Long-term impacts of boreal wildfire on carbon-cycling dynamics in Interior Alaska

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UAF

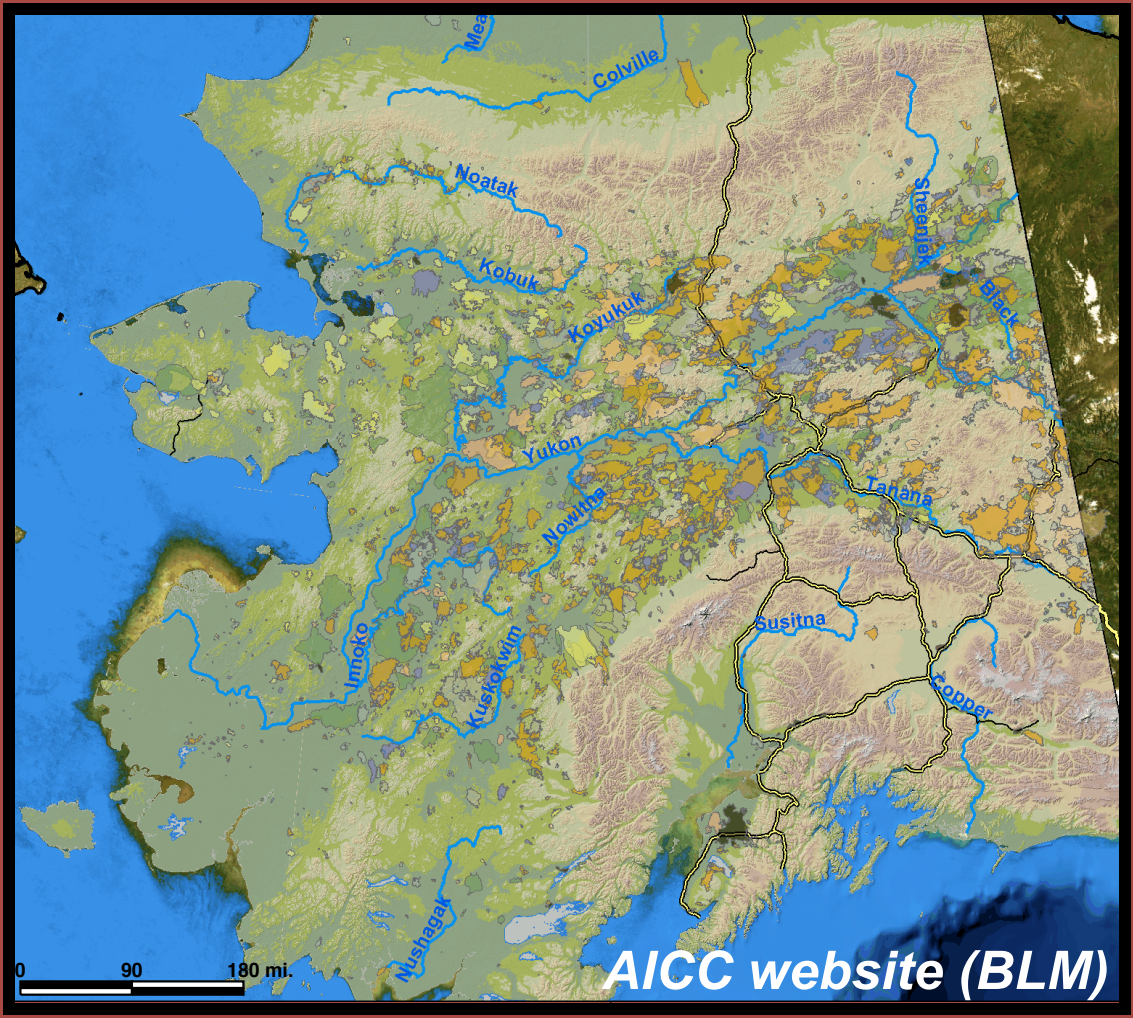
Talk Outline

- Why long-term?
- Approach
- Ace Lake: a precise fire archive
- Results: charcoal record and fire management.
- Carbon-cycling record
- Implications for landscape responses after fire.

Managing wildfire from a long-term perspective

1.) Fire frequency is unknown when FRI's are beyond historical fire record.

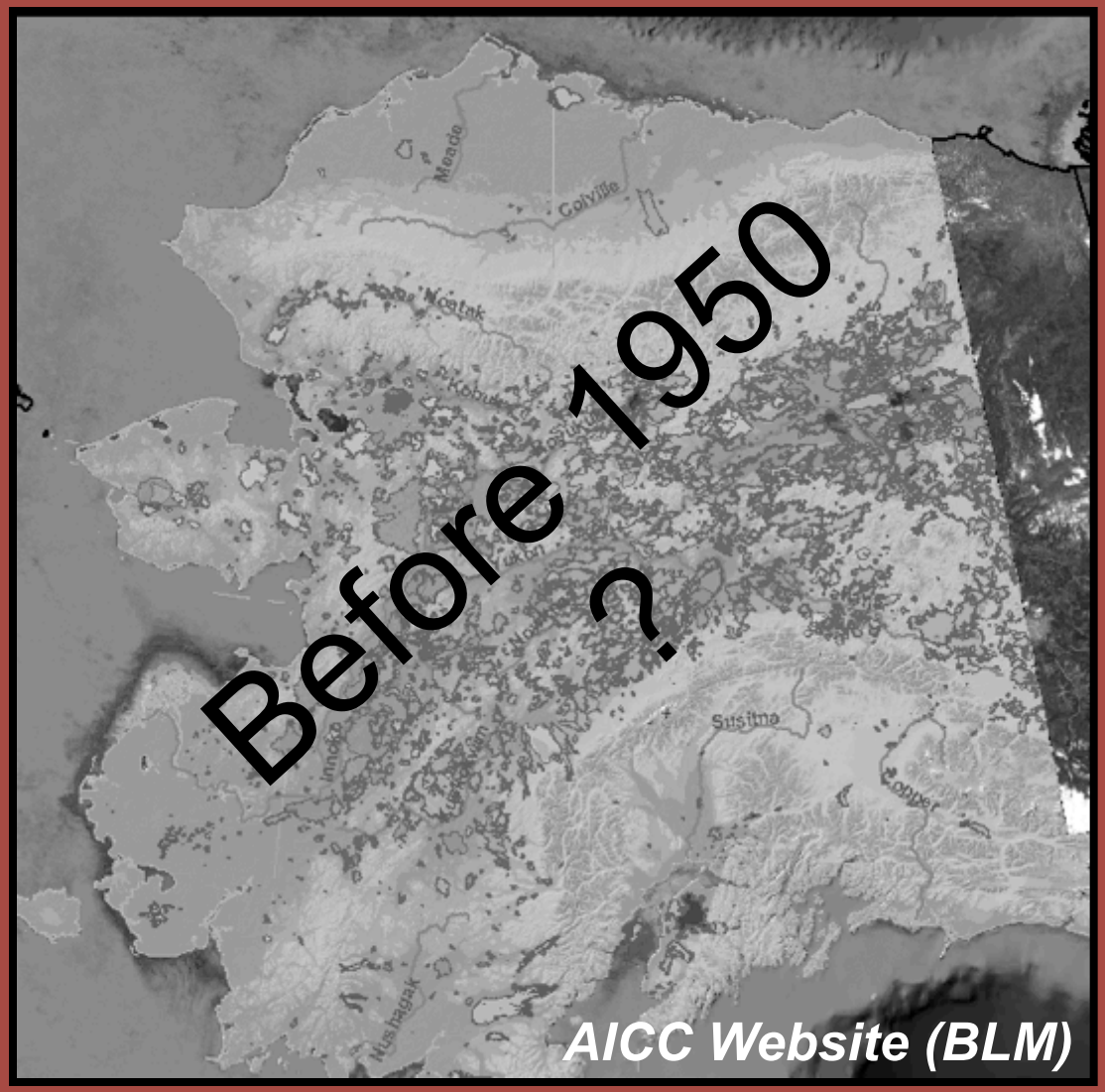
Perimeters of wildfires since 1950



AICC website (BLM)

Managing wildfire from a long-term perspective

1.) What is the pre-historic fire frequency?



Managing wildfire from a long-term perspective

2a.) How variable is the prehistoric fire frequency?

Managing wildfire from a long-term perspective

2a.) How variable is the prehistoric fire frequency?

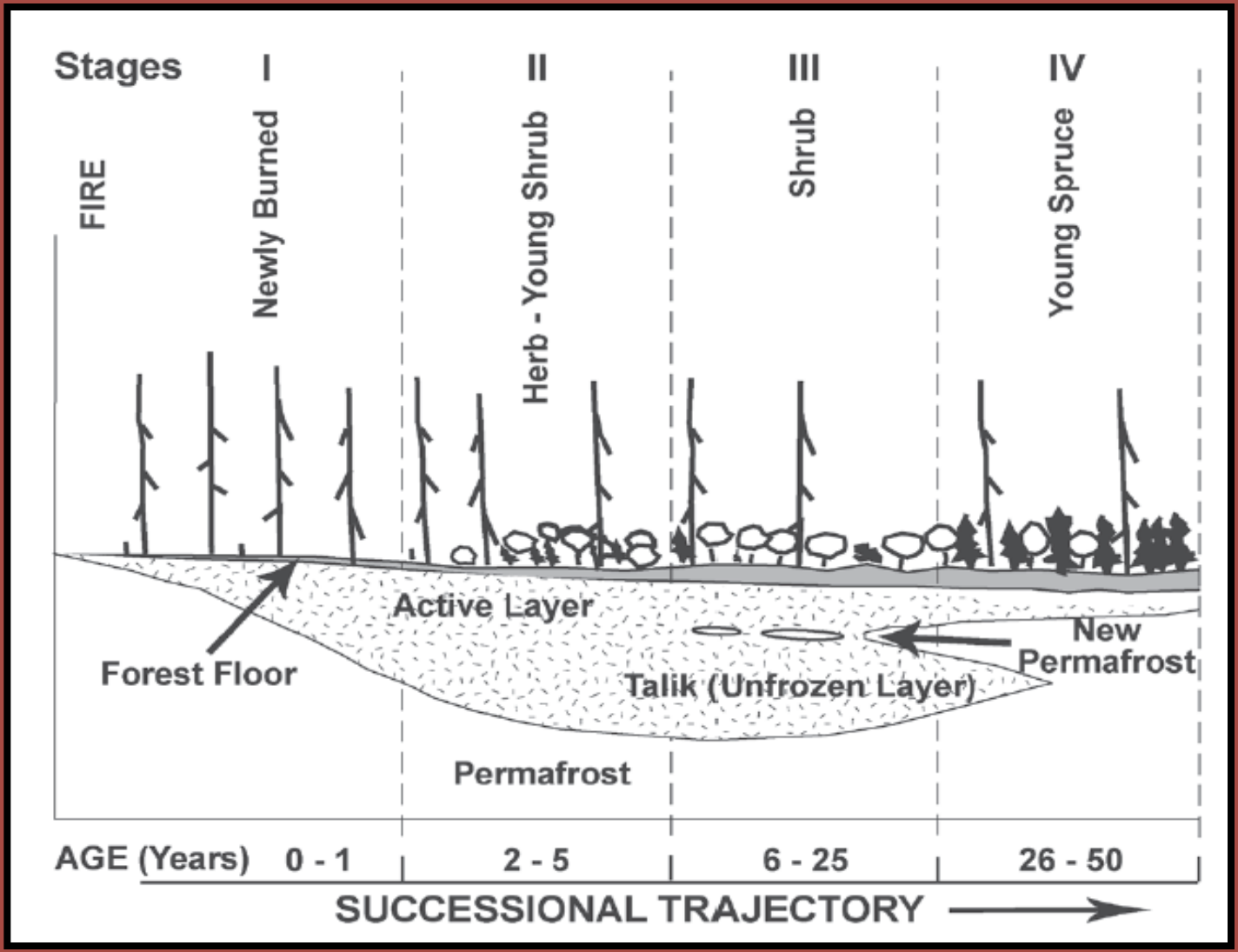
2b.) How did people affect FRI's around settled areas?

Managing wildfire from a long-term perspective

3.) What are the long-term effects of fire on permafrost and aquatic ecosystems?

