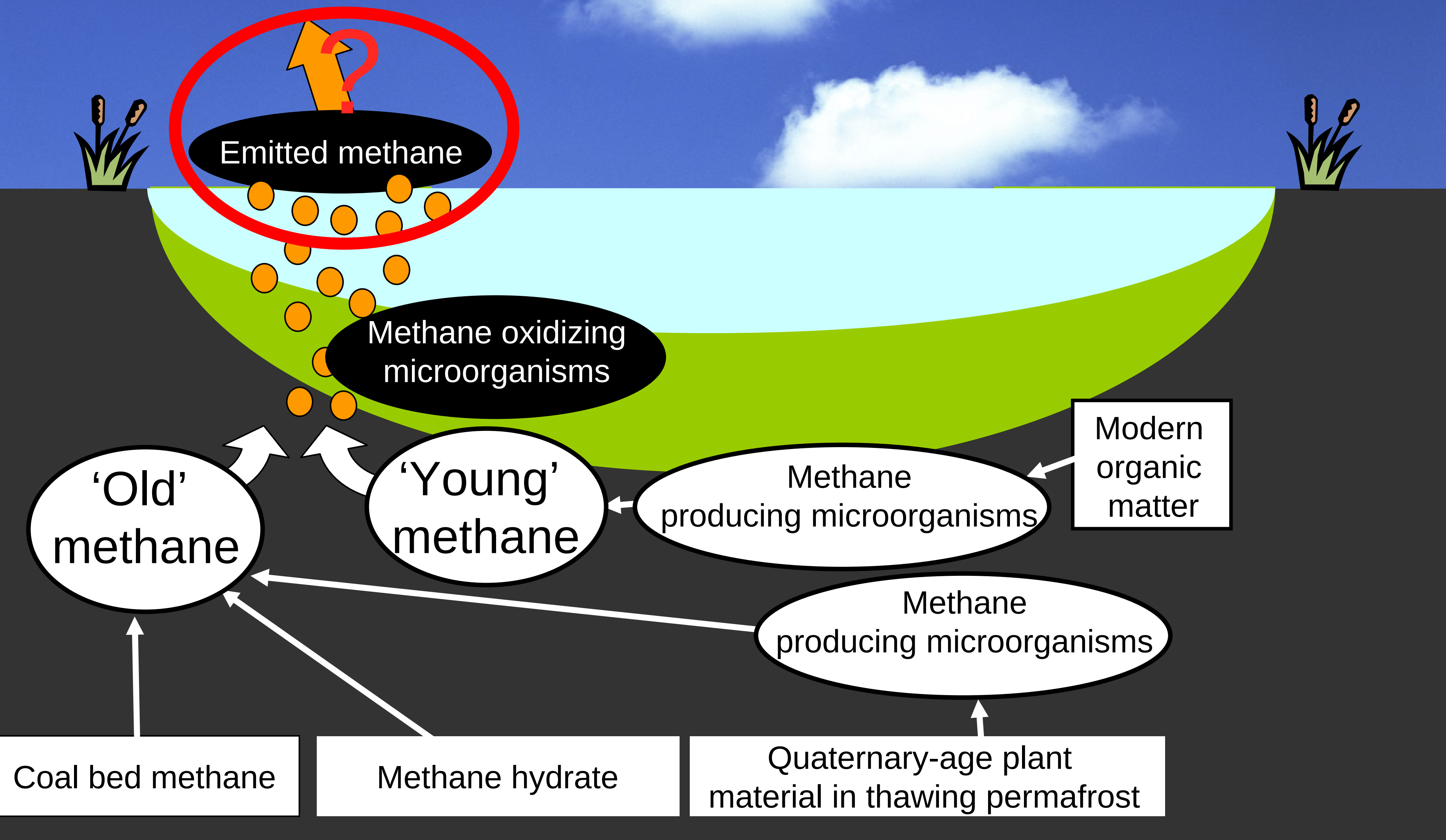
4) use the millennial-scale history of methane emissions as recorded in lake bottom sediment cores to predict the future impact of climate change on thermokarst lake methane emissions.

# Description of the work to be performed

Introducing study locations and methane in thermokarst lakes



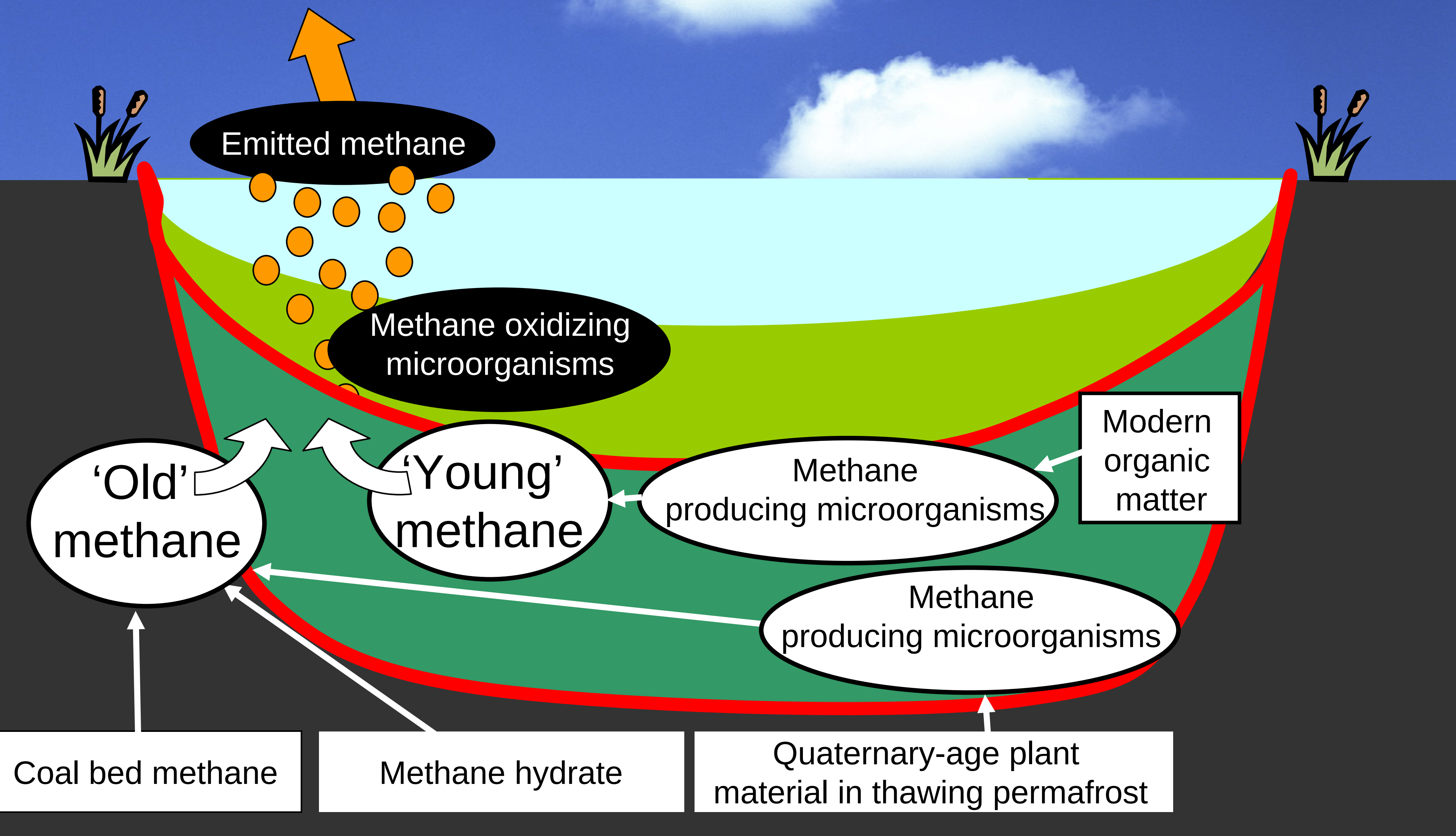
1) measure methane emissions over a range of timescales at thermokarst lakes and use reconnaissance imaging to identify gas source locations.



