Causes of Methanogenesis-Linked Climate Feedbacks in a Discontinuous Permafrost Peatland

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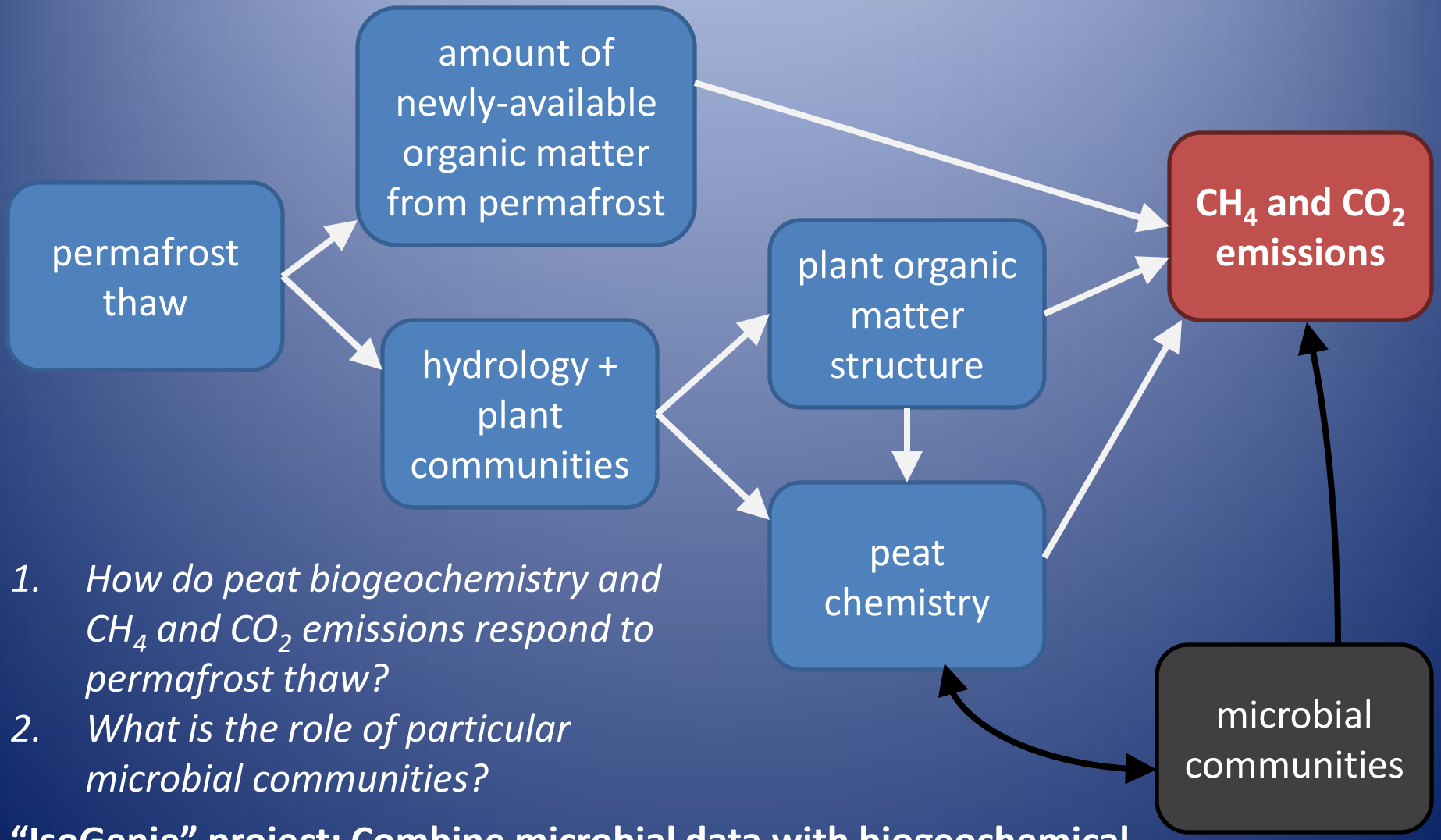
Study Site: Stordalen Mire, northern Sweden

- Peatland (wetland with organic soil).
- Underlain by patchy permafrost.

Extent of permafrost in the Northern Hemisphere. Stordalen Mire is marked with a star.

Research Questions



1. *How do peat biogeochemistry and CH_4 and CO_2 emissions respond to permafrost thaw?*
2. *What is the role of particular microbial communities?*

"IsoGenie" project: Combine microbial data with biogeochemical data to create a model of greenhouse gas responses to thawing.