Drunken Trees on Lake Shoreline

Post-fire permafrost thaw and regeneration

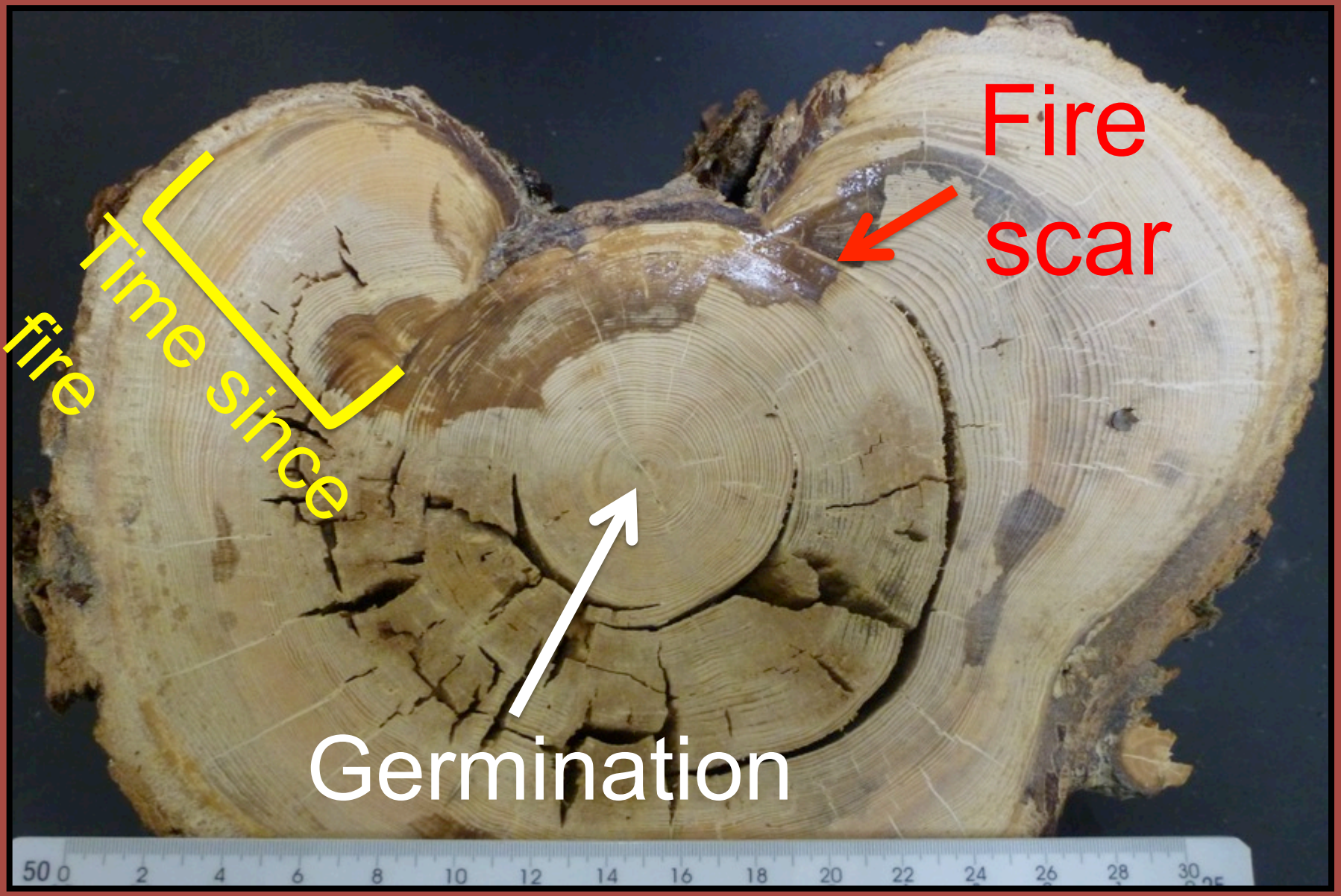


Viereck et al., 2008 Permafrost Conf. Proceedings

Approach:

1) Fire-scarred spruce trees in the watershed: Timing of fires in the last ~200 years

Approach: Fire scars

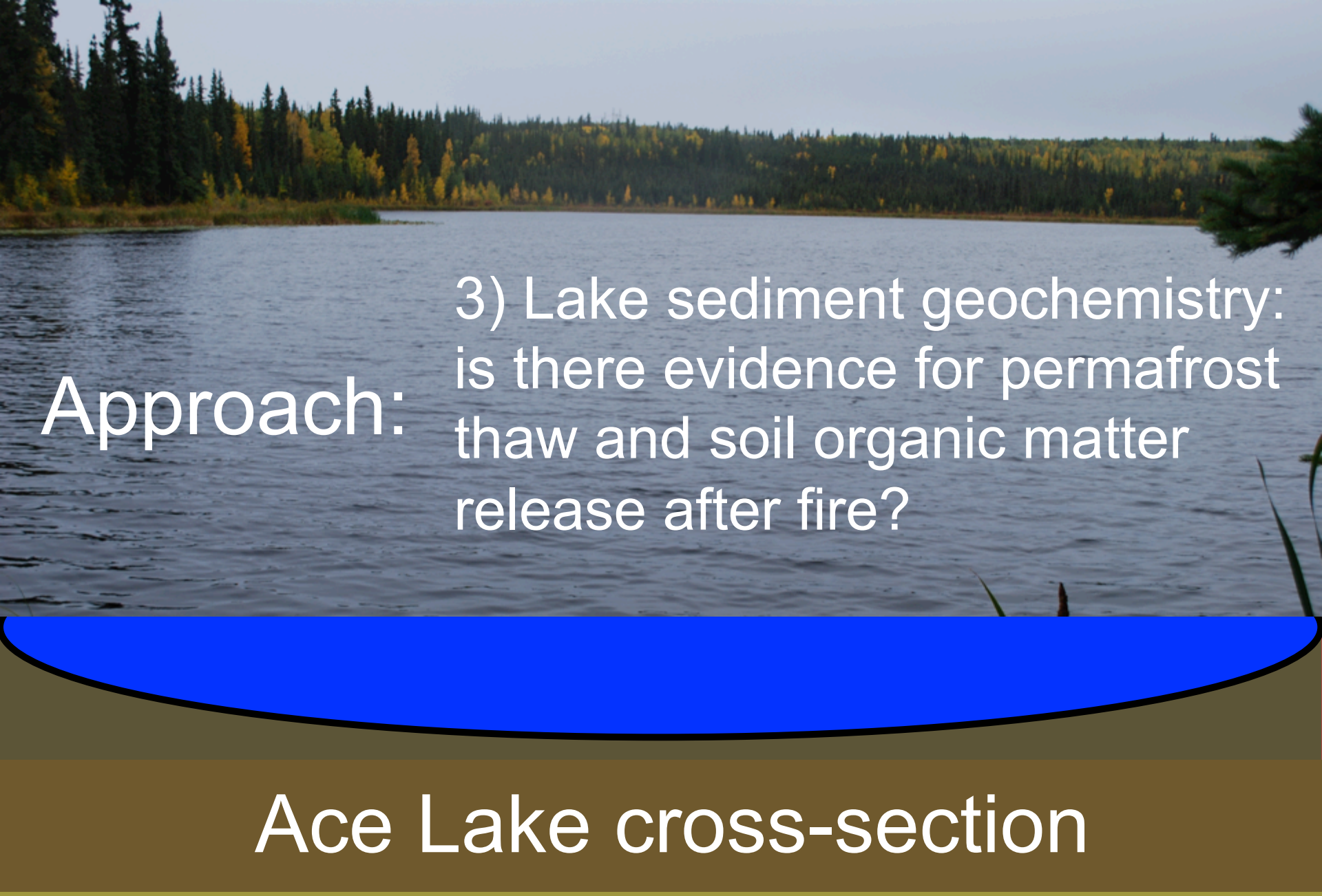


Approach:

2) Charcoal record in lake sediment: timing of fires in the last ~600 years.

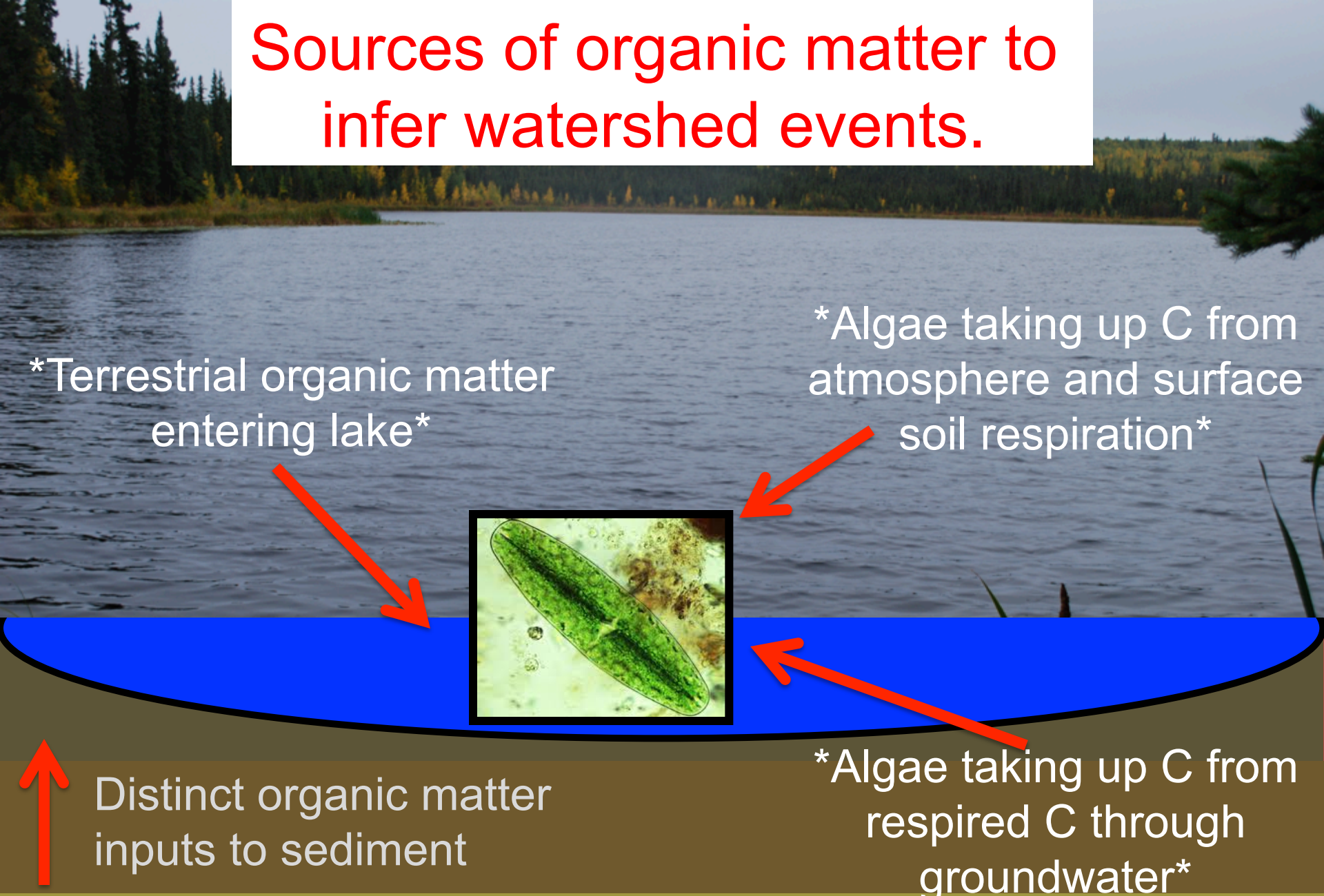
Approach:

3) Lake sediment geochemistry: is there evidence for permafrost thaw and soil organic matter release after fire?



Ace Lake cross-section

Sources of organic matter to infer watershed events.



Pre/post-fire hypotheses

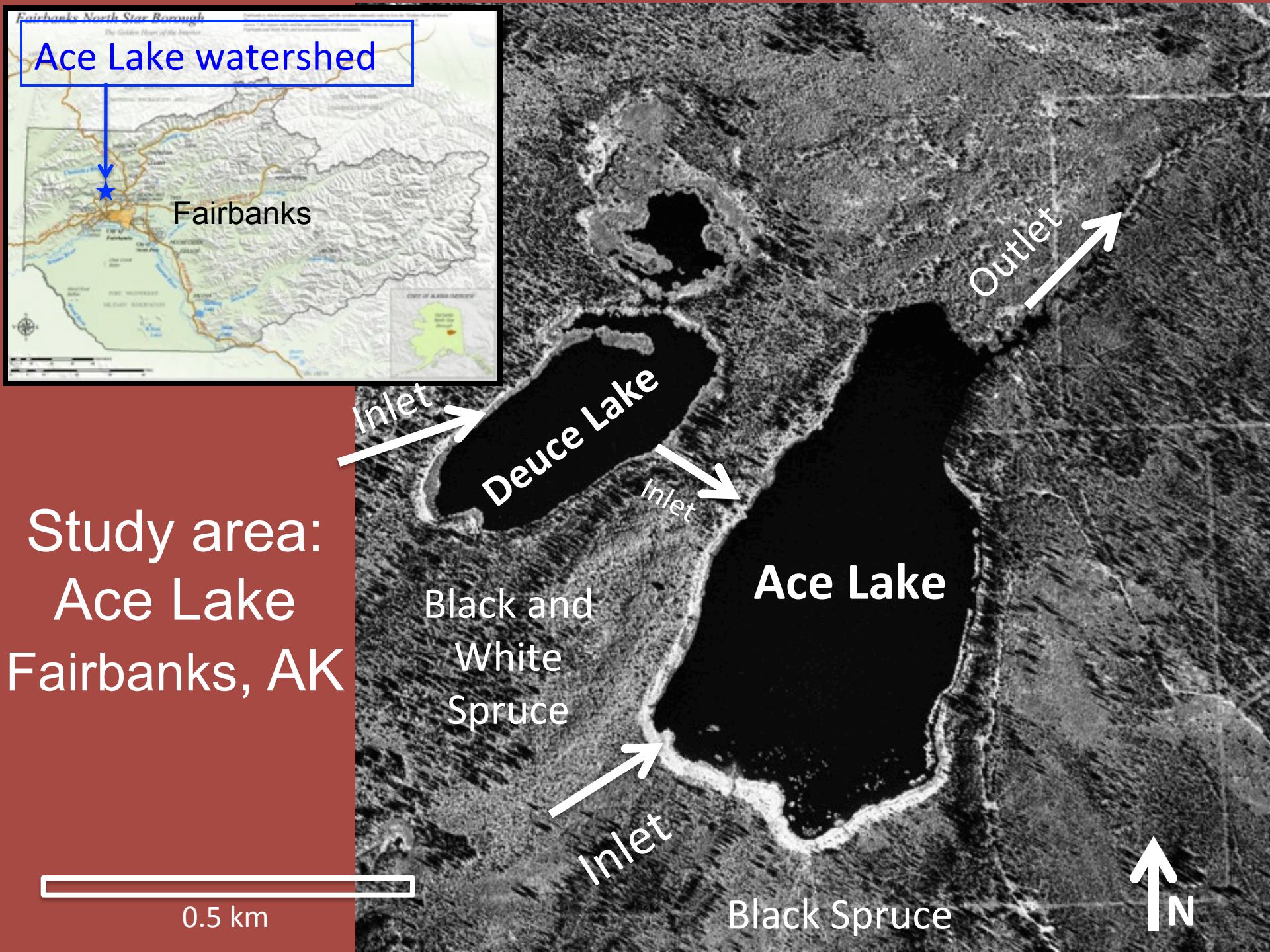
Period with stable permafrost in watershed

Low terrestrial org. inputs and young C sources for algae.