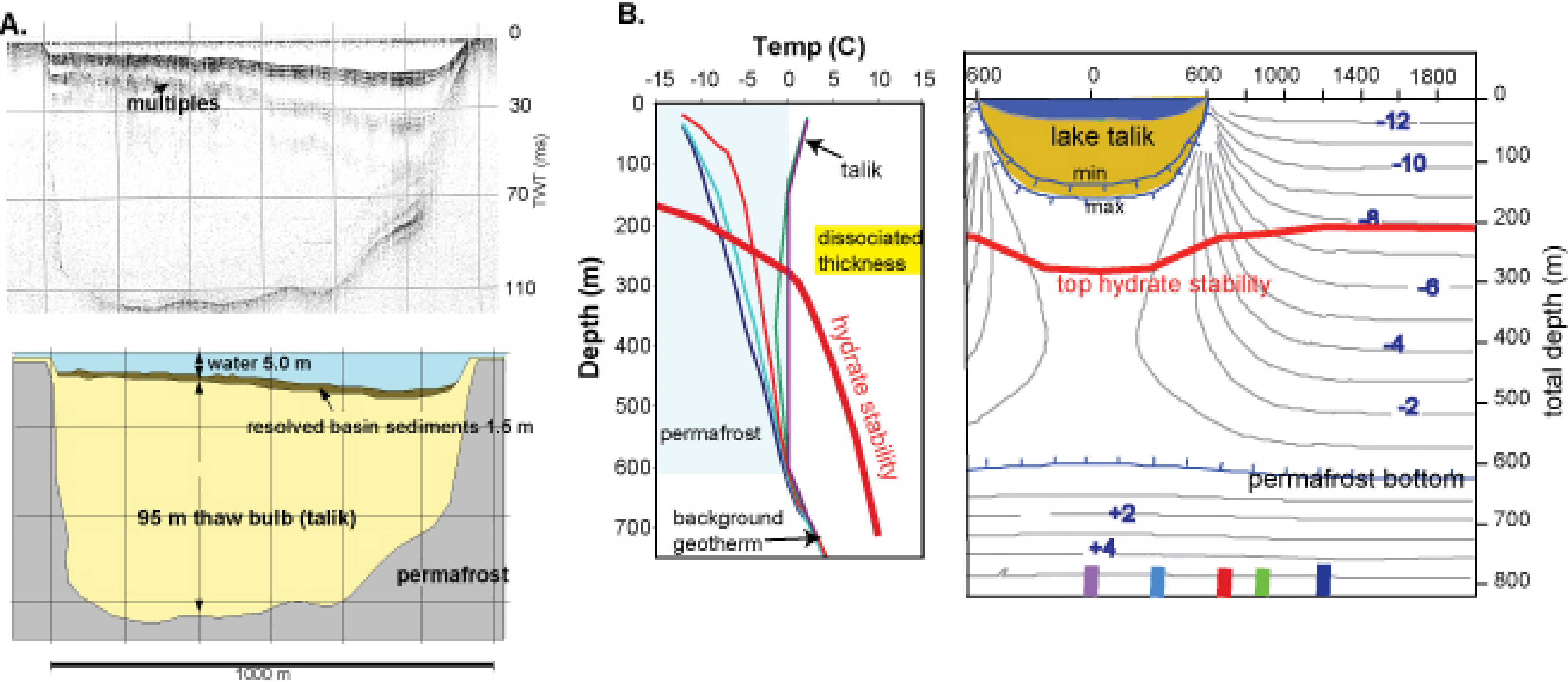
# Site measurements (Walter)

# Bubble traps (Walter)

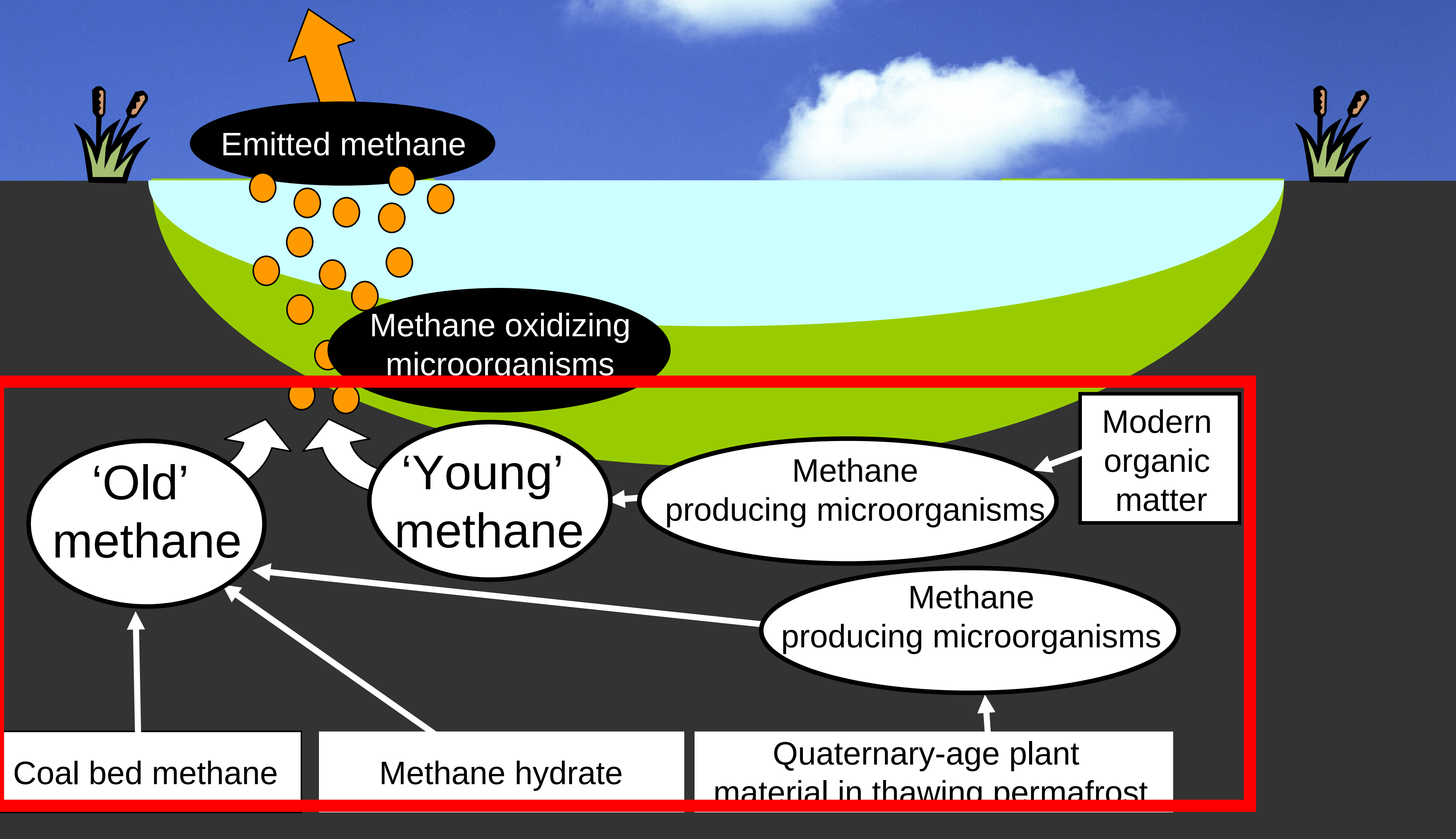
1) measure methane emissions over a range of timescales at thermokarst lakes and use reconnaissance imaging to identify gas source locations.



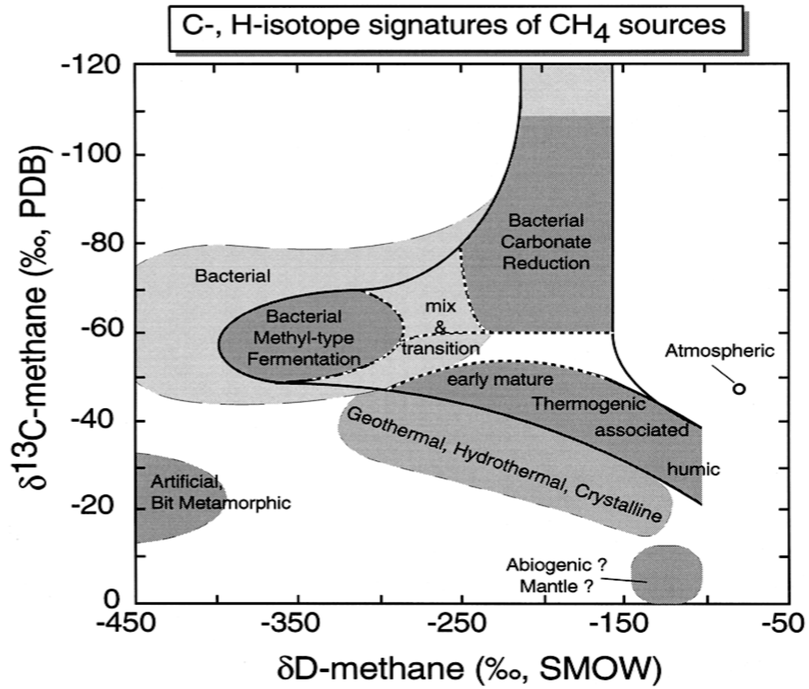
# Reconnaissance imaging (Ruppel)