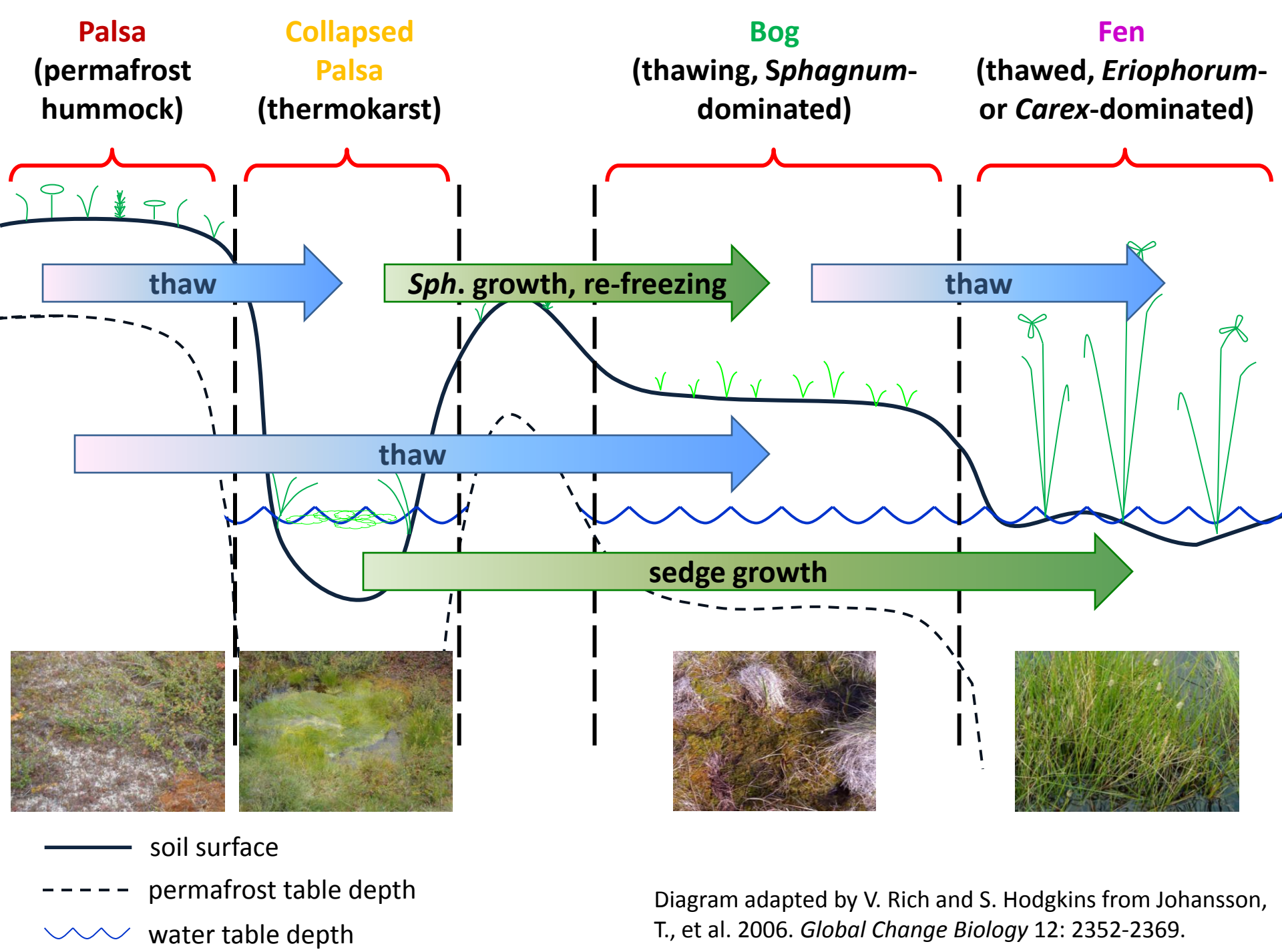
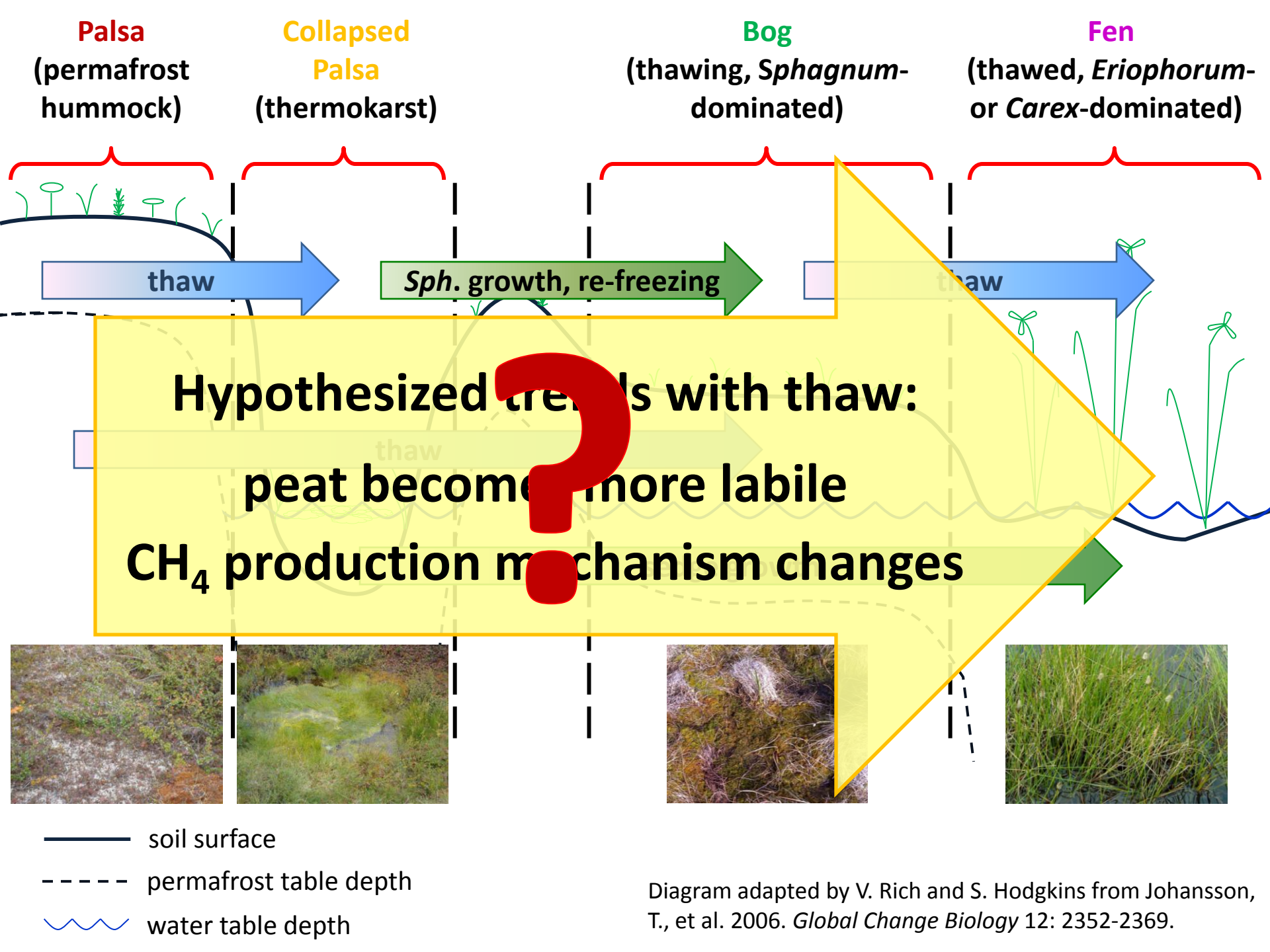