Period with permafrost thaw in watershed

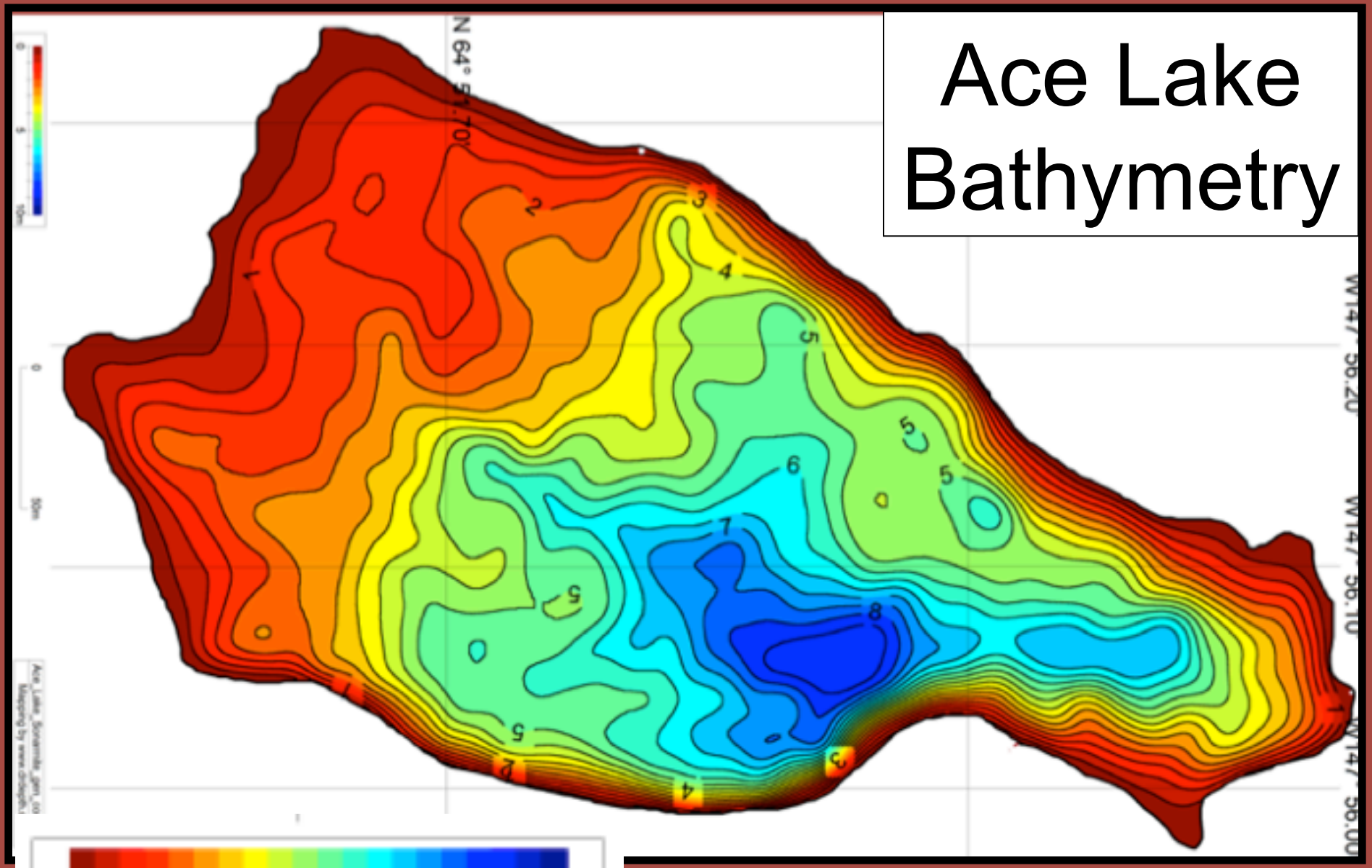
Enhanced terrestrial org. and old, recycled C sources for algae.

Proportion of reworked permafrost C sources…

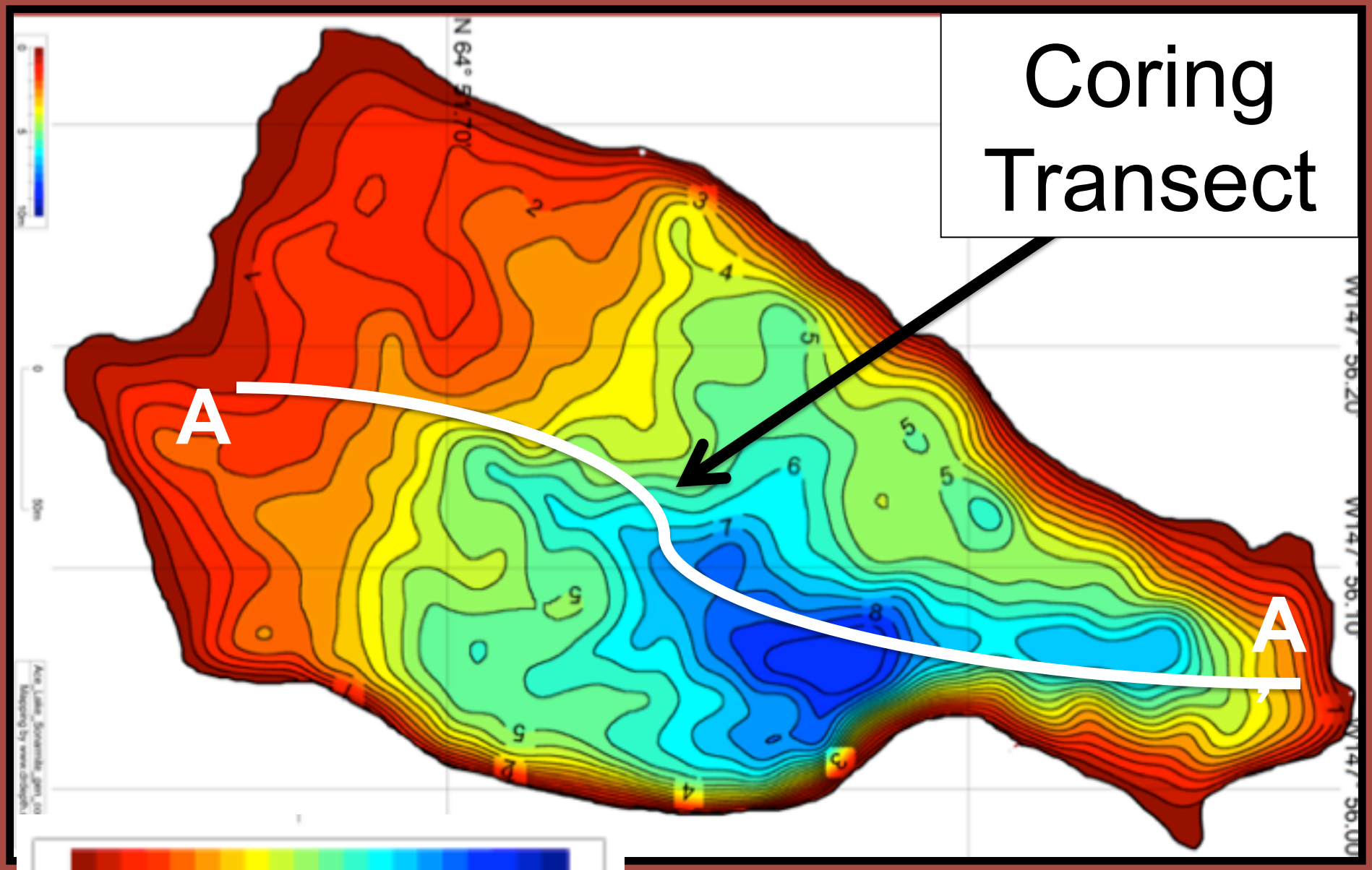


Study area:
Ace Lake
Fairbanks, AK

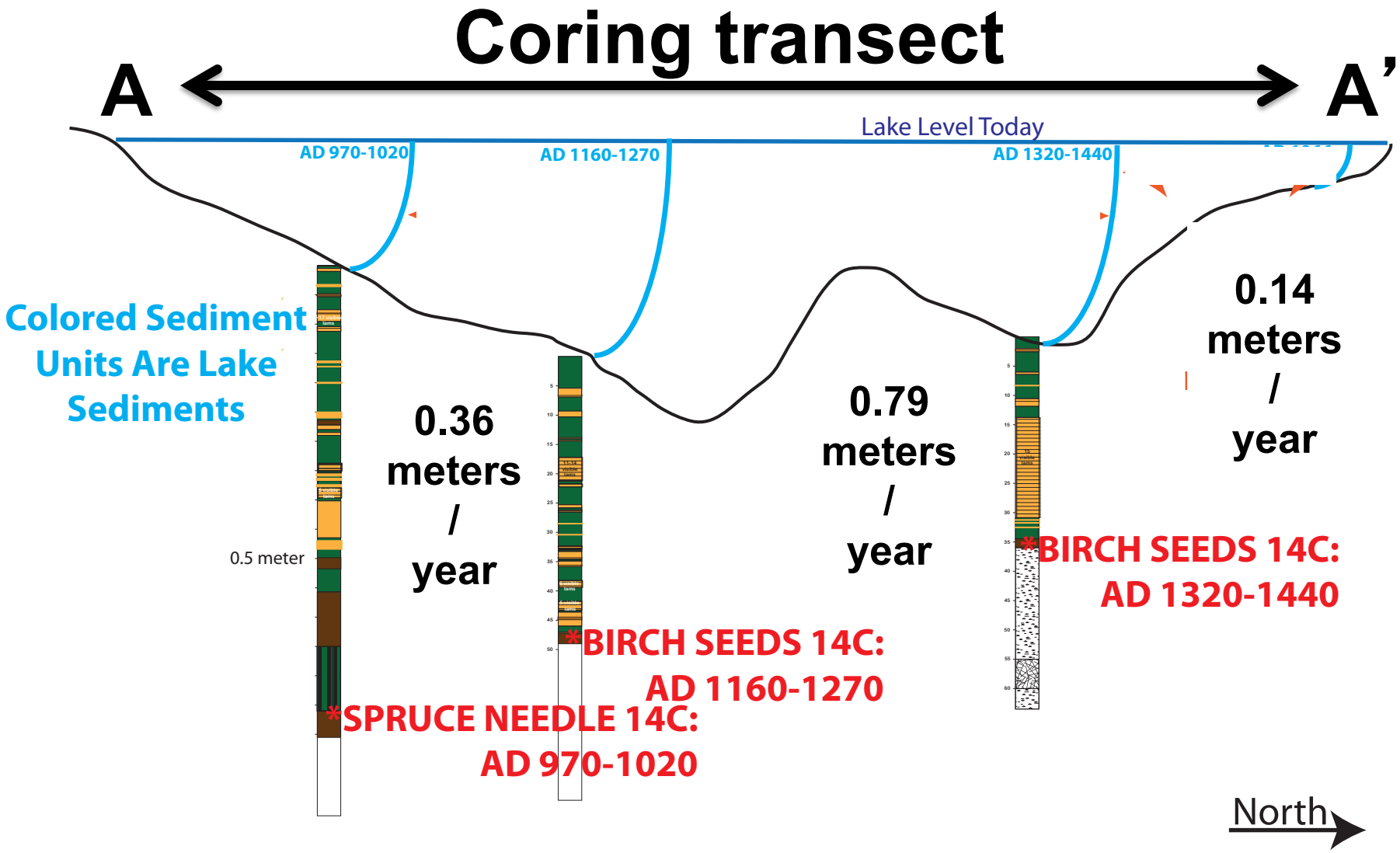
Ace Lake Bathymetry



N →


Coring Transect
A
A'
0
5
10m
N

Expansion rates of Ace Lake: 1000 years of migrating North…



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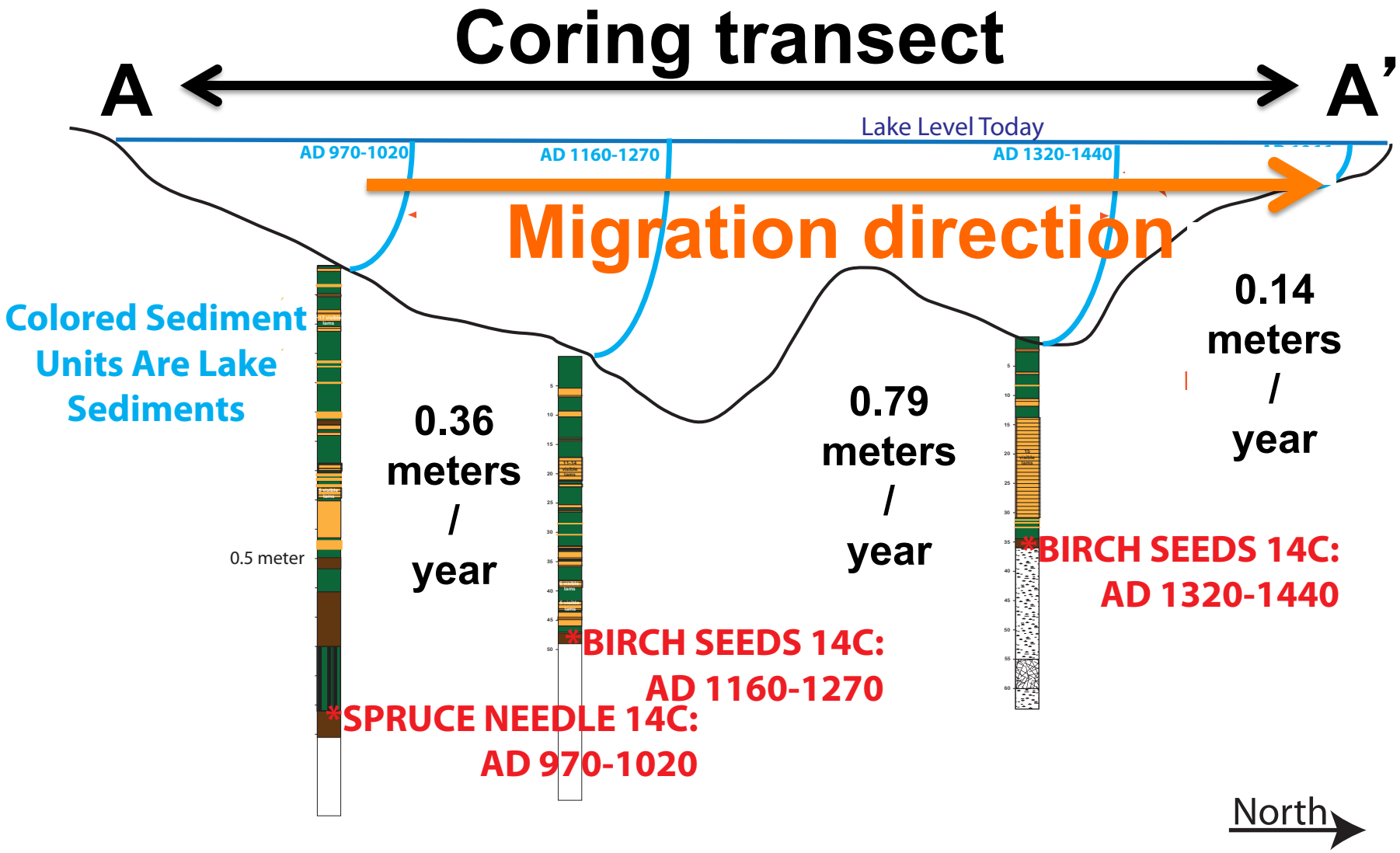