# 2) determine the methane sources.

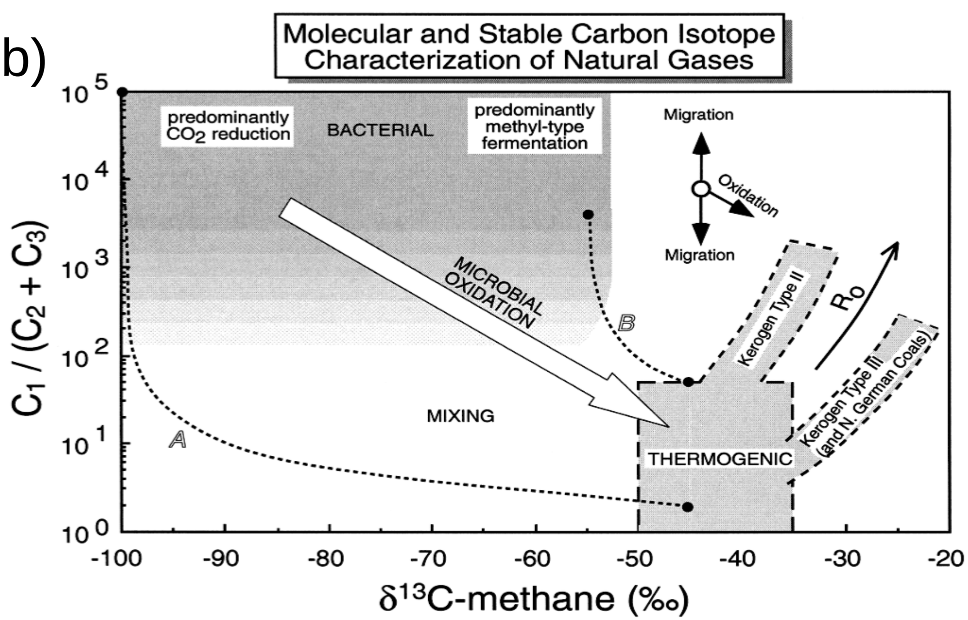


a)

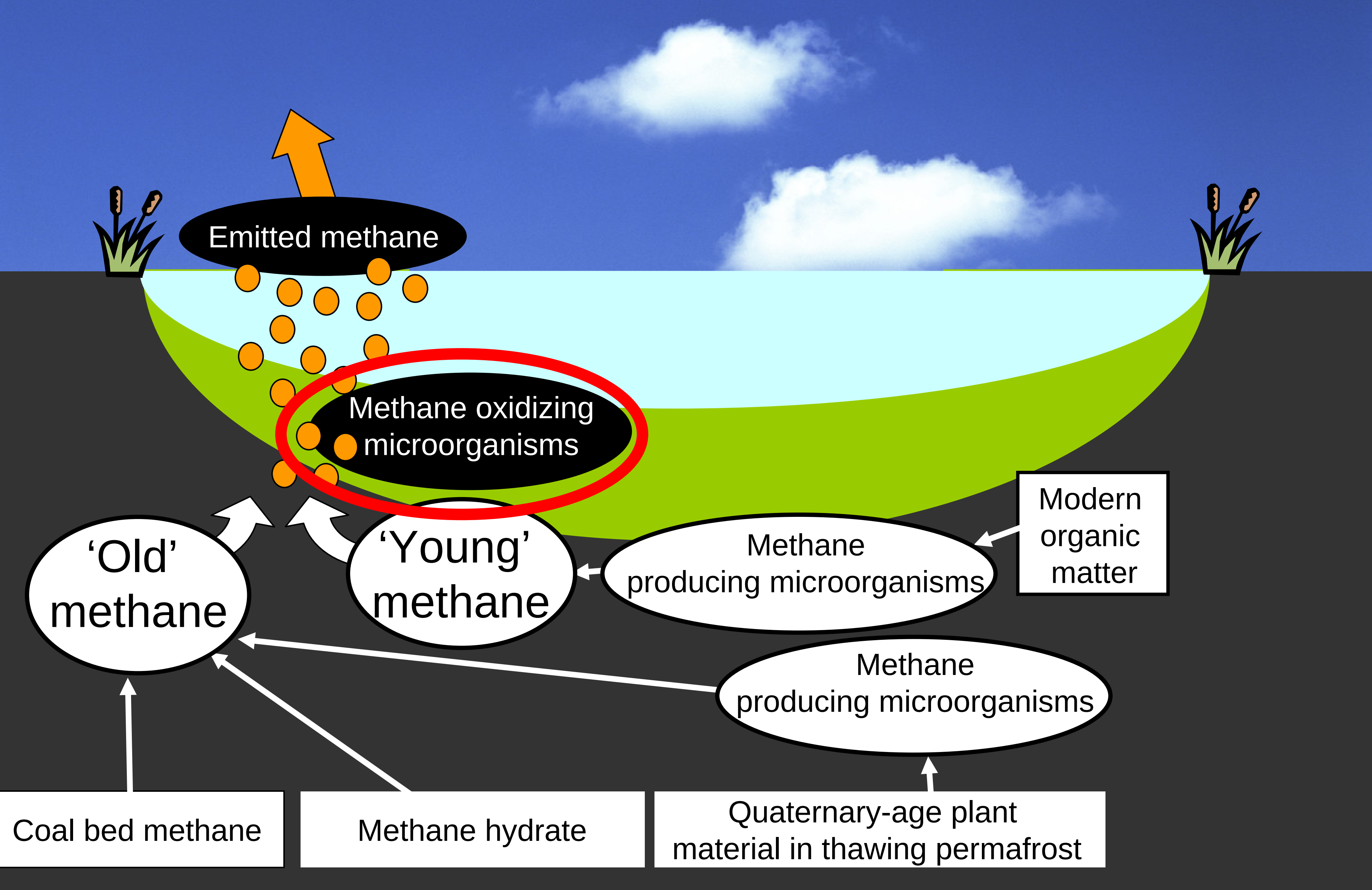



Chemical characterization of methane (Walter, Wooller, Pohlman):
i.e. Stable isotope analyses
AMS radiocarbon dating,
Noble gas analyses

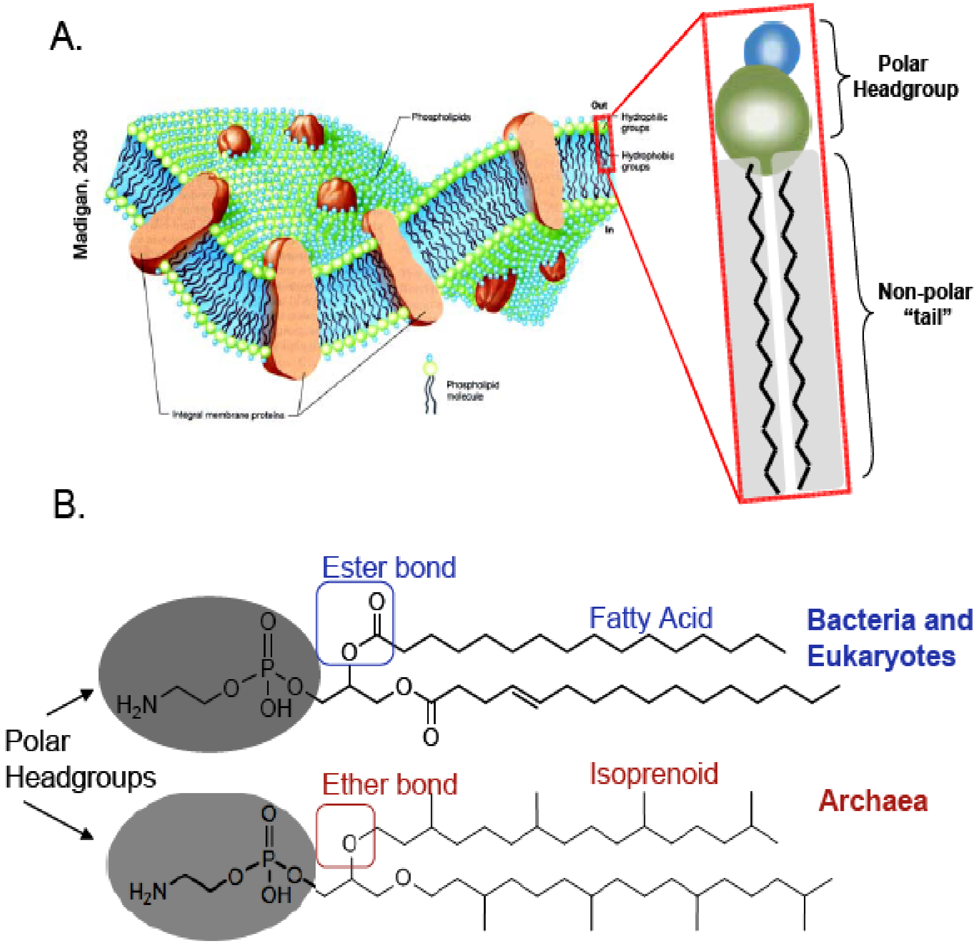
b)