Diagram adapted by V. Rich and S. Hodgkins from Johansson, T., et al. 2006. *Global Change Biology* 12: 2352-2369.



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CH_4 Production Mechanisms: C Isotopes in CH_4

CO_2 reduction:

$2\ CH_2O + 2\ H_2O \rightarrow 2\ CO_2 + 4\ H_2$

$CO_2 + 4\ H_2 \rightarrow CH_4 + 2\ H_2O$

net reaction: $2\ CH_2O \rightarrow CH_4 + CO_2$

acetate fermentation:

$2\ CH_2O$ (higher MW) $\rightarrow CH_3COOH$

$CH_3COOH \rightarrow CH_4 + CO_2$

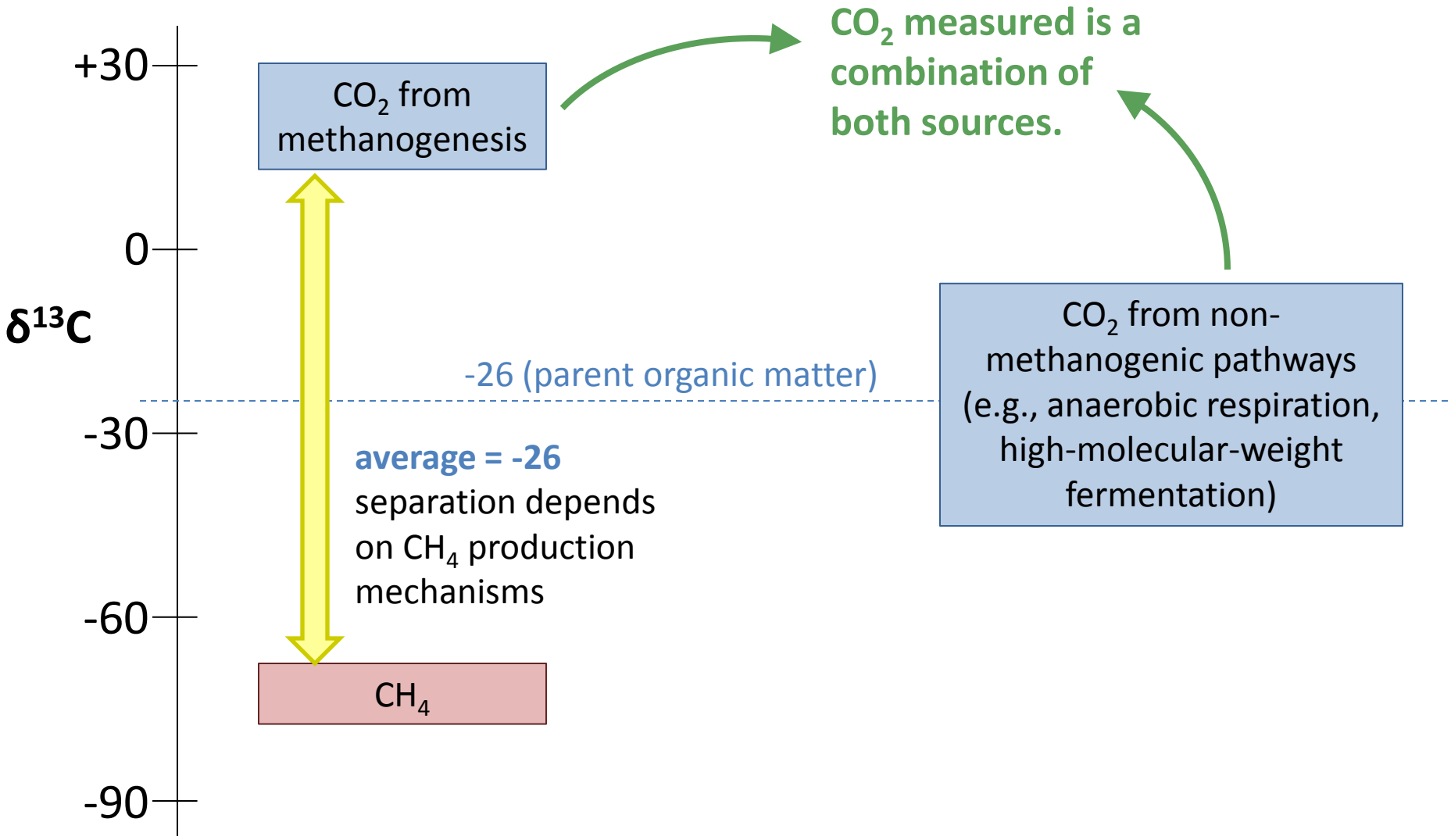
net reaction: $2\ CH_2O \rightarrow CH_4 + CO_2$

*typical of: lower-quality organic matter, low pH, deeper in peat column (**e.g. bog sites**)*