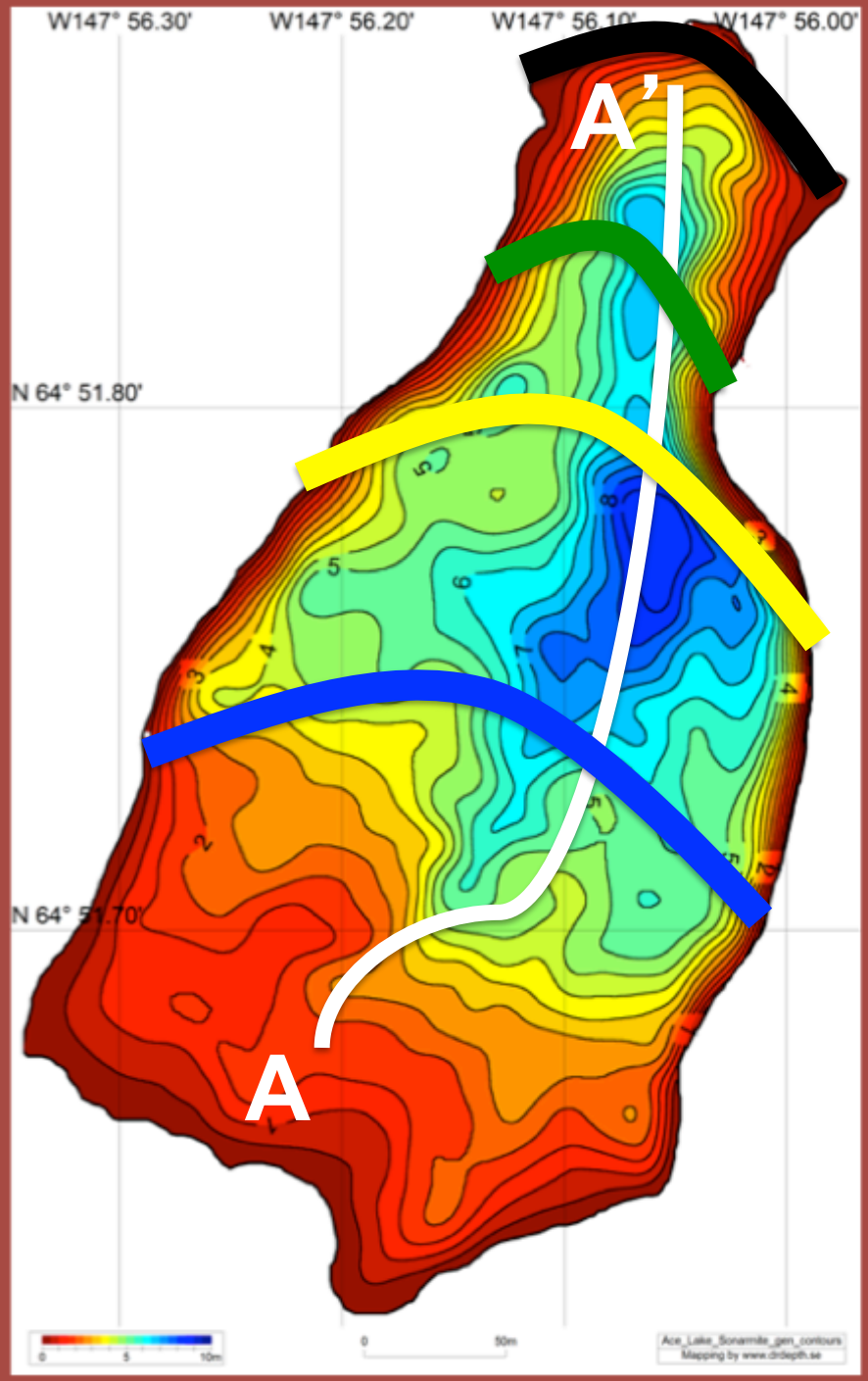
Lake extent over time

~AD 970

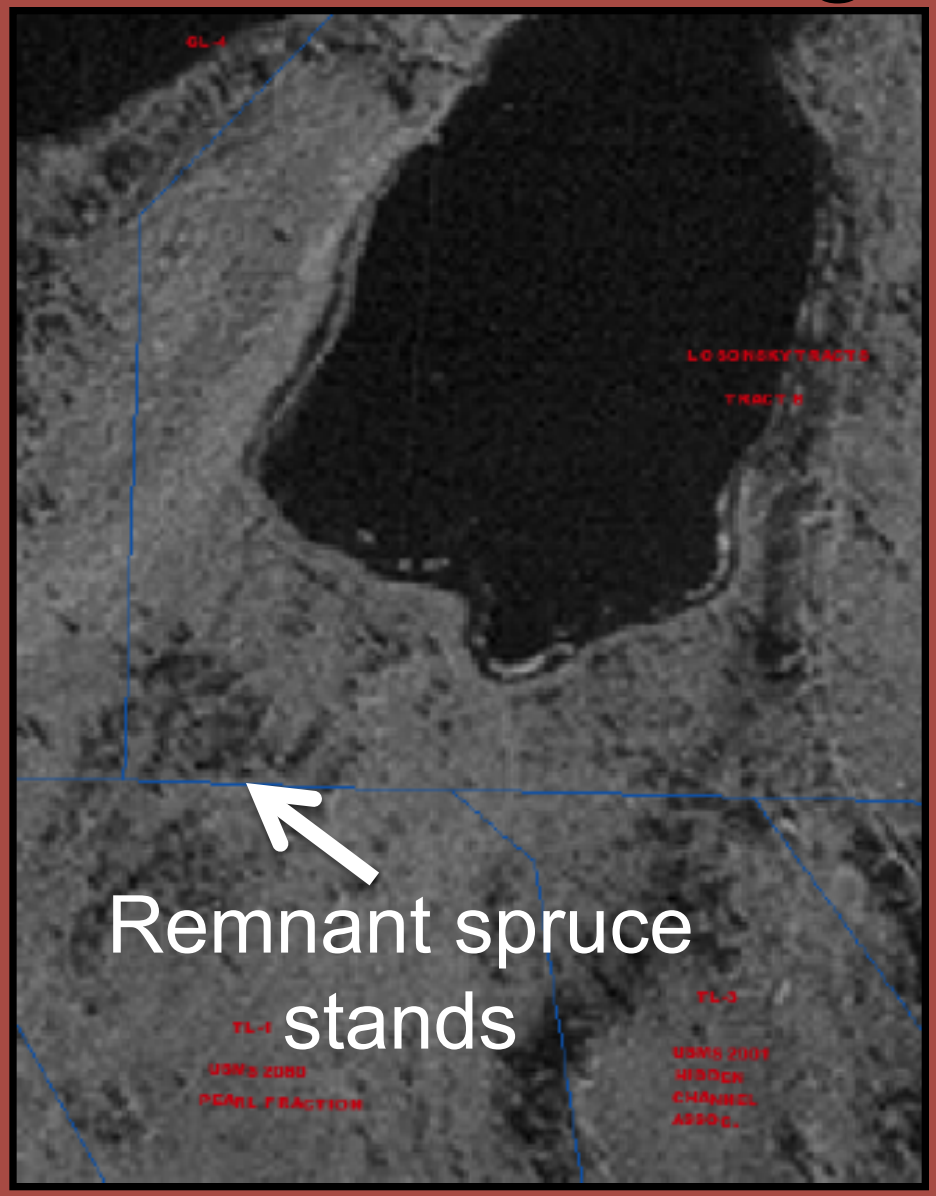
~AD 1160

~AD 1320

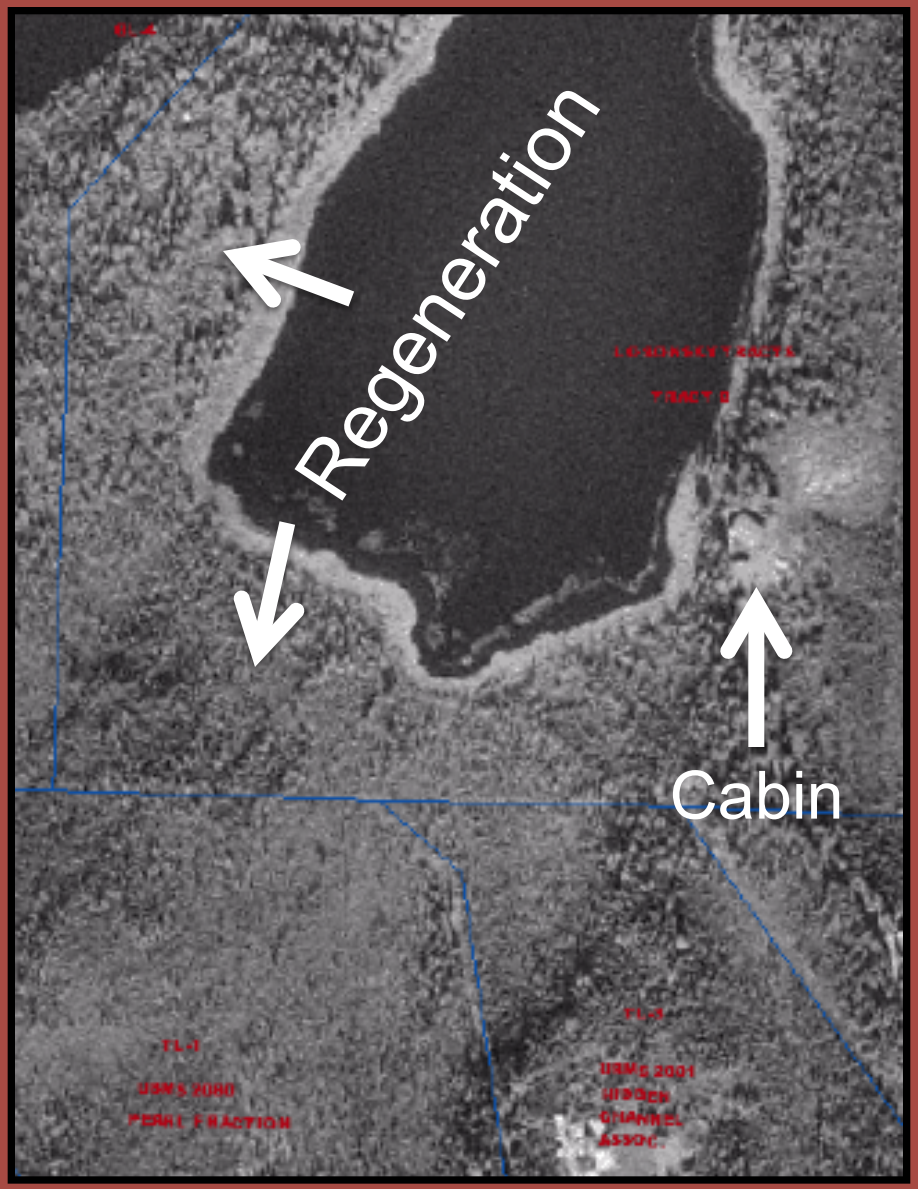
Today



Forest change: last 60 years



1949 aerial photo



1999 aerial photo

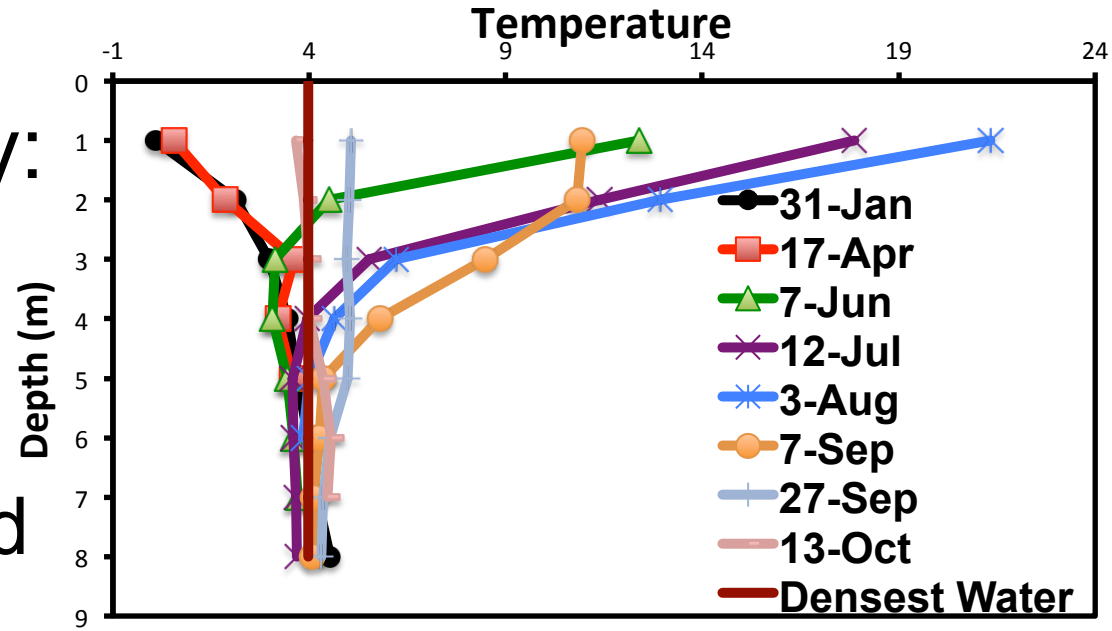
Ace Lake Limnology:

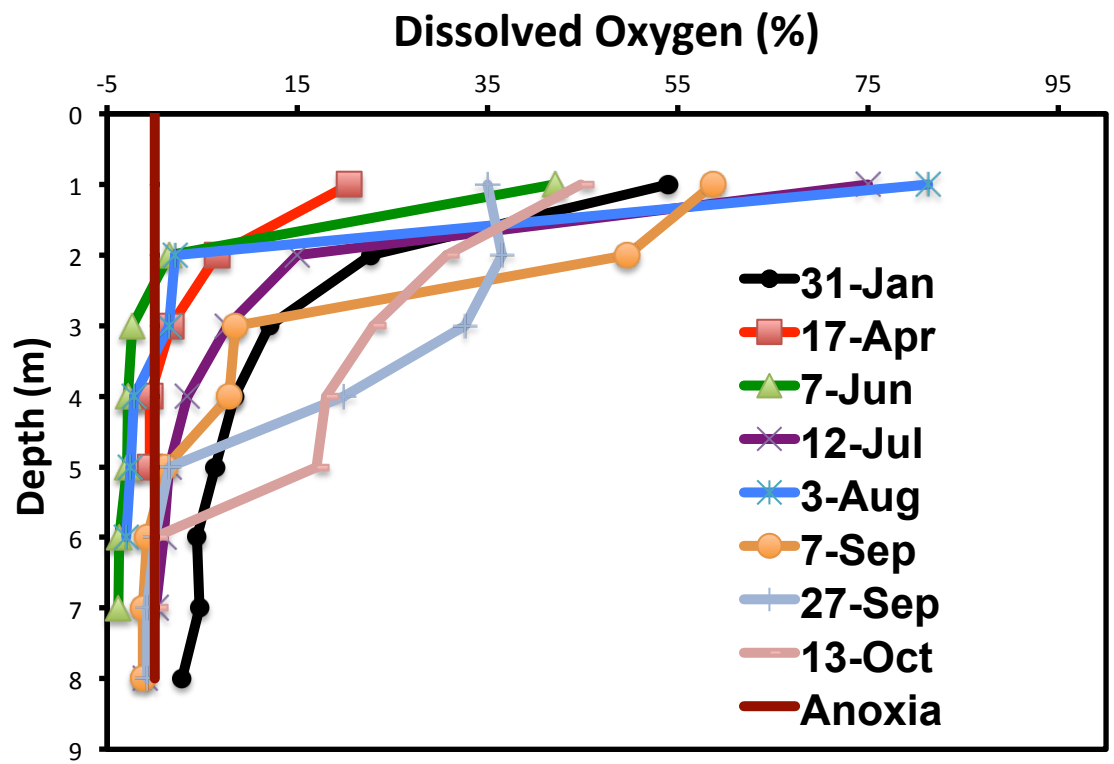
-Groundwater fed

-Consistently stratified

-Excludes oxygen in bottom-waters

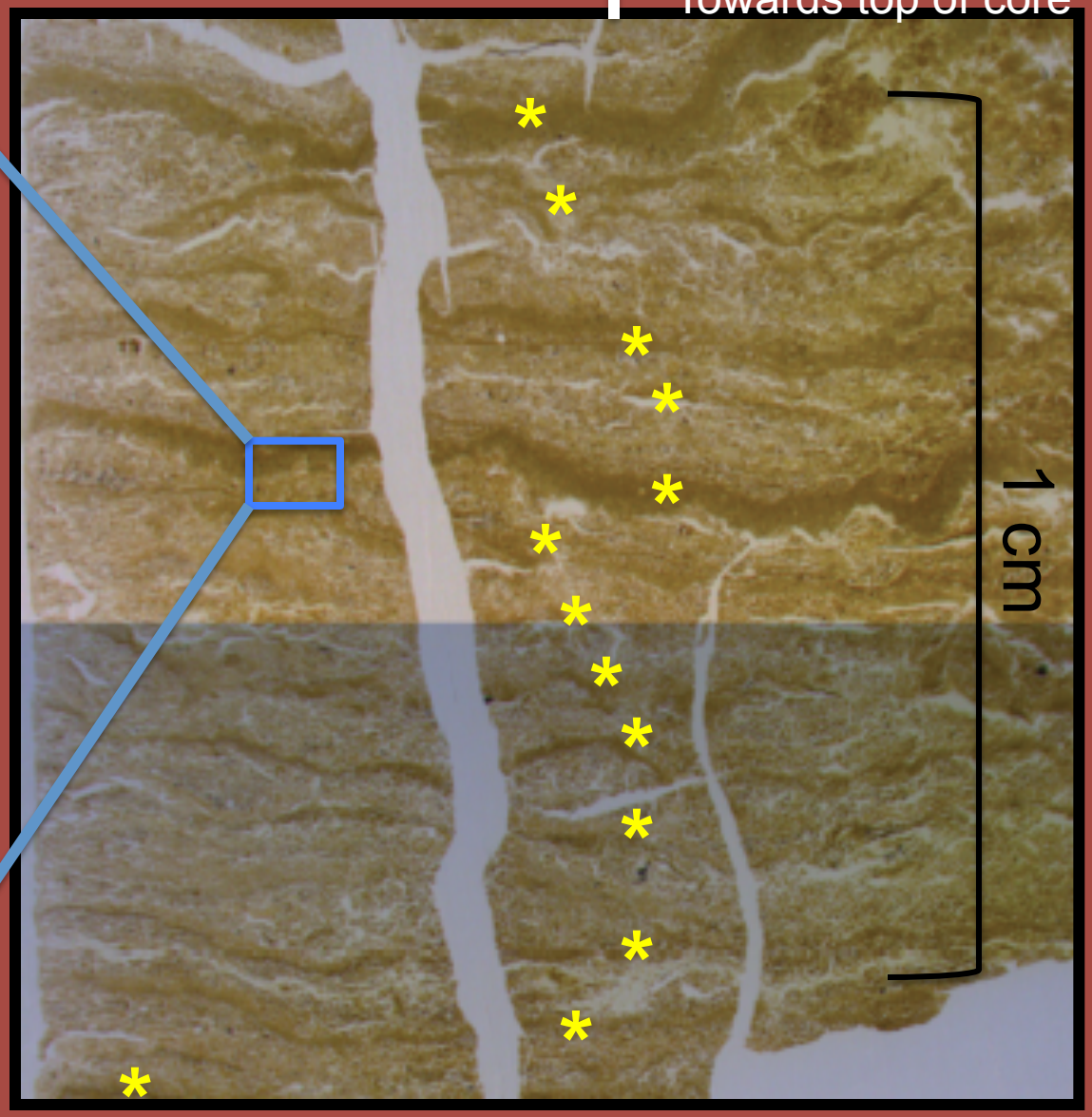
-Anoxia preserves sediment layering





The Anatomy of a biogenic varved lake core

Time	Algae/ Sediment	Layer
Aug.	Chryso-phyta	Light organics
July	Cyano	Stringy organics
June		
May	Chryso-phyta Coarse silt	Light org., coarse silt
Winter	Finer silt: settling	Fine silt



*= Annual Layers

Radiocarbon ages to validate layer-count timeline for charcoal record

Top of core

Estimated ages

AD 1963 ^{137}Cs Spike

AD 1900 ^{210}Pb Age

AD 1650-1870*

AD 1520-1800*

AD 1440-1630

AD 1300-1410

AD 1270-1380

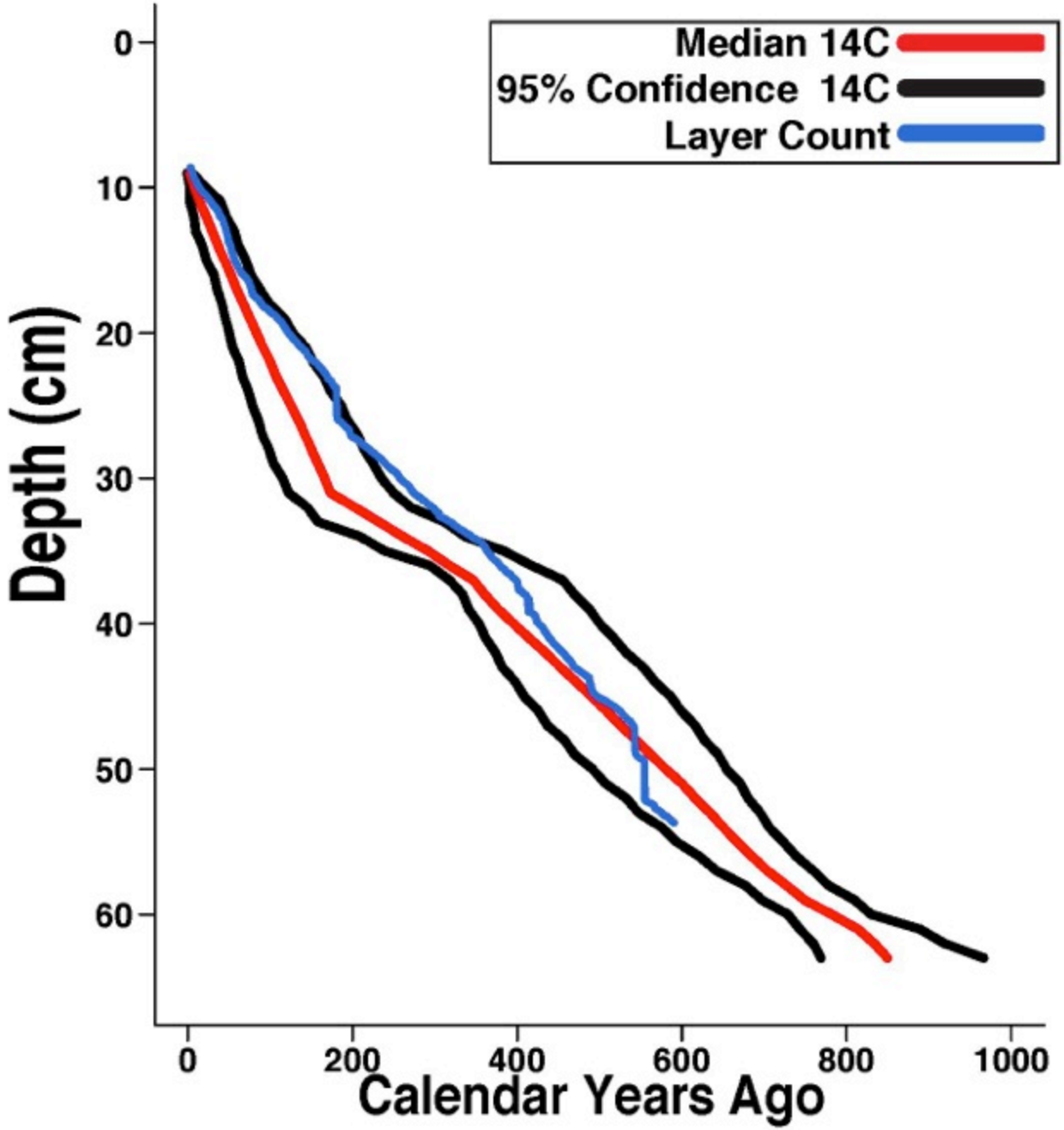
AD 1160-1270

AD 1025-1170

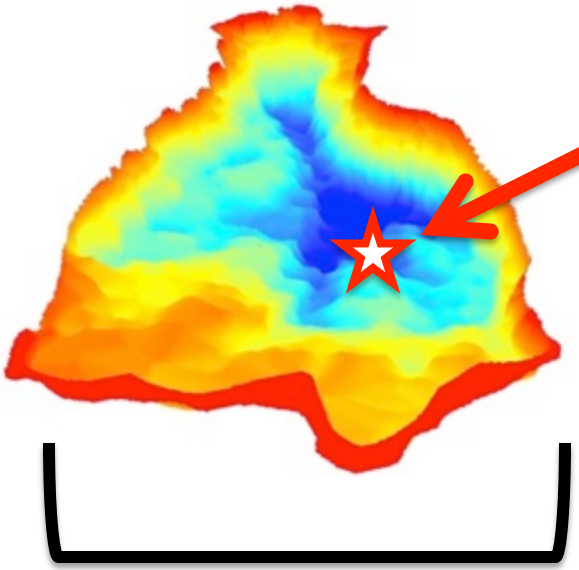
AD 1025-1165

*Had Calendar Peaks up to 1950 that were excluded because of Lead 210 and Cesium dates