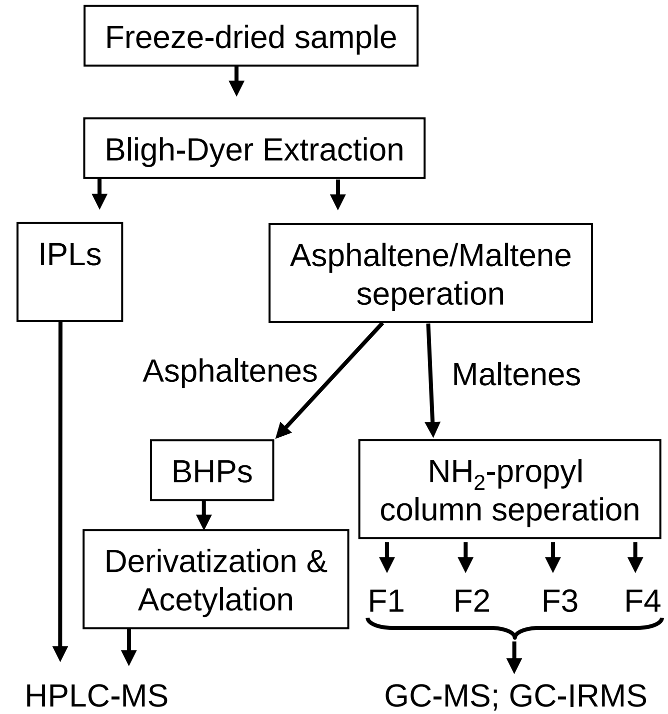


# 3) constrain methane sinks through analysis of methane oxidation pathways in lake water and lake bottom sediments



# Lipid biomarker analyses (Pohlman) and stable isotope probing (Leigh and Wooller)



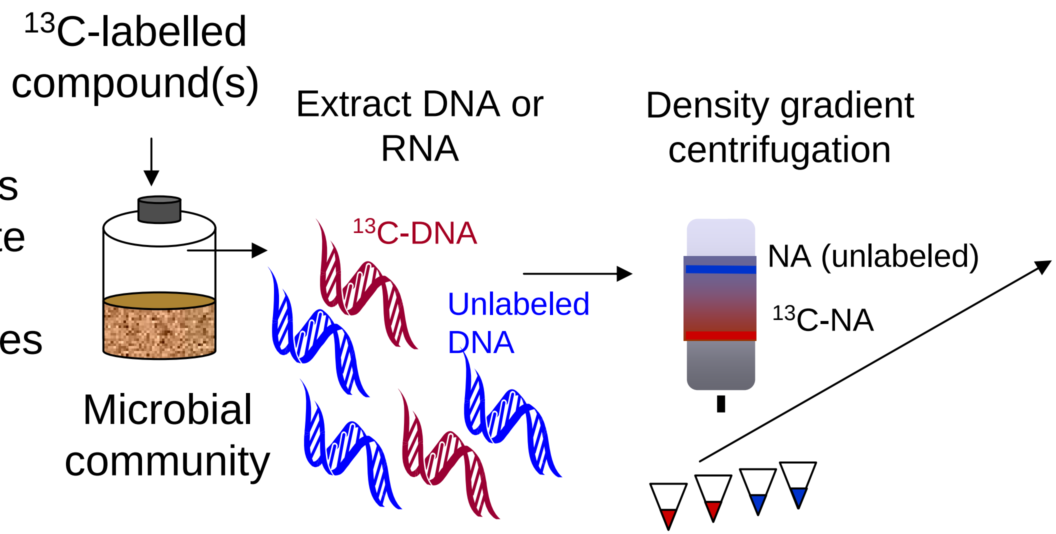



# Stable isotope probing (SIP) methods

## DNA-SIP or RNA-SIP

Degraders incorporate $^{13}C$ into biomolecules

- DNA
- RNA




**Community profiling**

- DGGE
- T-RFLP

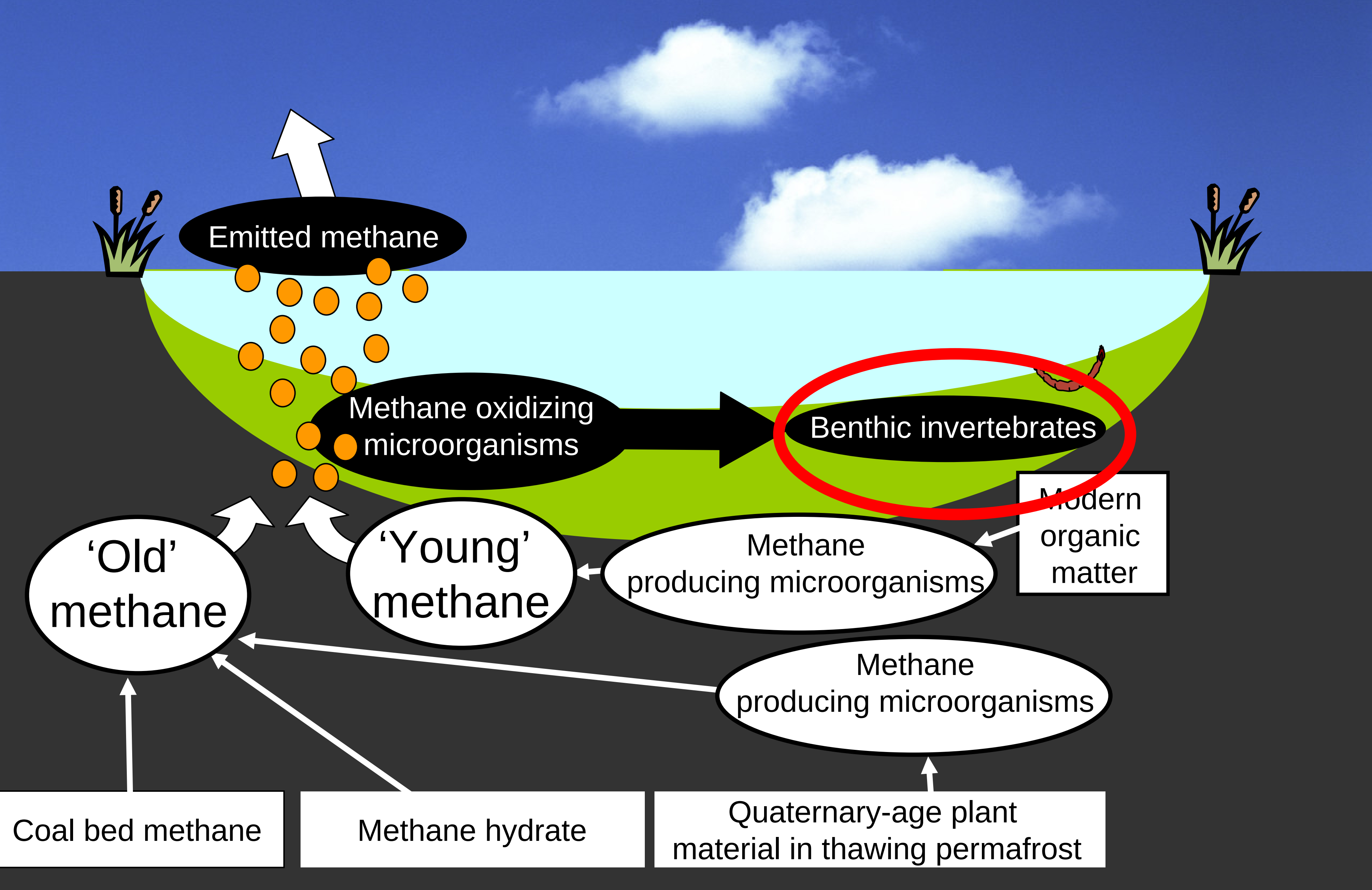
**Identification**

- Sequence analyses

**Functional genes (DNA only)**

- PCR + sequencing
- Functional gene arrays
- Metagenomics

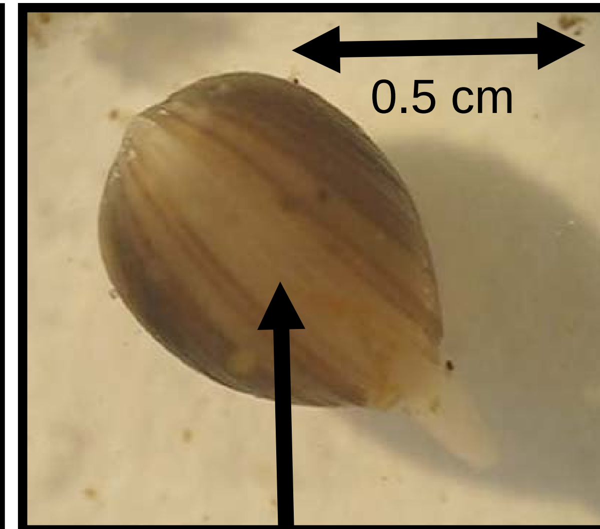
3) constrain methane sinks through analysis of methane oxidation pathways in lake water and lake bottom sediments