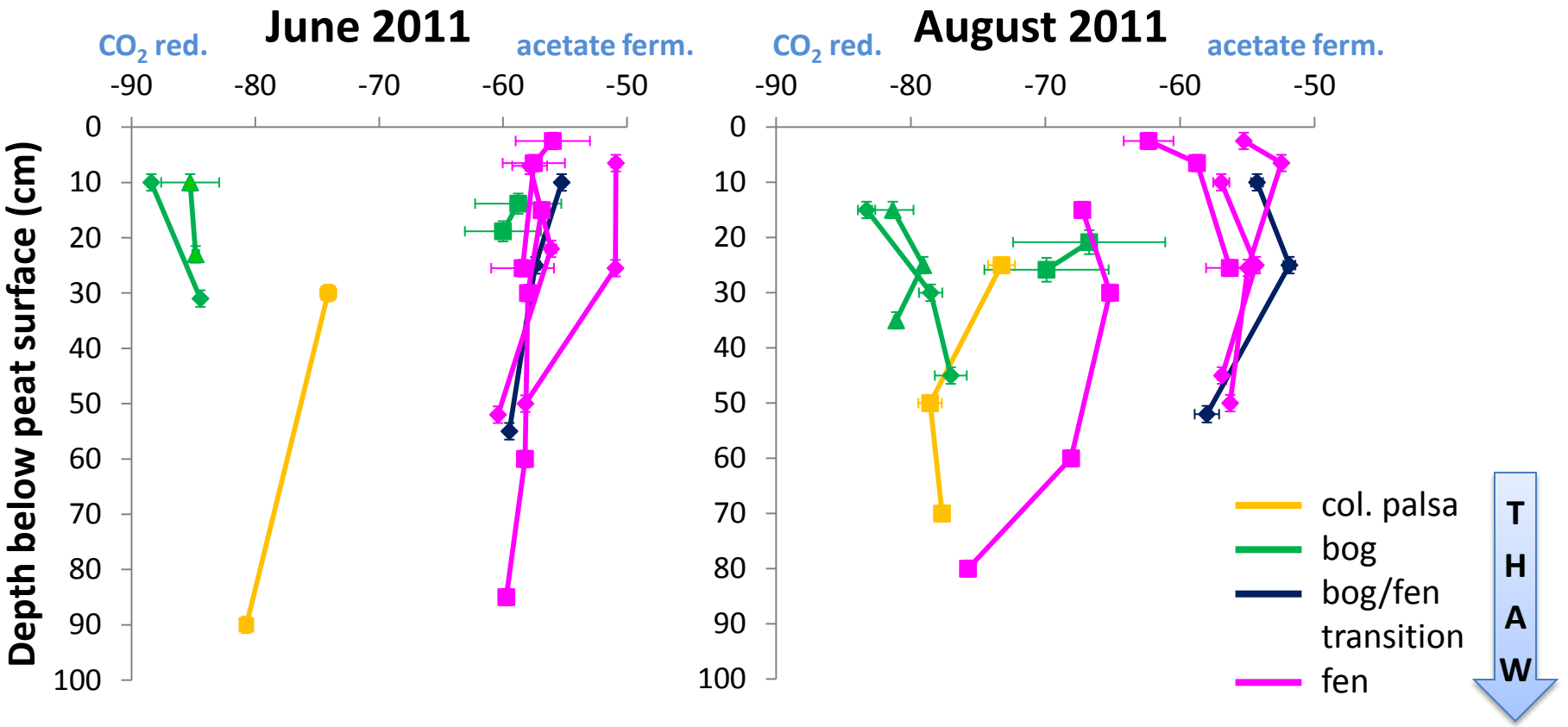
*typical of: higher-quality organic matter, higher pH, shallower in peat column (**e.g. fen sites**)*

- $\delta^{13}C\text{-}CH_4$ also affected by oxidation, so we also measure δD.