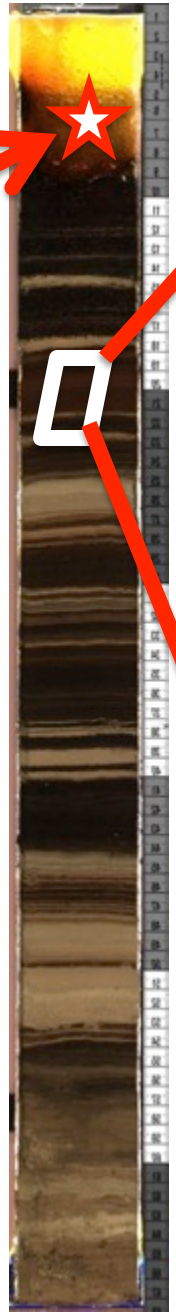
Independent timelines of charcoal record

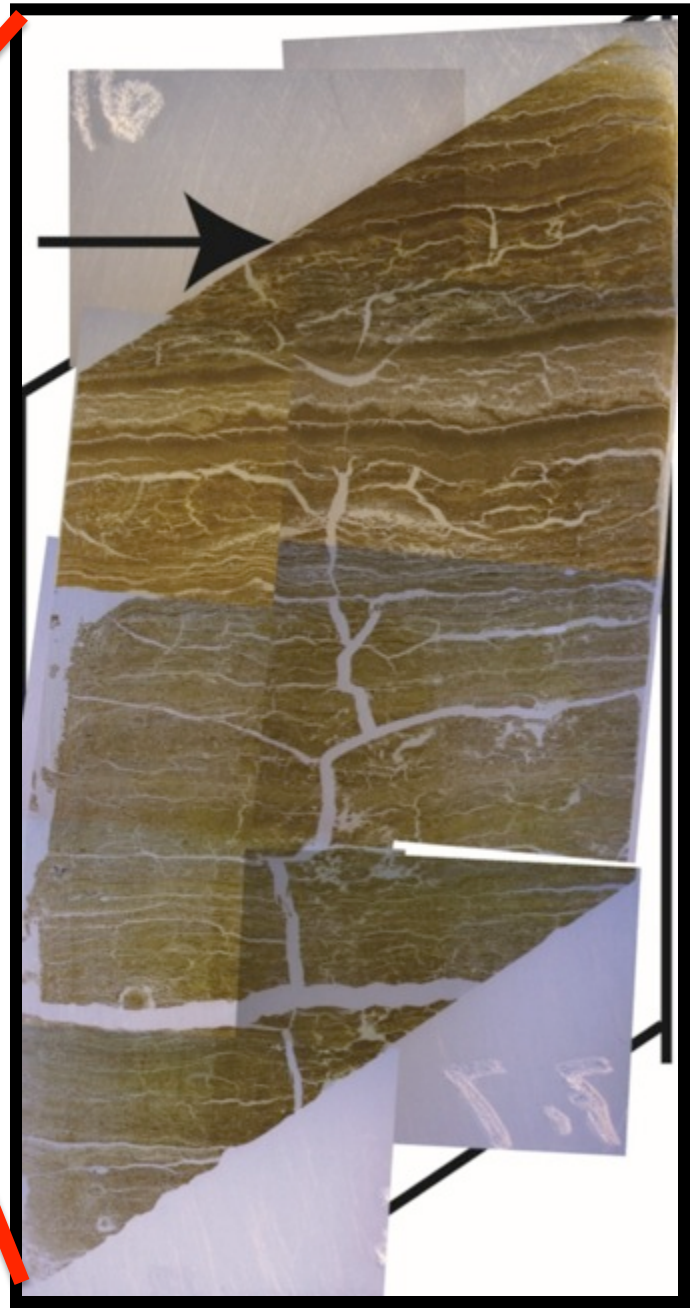


Petrographic Thin Sections



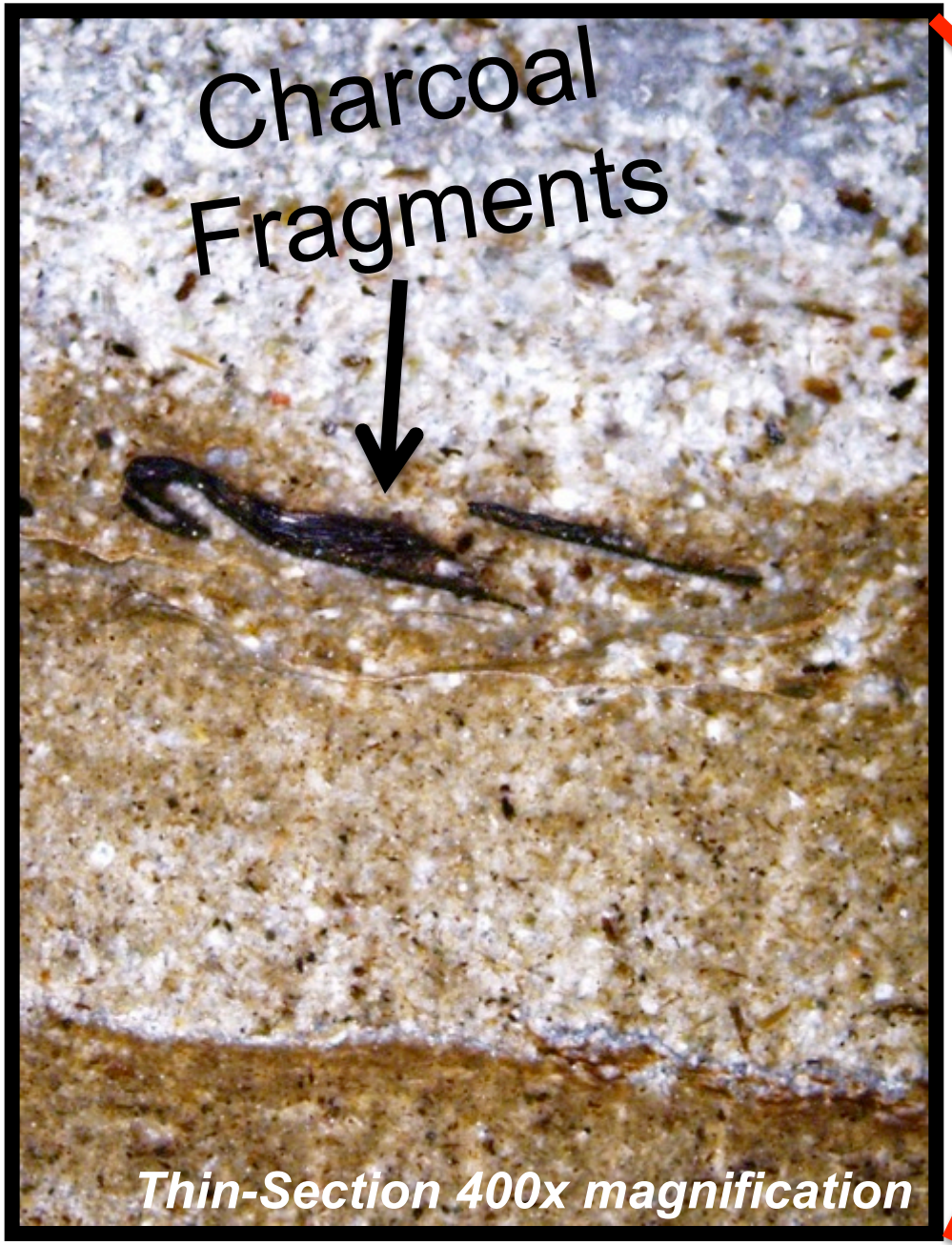
Ace Lake:
main
coring
location

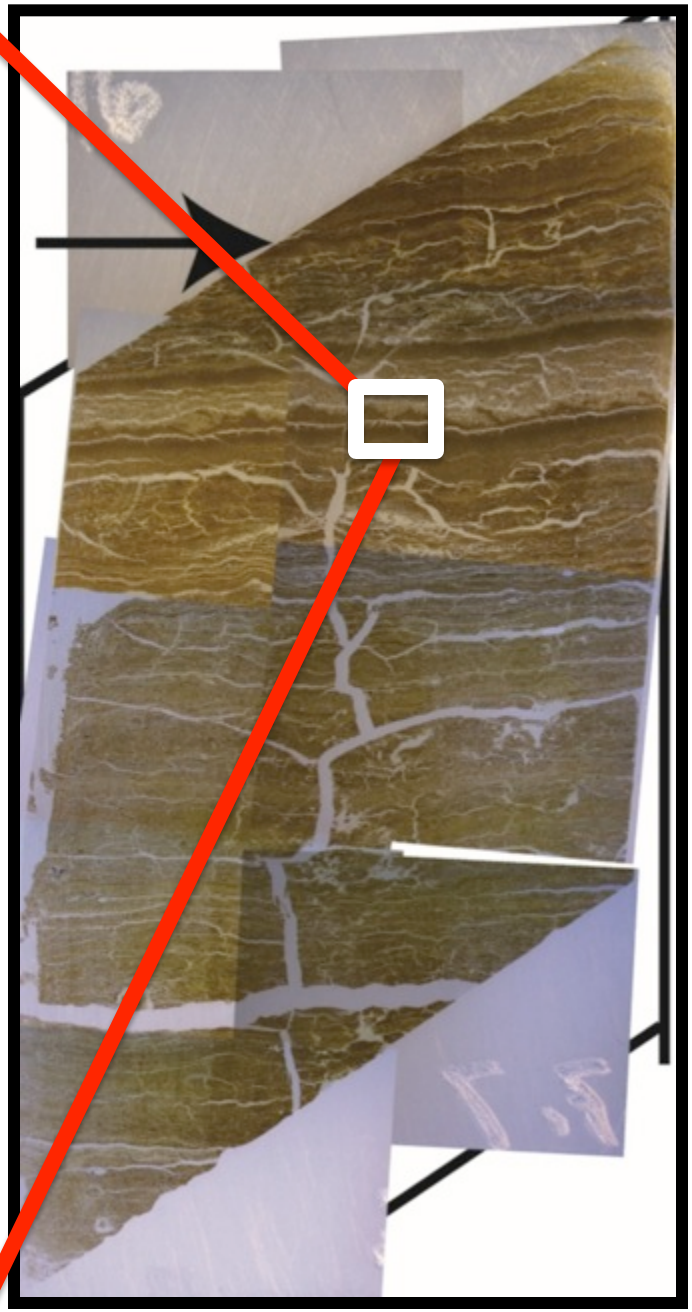




1 cm

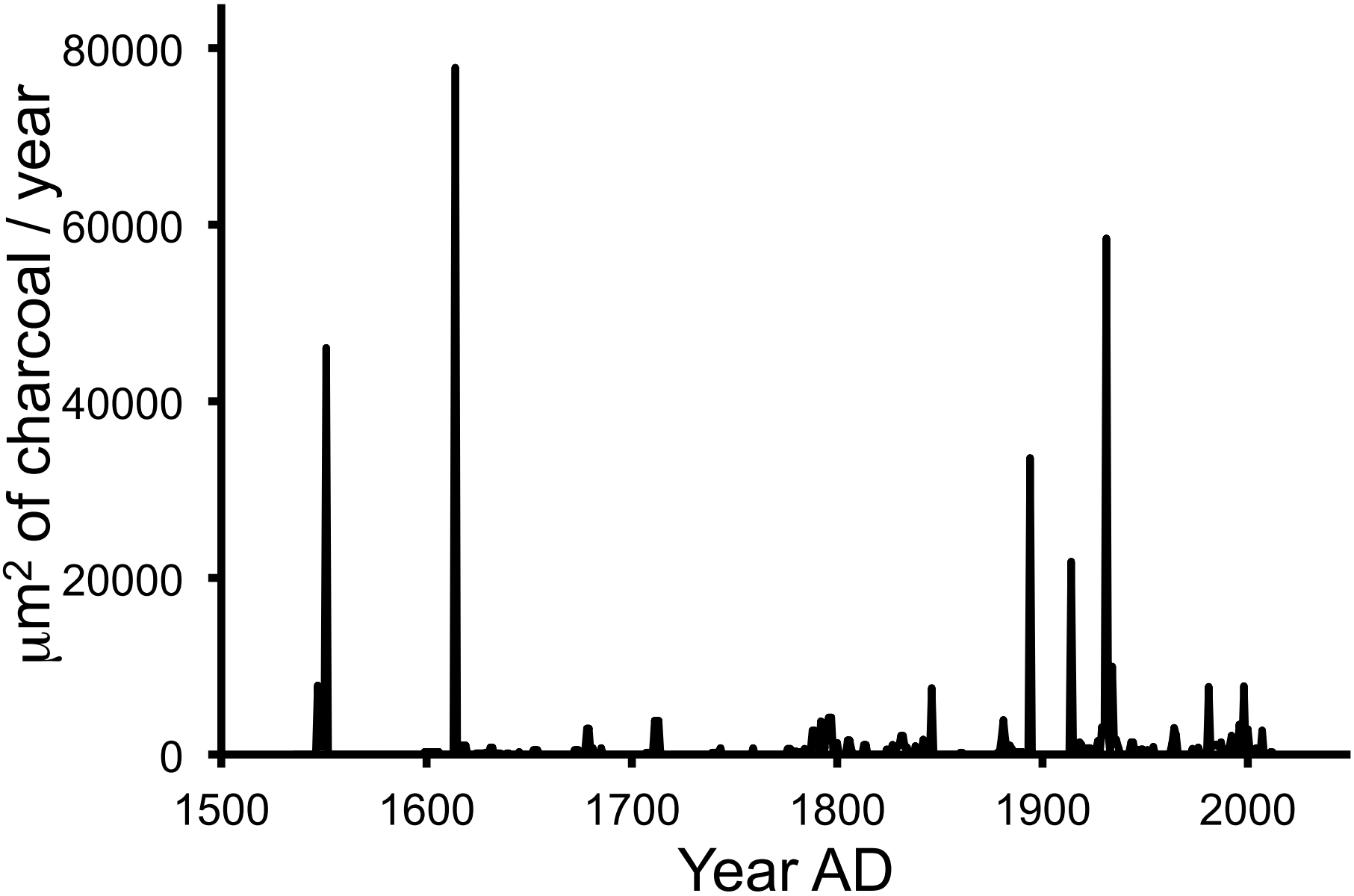