# Benthic invertabrates from a methane seep in a thermokarst lake

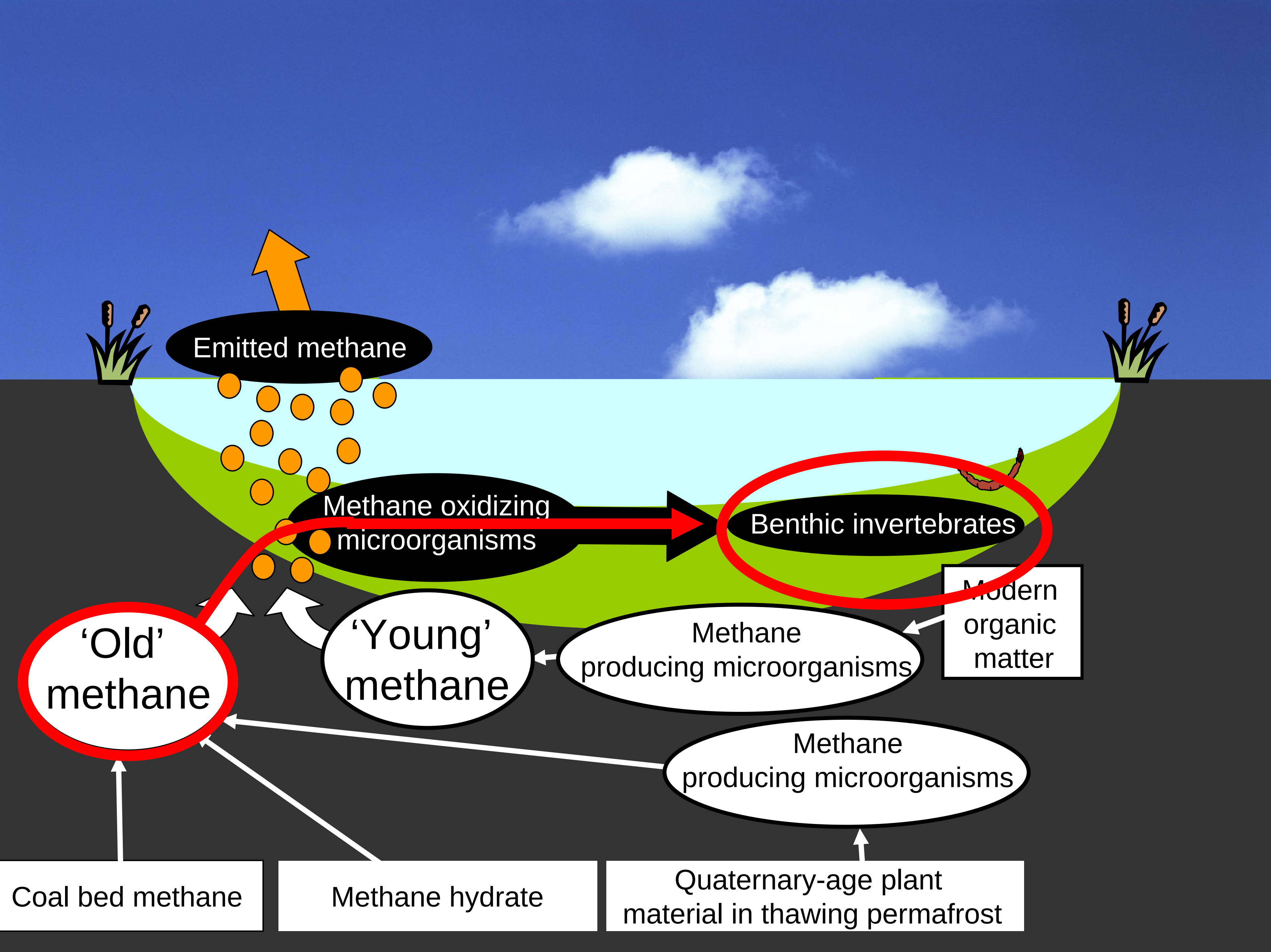

Chironomid
(blood ‘worm’)
larvea

Worms

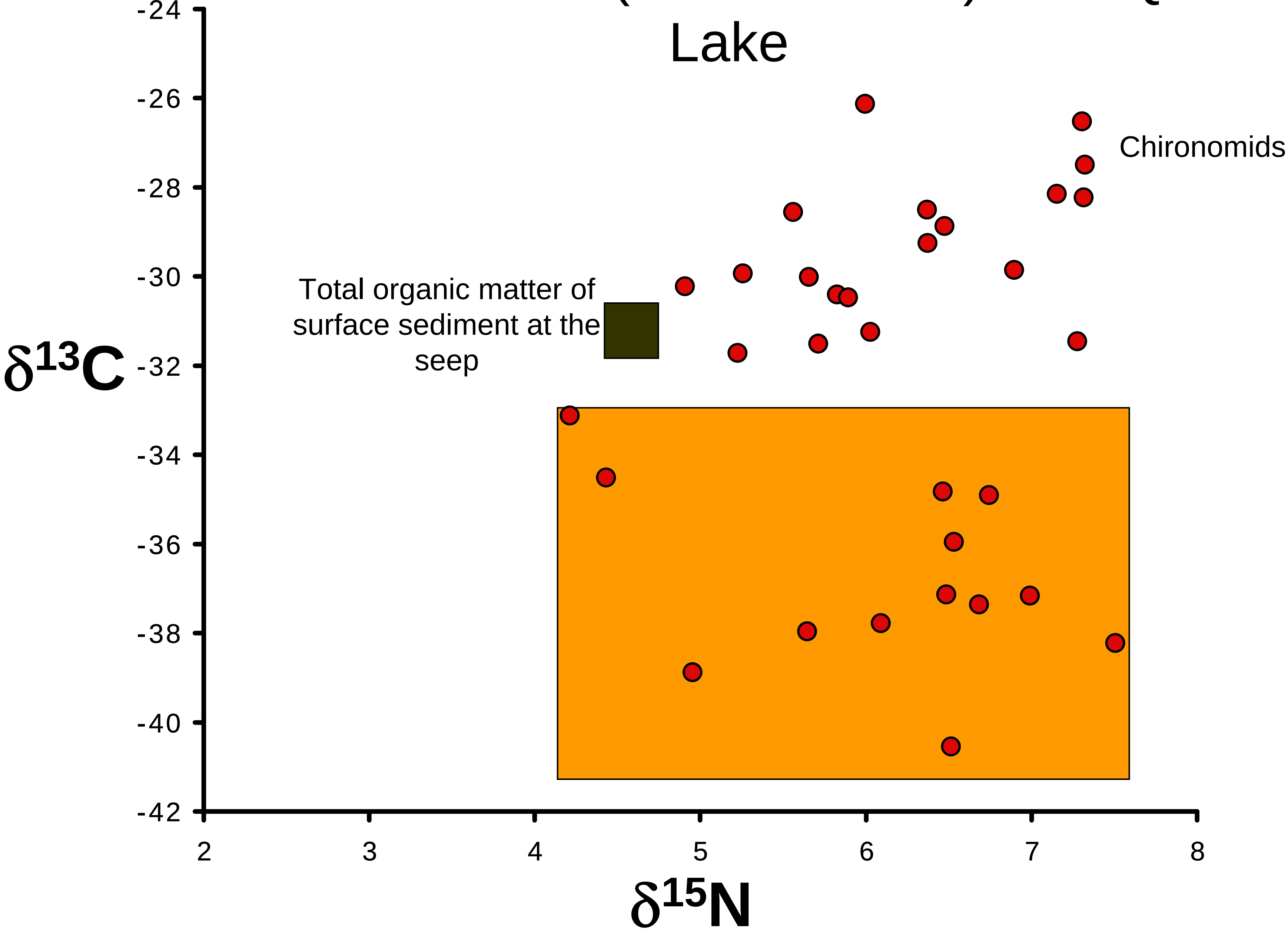



Fingernail clams

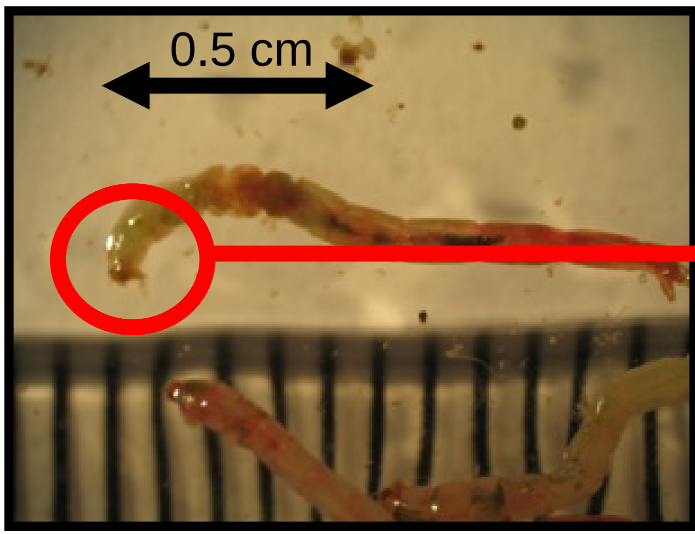
A radiocarbon analysis of these **<u>live</u>** chironomid larvae produced a $^{14}C$ ‘age’ of **<u>1760 years</u>** (Wooller and Walter preliminary data).