CO_2 Production Mechanisms: C Isotopes in CH_4 and CO_2



$\delta^{13}C$ of Dissolved CH_4

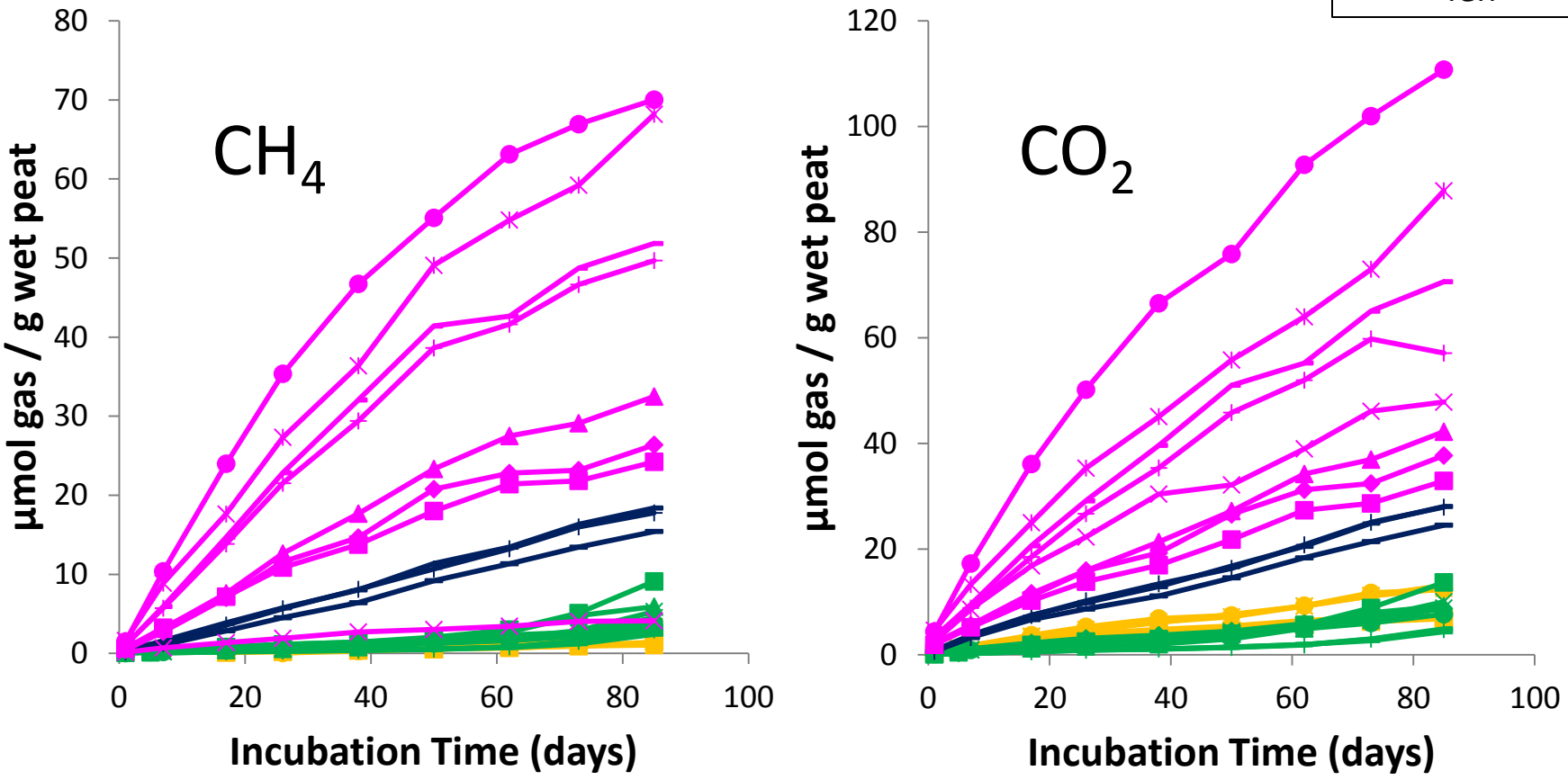


- Thaw → more acetate fermentation.
- Greater depth in peat column (older OM) → more CO_2 reduction.
- Porewater gas concentrations and $\delta D\text{-}CH_4$ were inconclusive.

Incubations: Obtaining a More Detailed Picture

- Procedure:
  - Waterlogged peat incubated anaerobically in the dark.
  - Measure buildup and $\delta^{13}C$ of CH_4 and CO_2 in headspace.
- What we learn:
  - Organic matter lability, e.g. “rotting potential:”
    - gas production rates
  - CH_4 production mechanisms:
    - $\delta^{13}C$ of CH_4
  - Relative rates of methanogenesis vs. non-methanogenic decomposition:
    - relative rates of CH_4 and CO_2 production
    - $\delta^{13}C$ of CO_2