Petrographic Thin Sections



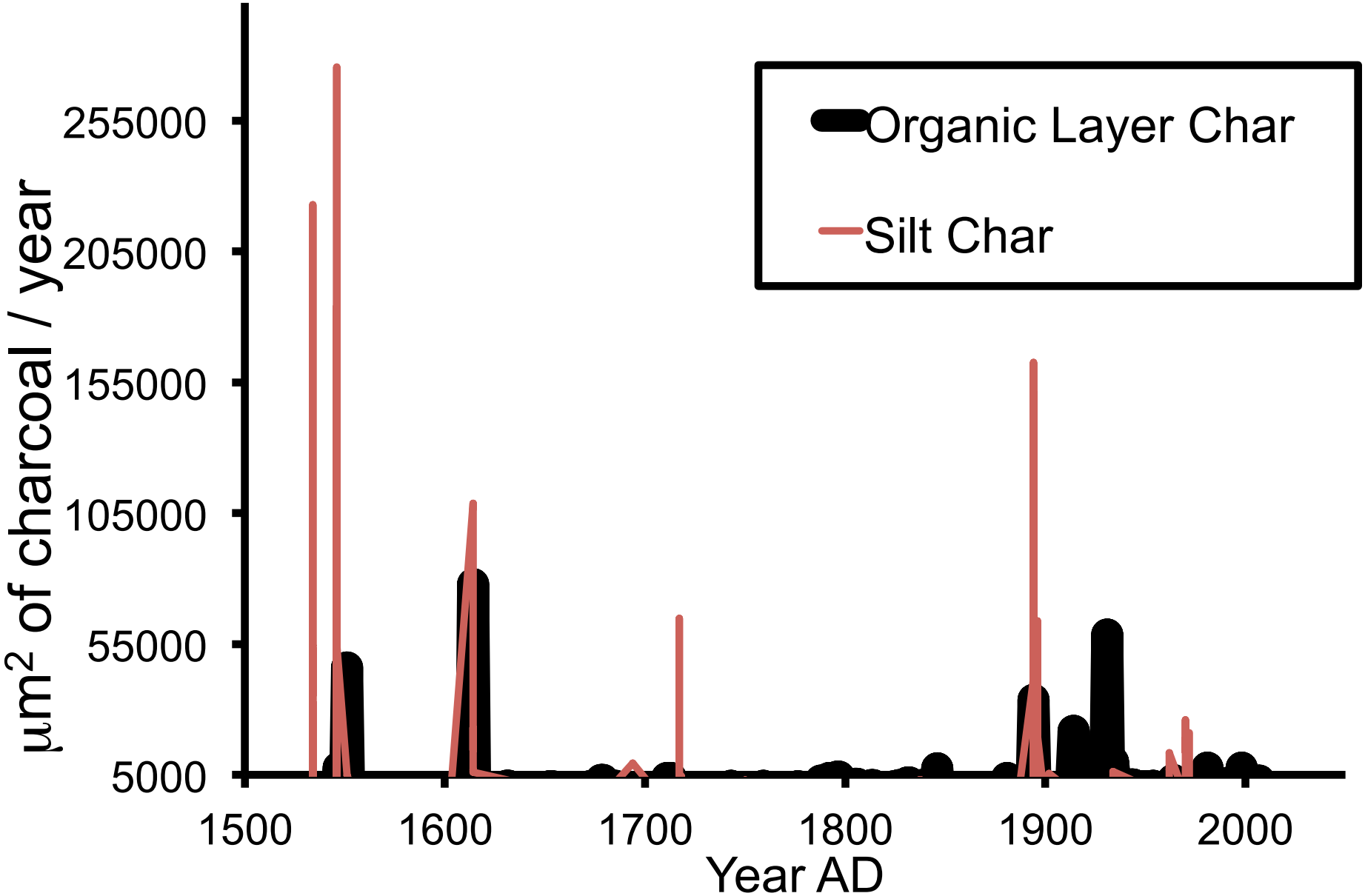


1 cm

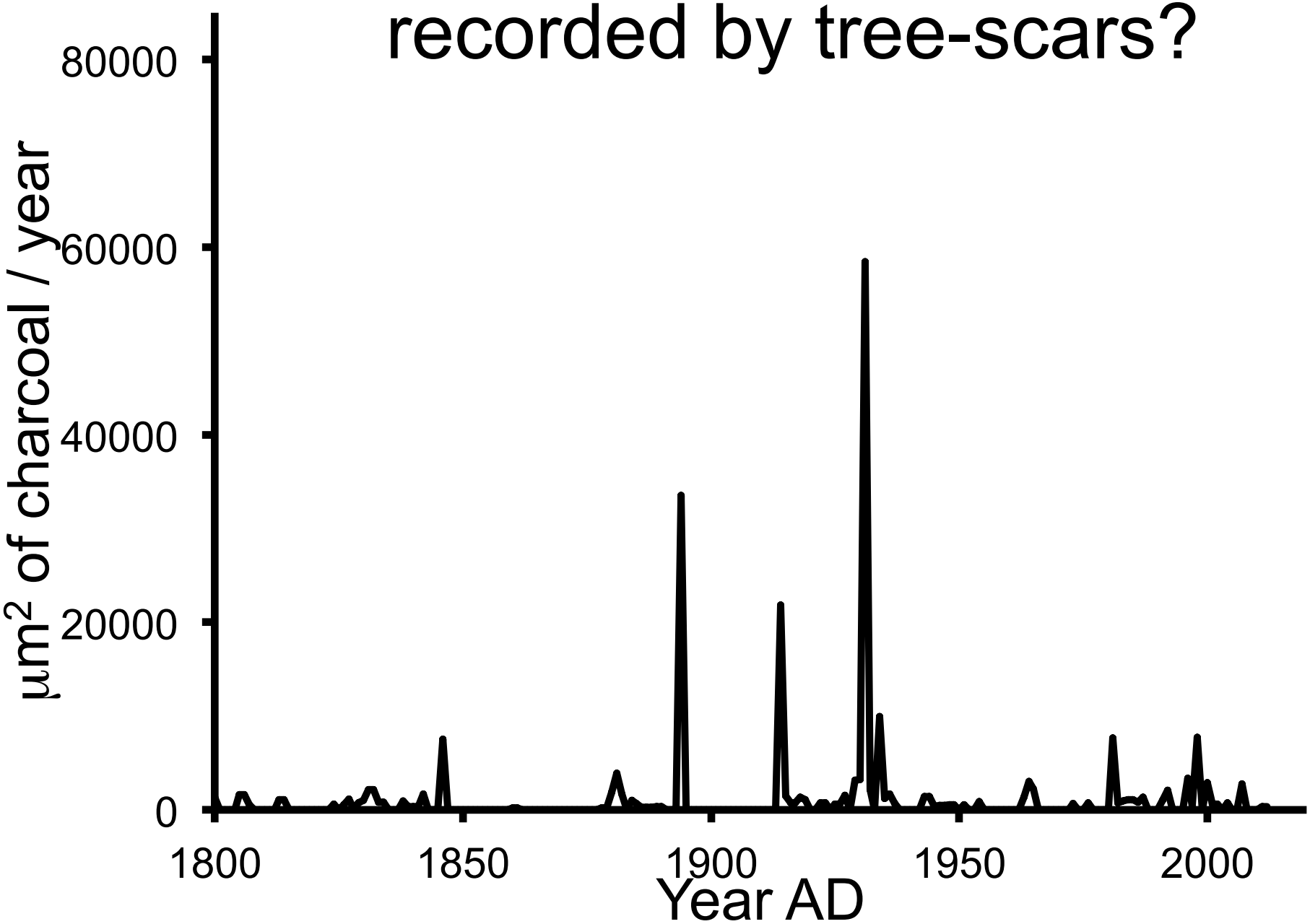
Charcoal in organic layers



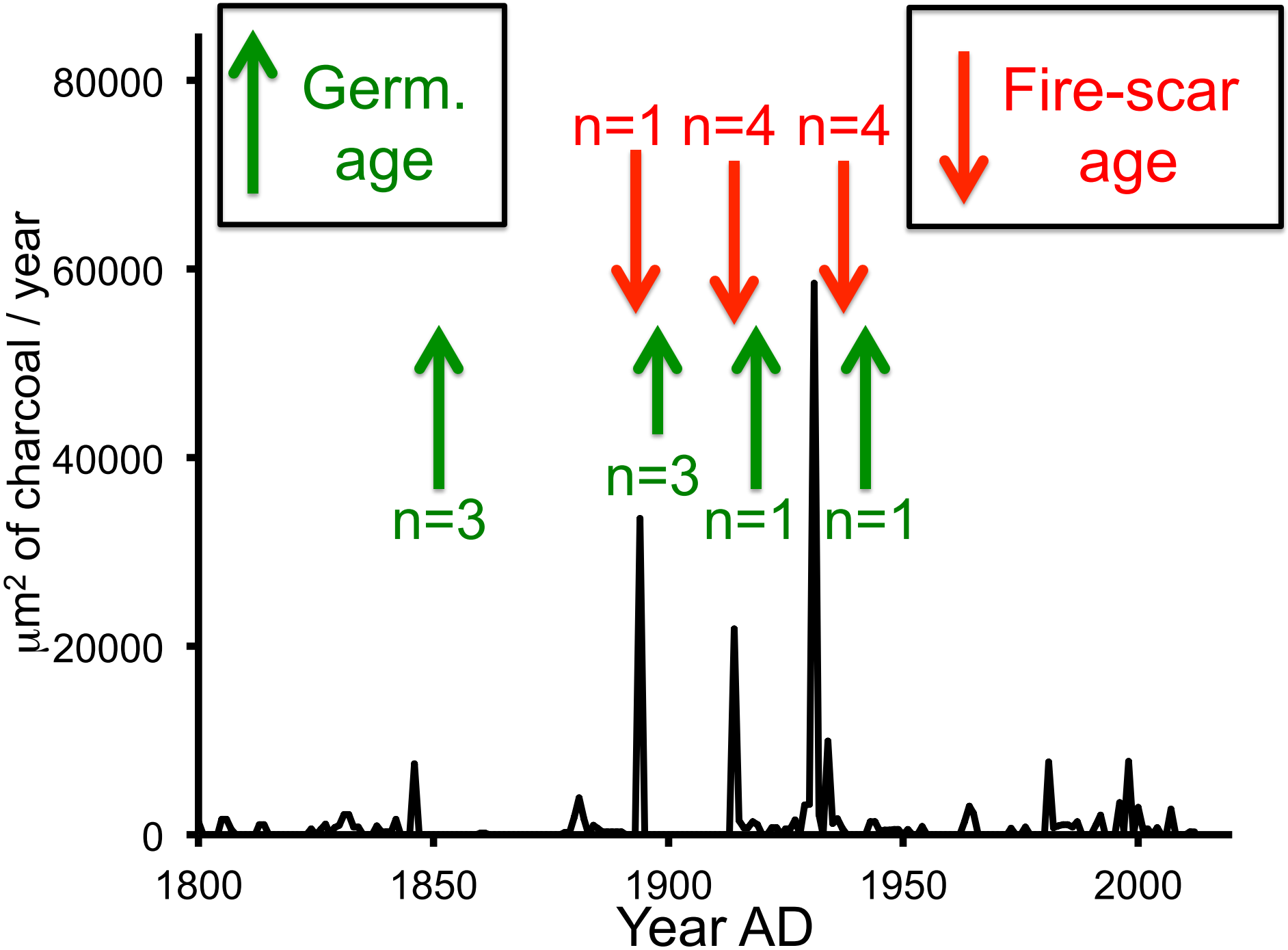
Total charcoal

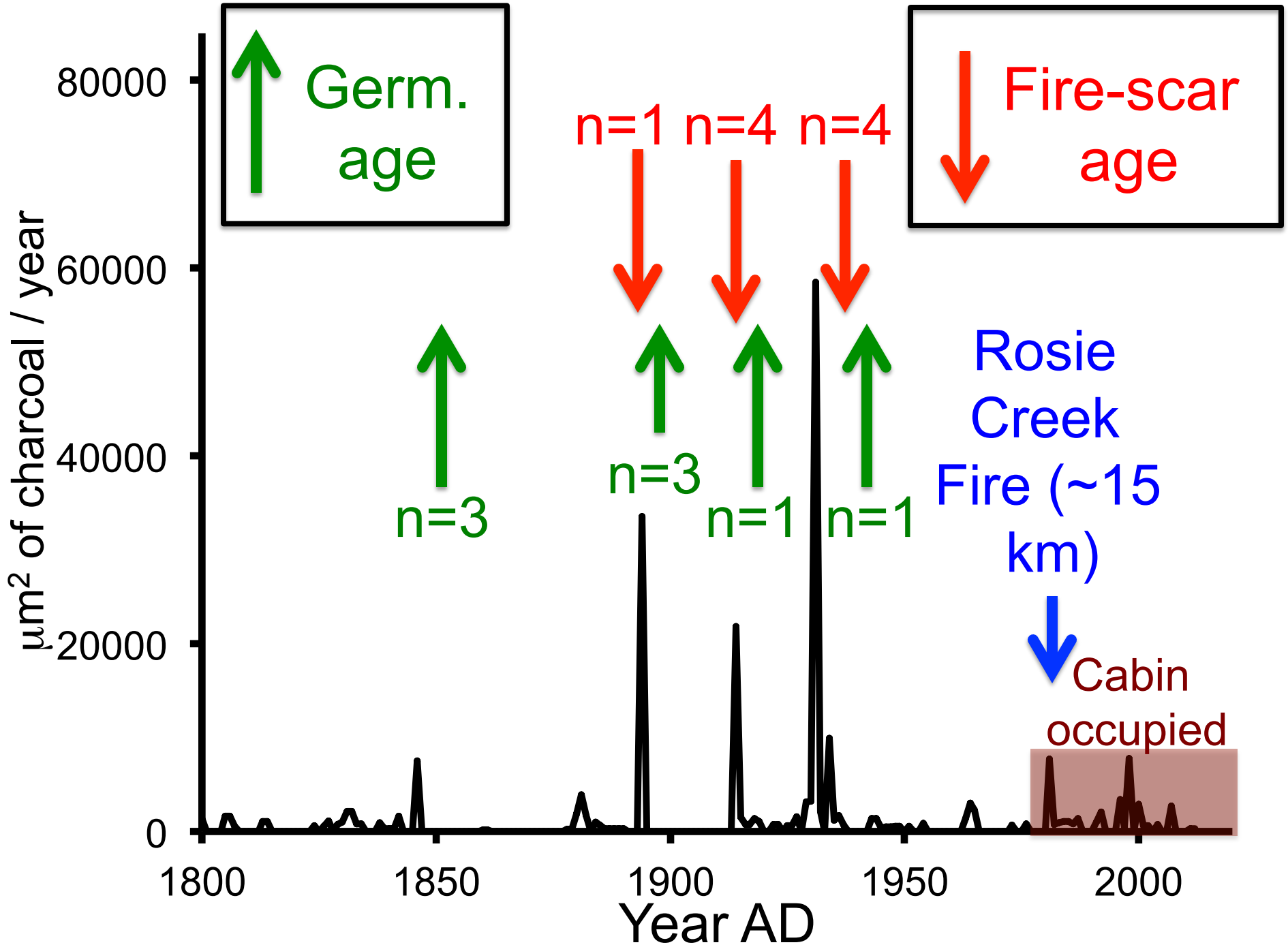


Which charcoal spikes are fires recorded by tree-scars?