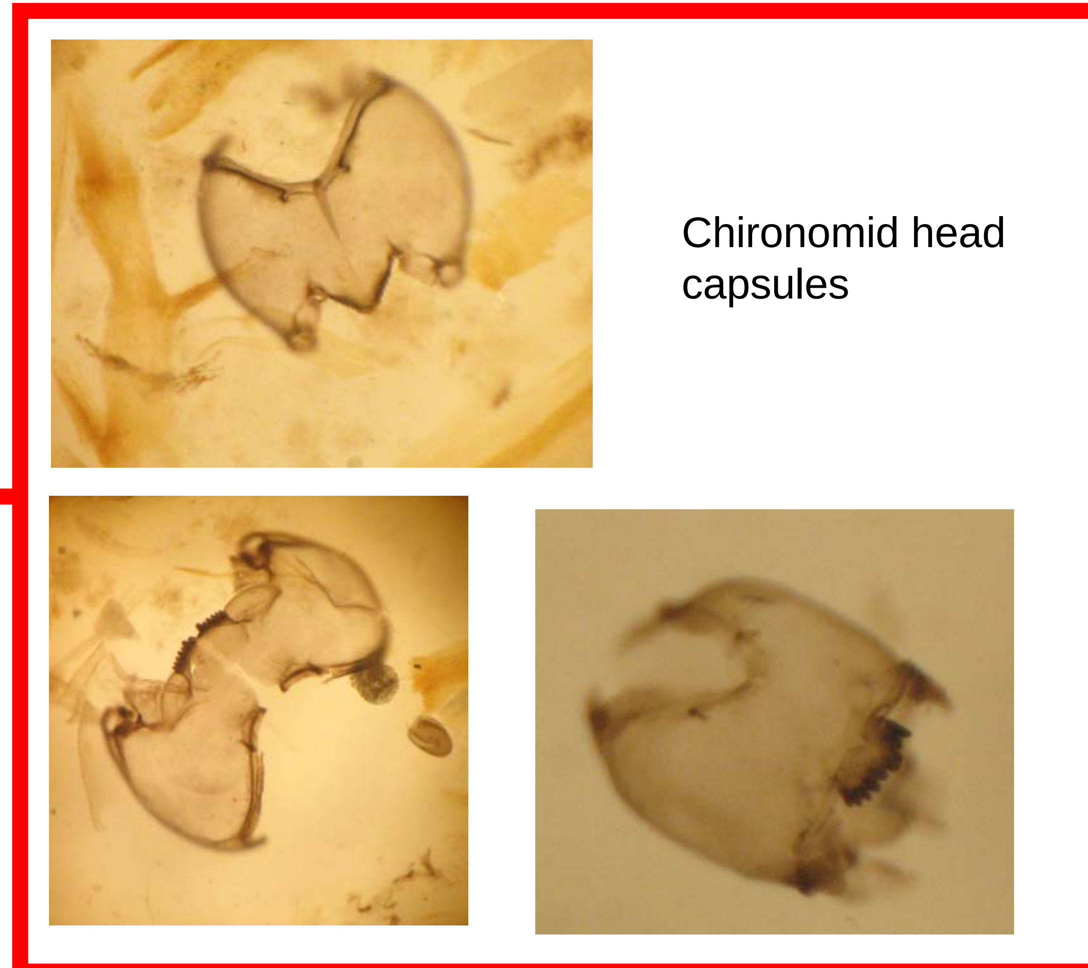

Emitted methane
Methane oxidizing microorganisms
Benthic invertebrates
Modern organic matter
'Old' methane
'Young' methane
Methane producing microorganisms
Methane producing microorganisms
Coal bed methane
Methane hydrate
Quaternary-age plant material in thawing permafrost

# Stable carbon and nitrogen isotope composition of modern chironomids (and sediment) from Qalluuraq Lake



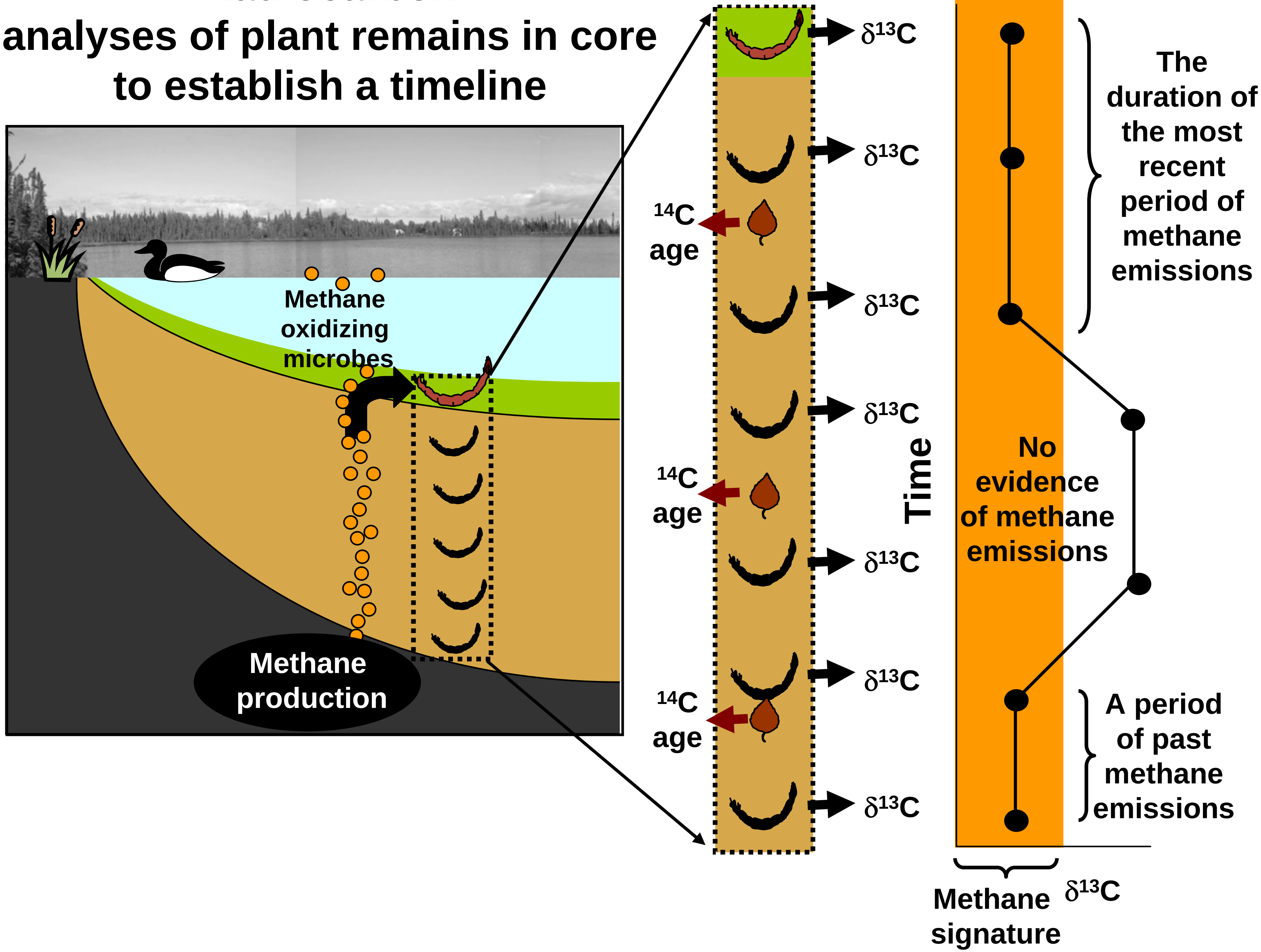
4) Use the millennial-scale history of methane emissions as recorded in lake bottom sediment cores to predict the future impact of climate change on thermokarst lake methane emissions (Wooller and Pohlman).