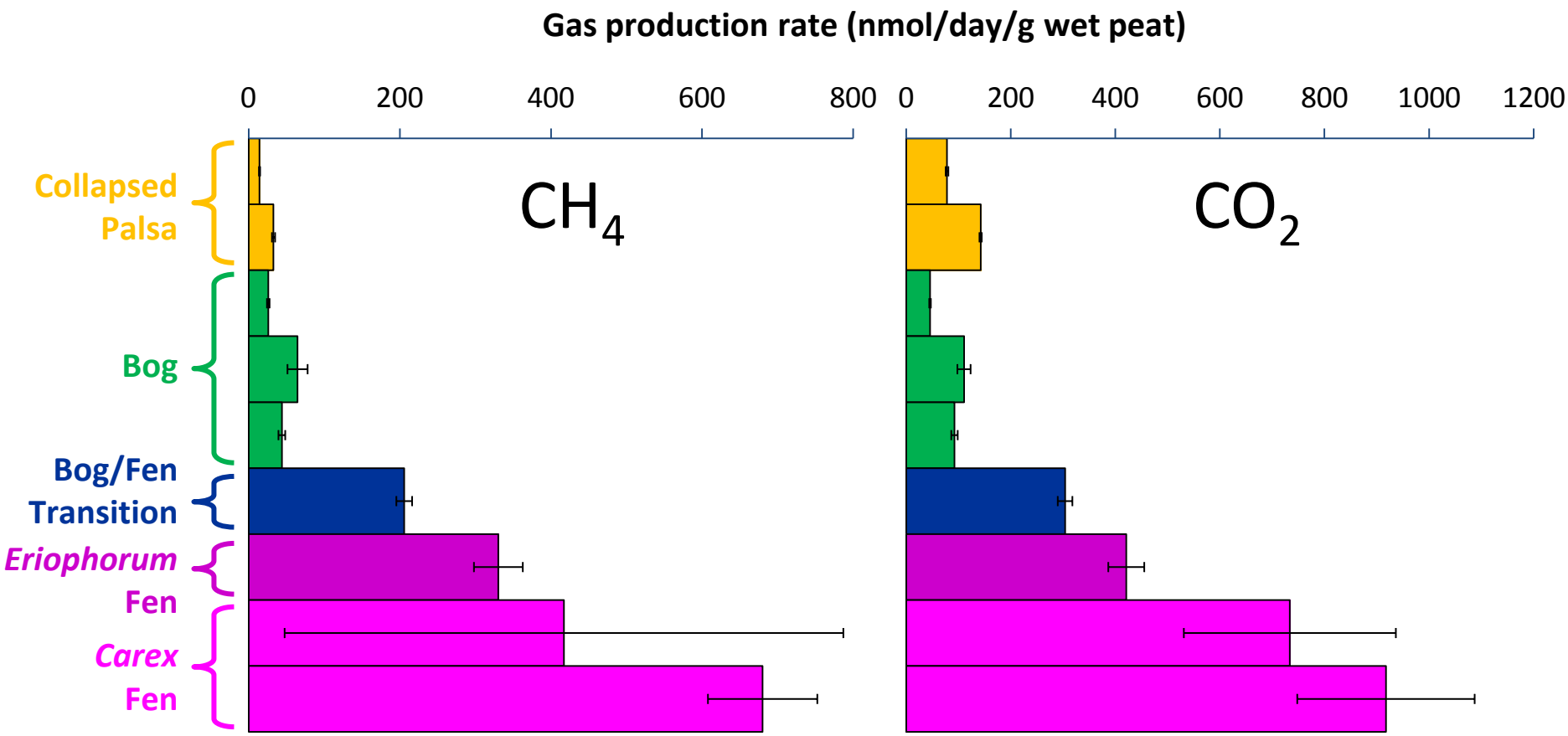
Incubation Results



Overall peat “rotting potential”:

fens >> bogs = col. palsas

Incubation Results



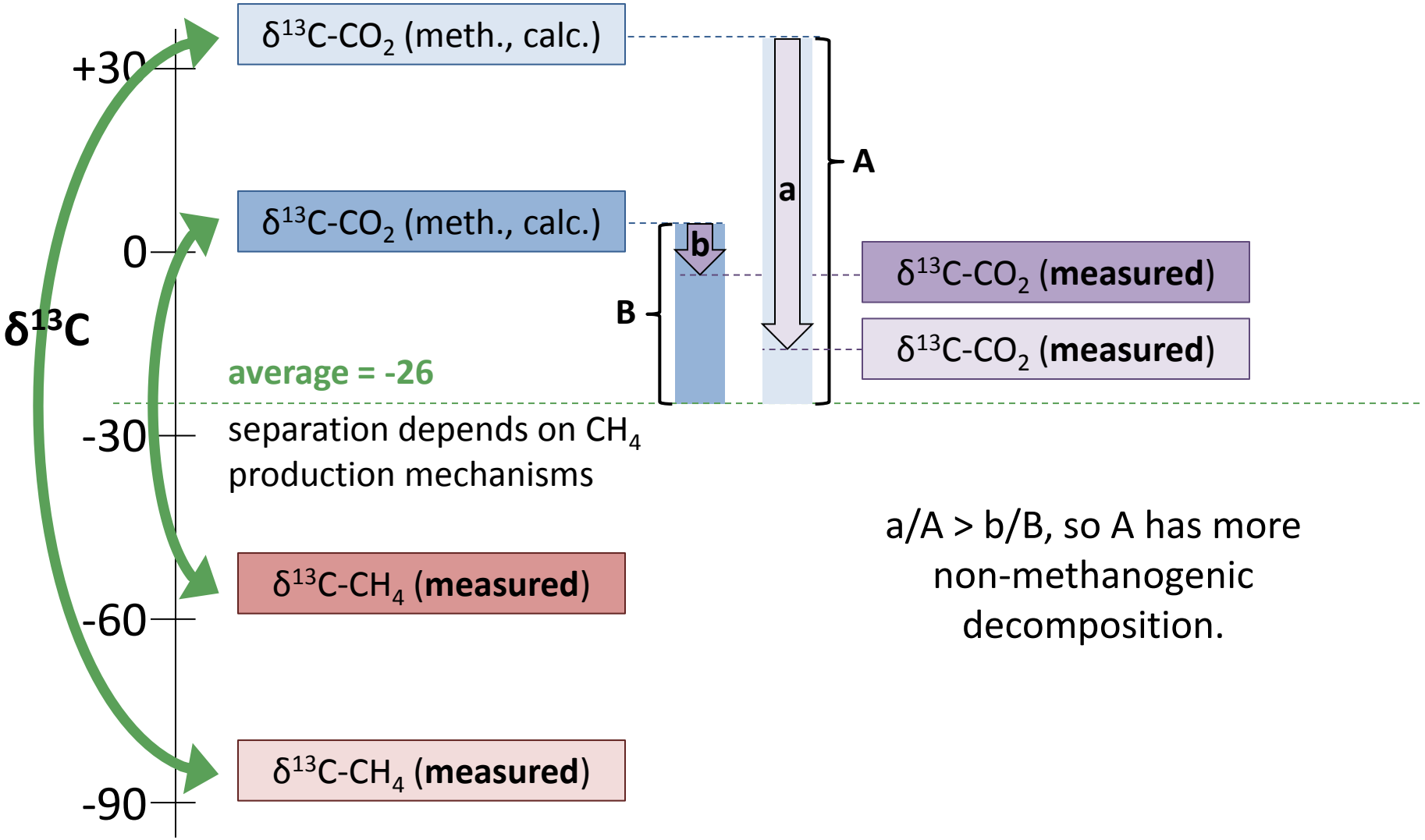
Overall peat “rotting potential”:

fens >> bogs = col. palsas

Interpreting Isotope Data for CO_2 Sources

(1) Use known $\delta^{13}C$-CH_4 to determine theoretical $\delta^{13}C$-CO_2 if there were no non-methanogenic CO_2 production.

(2) Downward shift of $\delta^{13}C$-CO_2 from theoretical values indicates amount of non-methanogenic production.