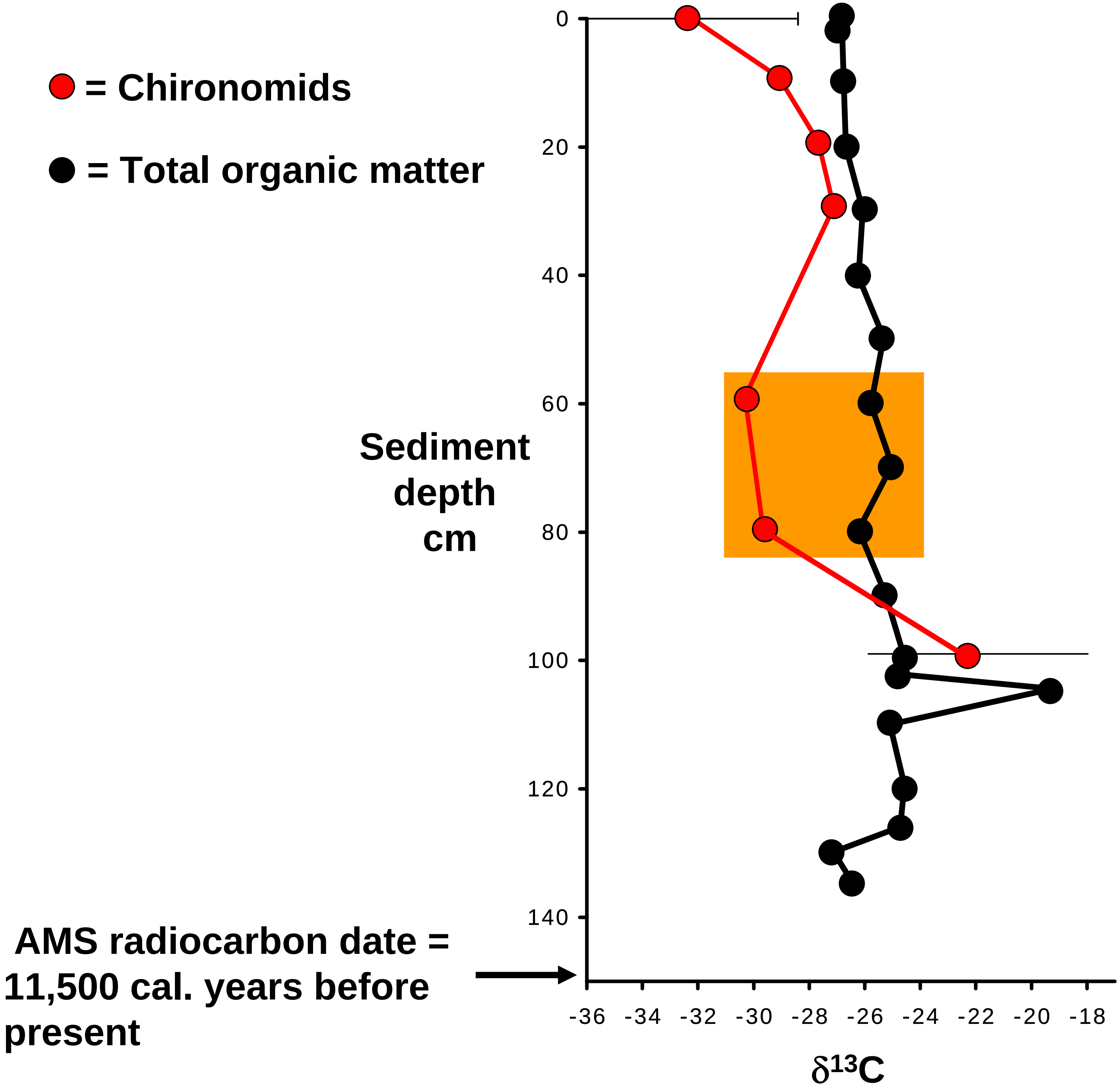


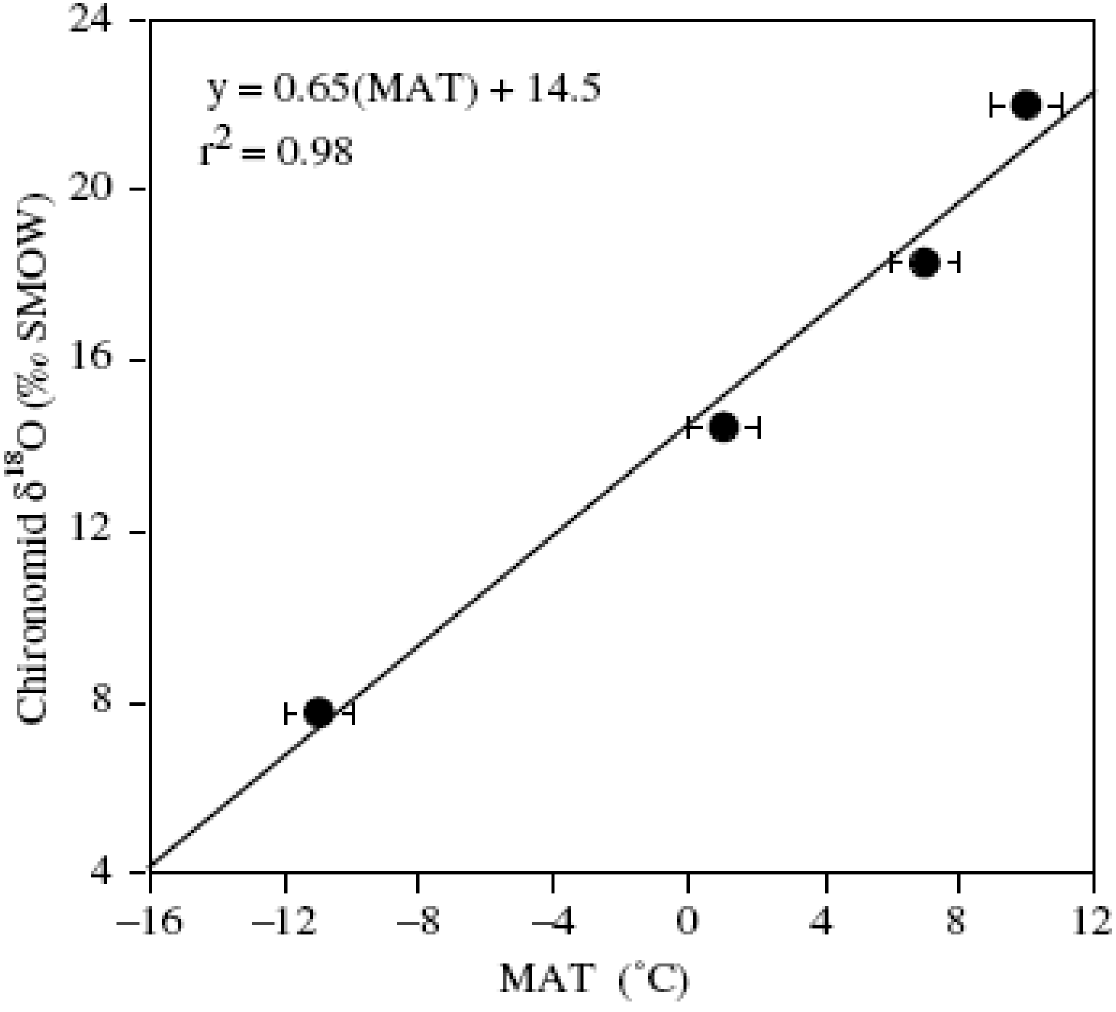
## Radiocarbon analyses of plant remains in core to establish a timeline