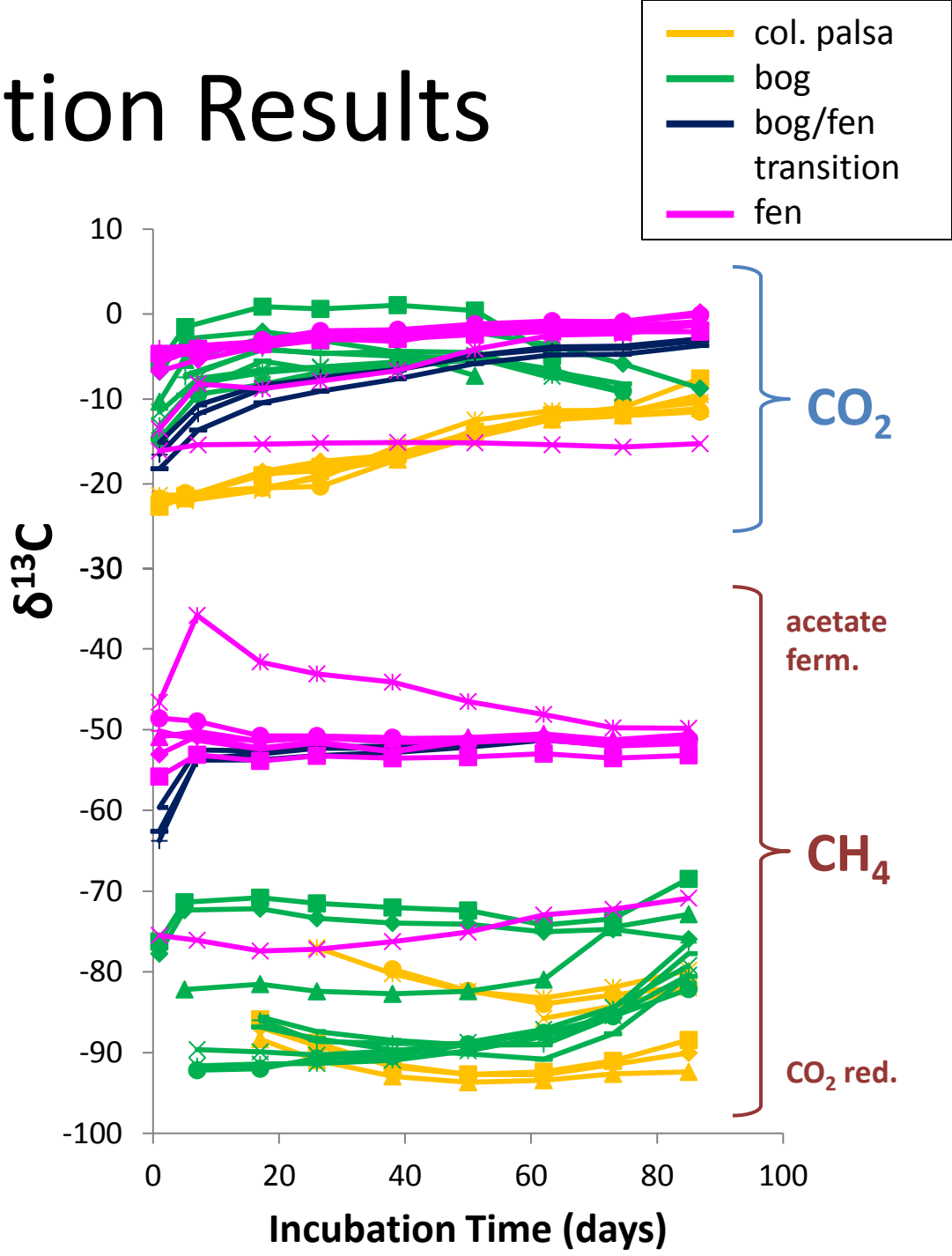


a/A > b/B, so A has more non-methanogenic decomposition.