## Stable carbon isotope analyses of biomarkers and chironomid indicators of methane

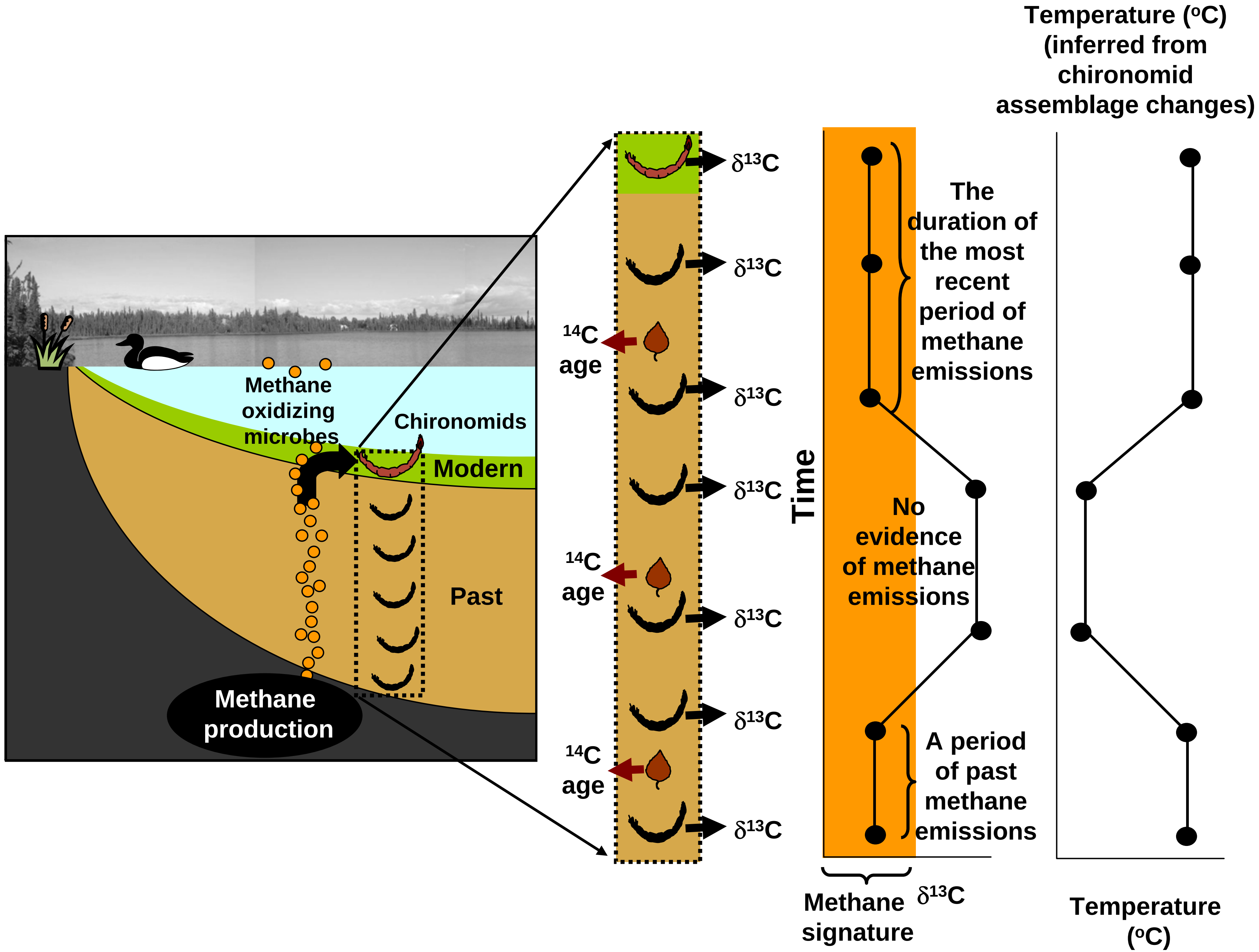




= Chironomids
= Total organic matter
Sediment depth cm
0
20
40
60
80
100
120
140
AMS radiocarbon date = 11,500 cal. years before present
-36
-34
-32
-30
-28
-26
-24
-22
-20
-18
$\delta^{13}C$




Wooller et al. 2004



Temperature (°C) (inferred from chironomid assemblage changes)
Methane oxidizing microbes
Chironomids
Modern
Past
Methane production
δ13C
14C age
The duration of the most recent period of methane emissions
No evidence of methane emissions
A period of past methane emissions
Time
Methane signature
δ13C
Temperature (°C)

# Expected impacts of the project include:

## Our project will ……

- be among the first to acquire direct, targeted data to assess the dogma that permafrost gas hydrates are among the most susceptible to climate change.

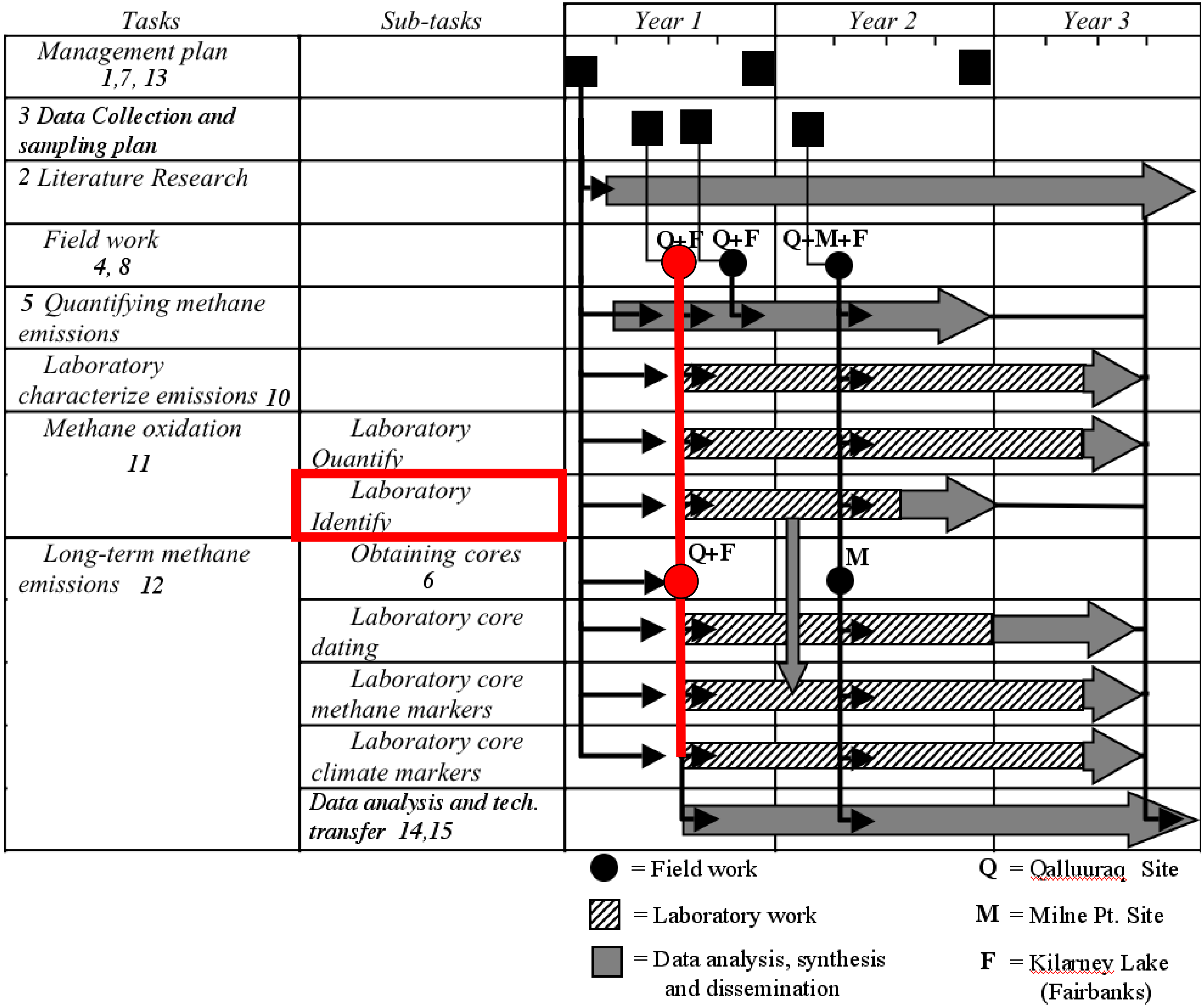
- involve applying cutting edge methane hydrate fingerprinting techniques and extend these methods to the terrestrial hydrate system.

- provide baseline data that will be invaluable in decades to come as potential climate warming scenarios play out.

- help to further refine contemporary estimates of the component of atmospheric methane derived from arctic sources, as previous studies already have shown.

- broach first-order scientific questions, develop new techniques and extend existing techniques to new environments, and build synergies between marine and terrestrial methane seep and gas hydrate communities.

# Project schedule and milestones



| | | | |
|---|---|---|---|
| Period 1 | 2009 | May | Field work: Spring measurements of gas emissions Qalluuraq Lake seep and Kilarney Lake.<br><br>Field work: collection of cores from Qalluuraq and Kilarney. |
| | 2009 | July | Field work: Summer measurements of gas emissions Qalluuraq Lake seep and Kilarney Lake. |
| | | | |
| Period 2 | 2010 | March | Laboratory: Analyses of samples from Qalluuraq Lake seep complete. |
| | 2010 | August | Laboratory: Analyses of samples from Kilarney complete. |
| | | | |
| | 2010 | May | Laboratory: Pore water and solid phase analysis, radiocarbon dating, methane biomarker and climate marker analyses initiated on samples from Milne Point initiated.<br><br>Laboratory: Analyses of gas samples from Milne Point initiated. |
| Period 3 | | | |
| | 2011 | September | PROJECT COMPLETION |