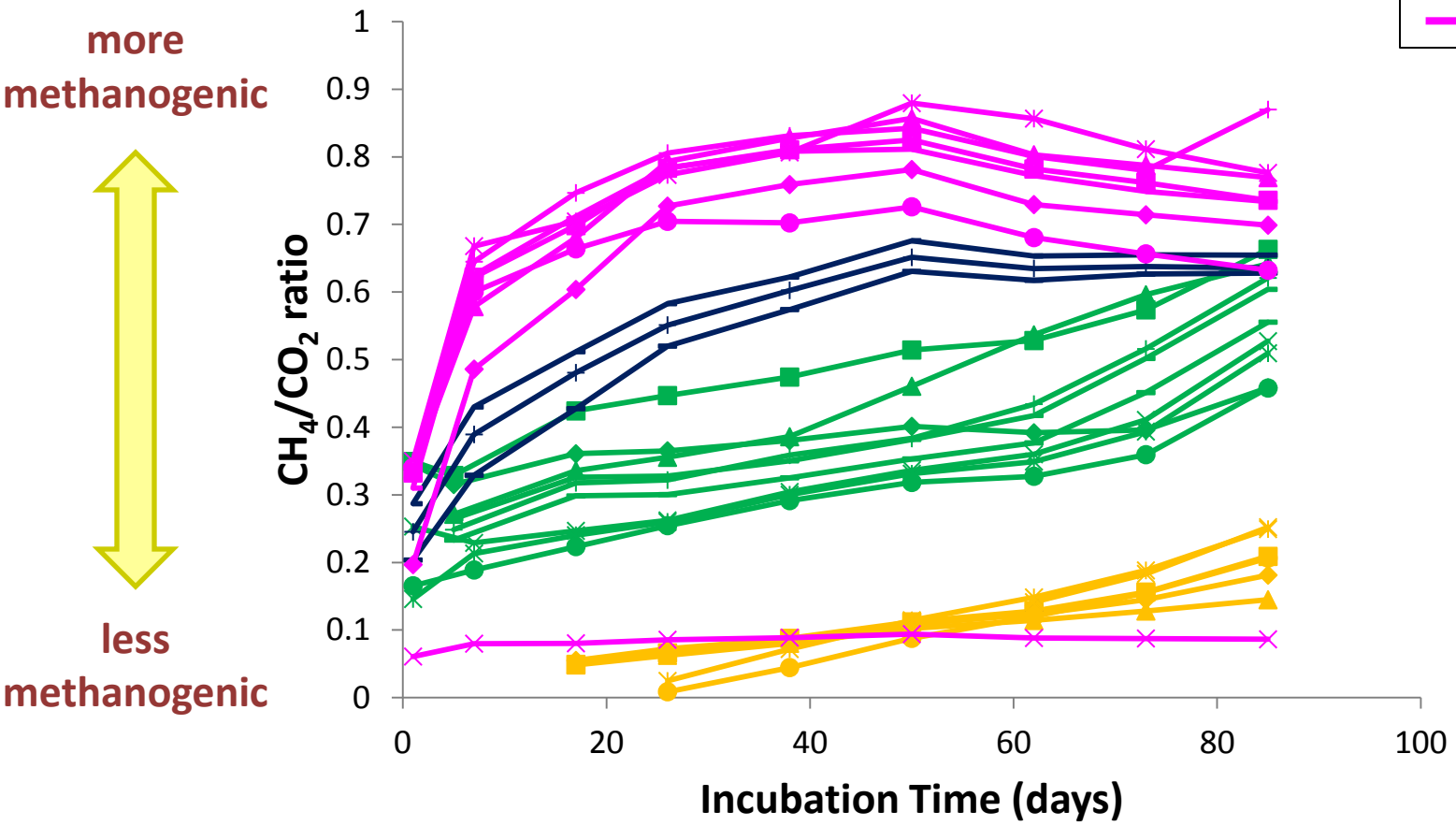
Incubation Results

- $\delta^{13}C$-CH_4 reveals methanogenesis dominated by:
  - acetate fermentation in fens
  - CO_2 reduction in bogs and col. palsas
- $\delta^{13}C$-CO_2 vs. $\delta^{13}C$-CH_4 reveals amount of methanogenesis rel. to non-methanogenic decomposition:

  fens > bogs > col. palsas



Incubation Results



- CH_4/CO_2 ratios confirm non-methanogenic CO_2 production trend predicted by $\delta^{13}C$-CO_2.
- Clear separation between habitat types.

Conclusions

- Overall peat lability:

  fen > (bog = collapsed palsa)

- Amount of methanogenesis relative to non-methanogenic decomposition:

  fen > bog > collapsed palsa

  - The absolute rate of non-methanogenic decomposition is unusually high in collapsed palsas, possibly due to a higher concentration of electron acceptors.
    - Porewater has been tested for NO_3^-, but there was no correlation.
    - Increased non-methanogenic decomposition could be due to some other electron acceptor.

- Methane production mechanisms:

  bog, collapsed palsa: CO_2 reduction

  fen: acetate fermentation

- Future work:
  - More detailed analysis of peat/porewater chemistry.
  - Integration with microbial data into Wetland-DNDC model.

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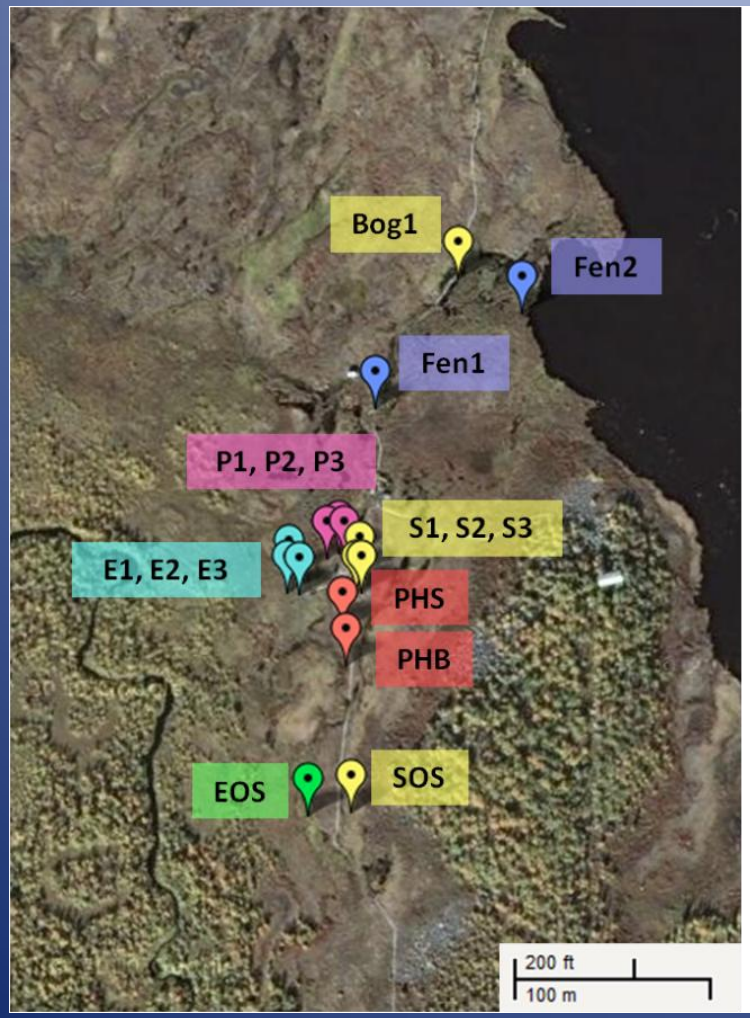
Sampling Sites



Key:

- palsa
- collapsed palsa
- *Sphagnum*
- *Sphagnum/Eriophorum transition*
- *Eriophorum angustifolium*
- *Carex*