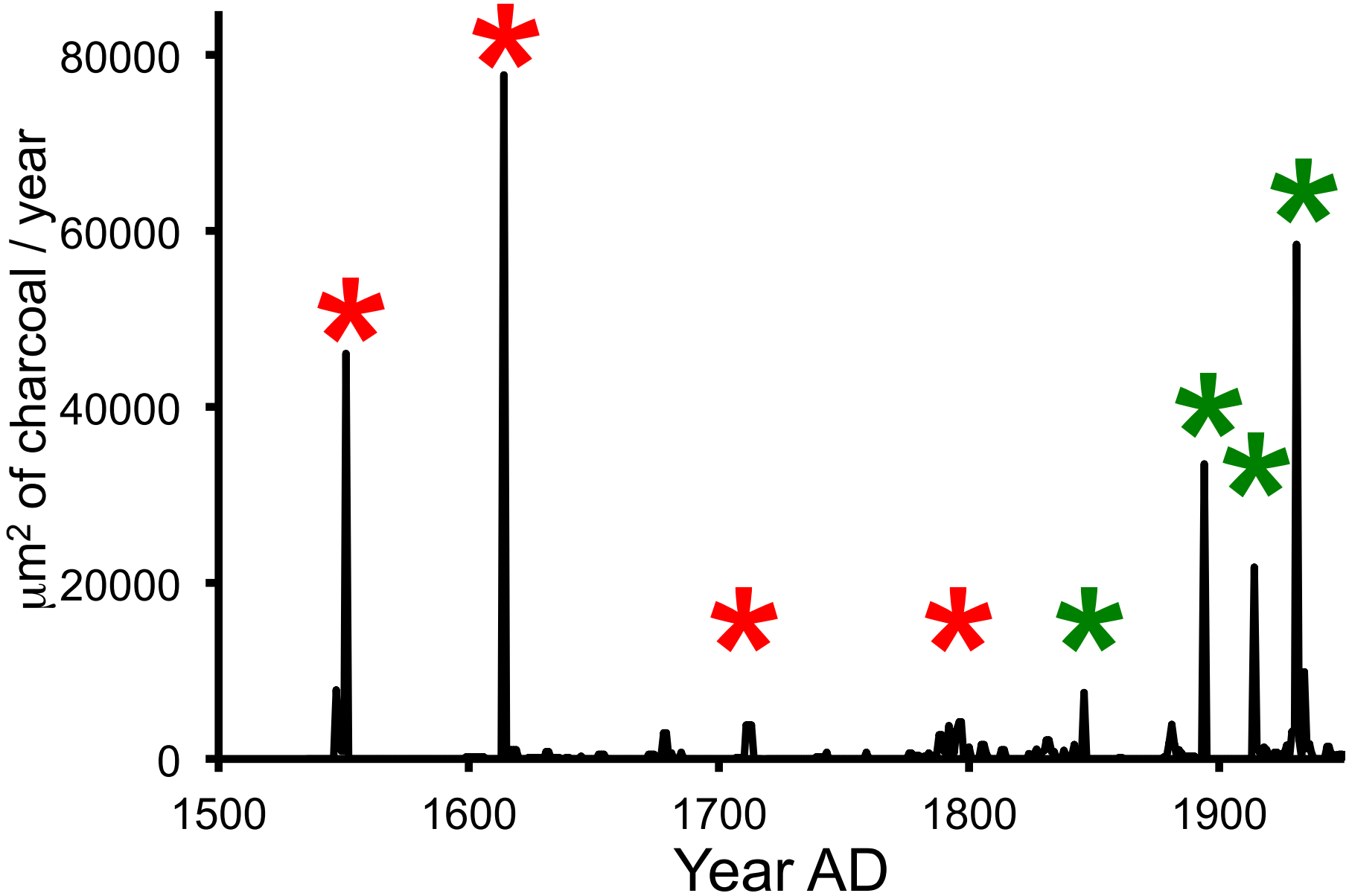


Germination and fire-scar ages around Ace Lake

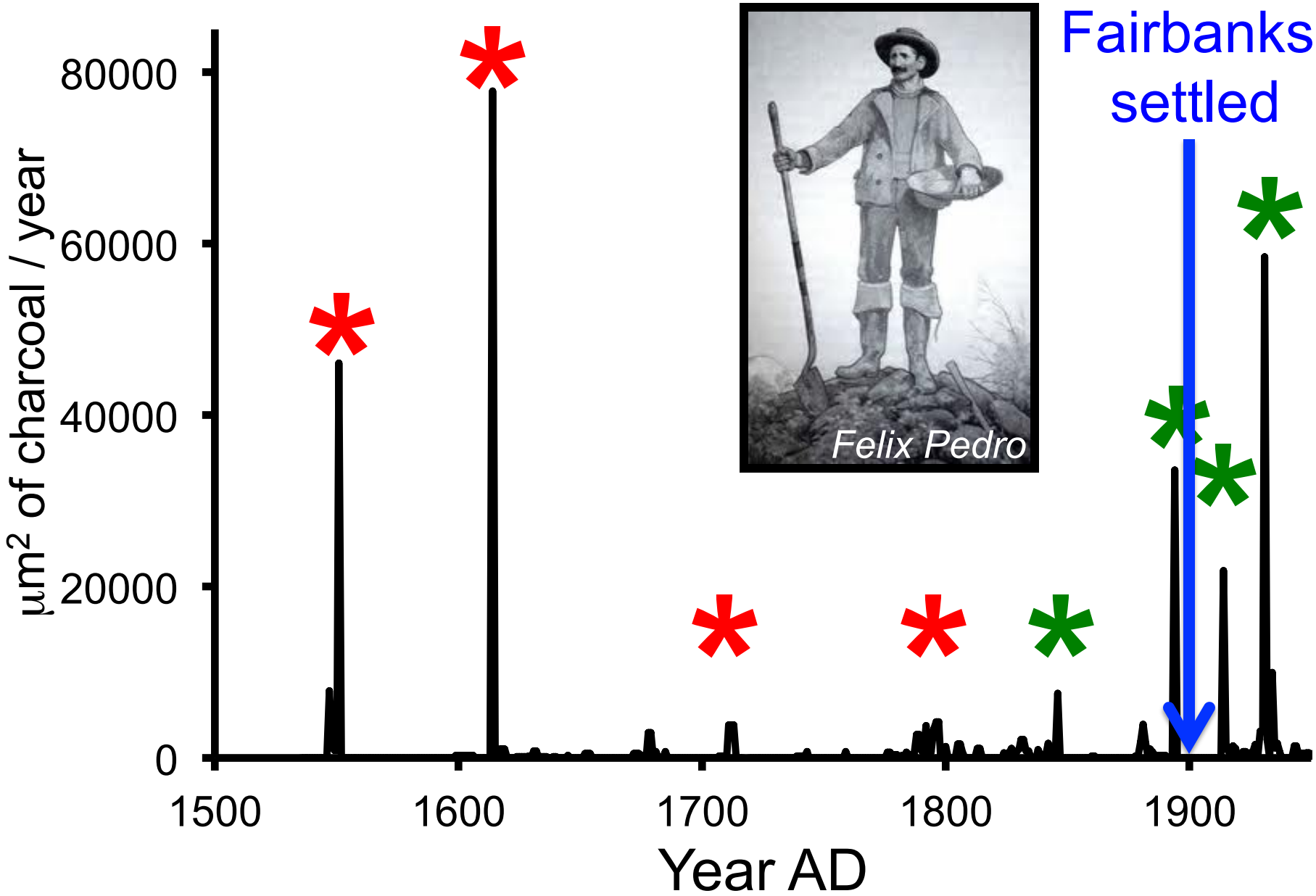

Germ. age
Fire-scar age
n=1
n=4
n=4
n=3
n=3
n=1
n=1
80000
60000
40000
20000
0
μm² of charcoal / year
1800
1850
1900
1950
2000
Year AD

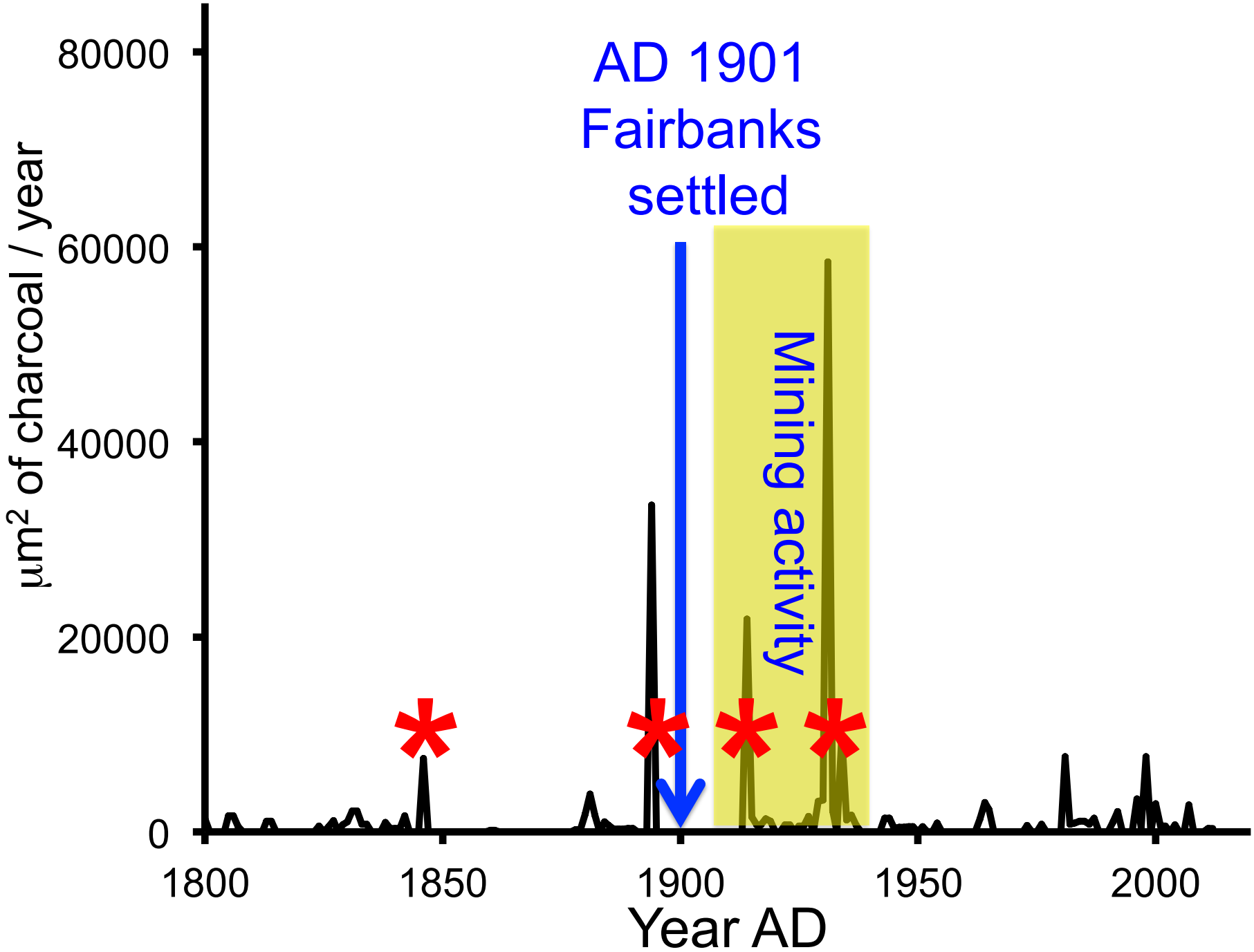

Germ. age
Fire-scar age
n=1
n=4
n=4
n=3
n=3
n=1
n=1
Rosie Creek Fire (~15 km)
Cabin occupied
80000
60000
40000
20000
0
μm² of charcoal / year
1800
1850
1900
1950
2000
Year AD

Confirmed/probable fires

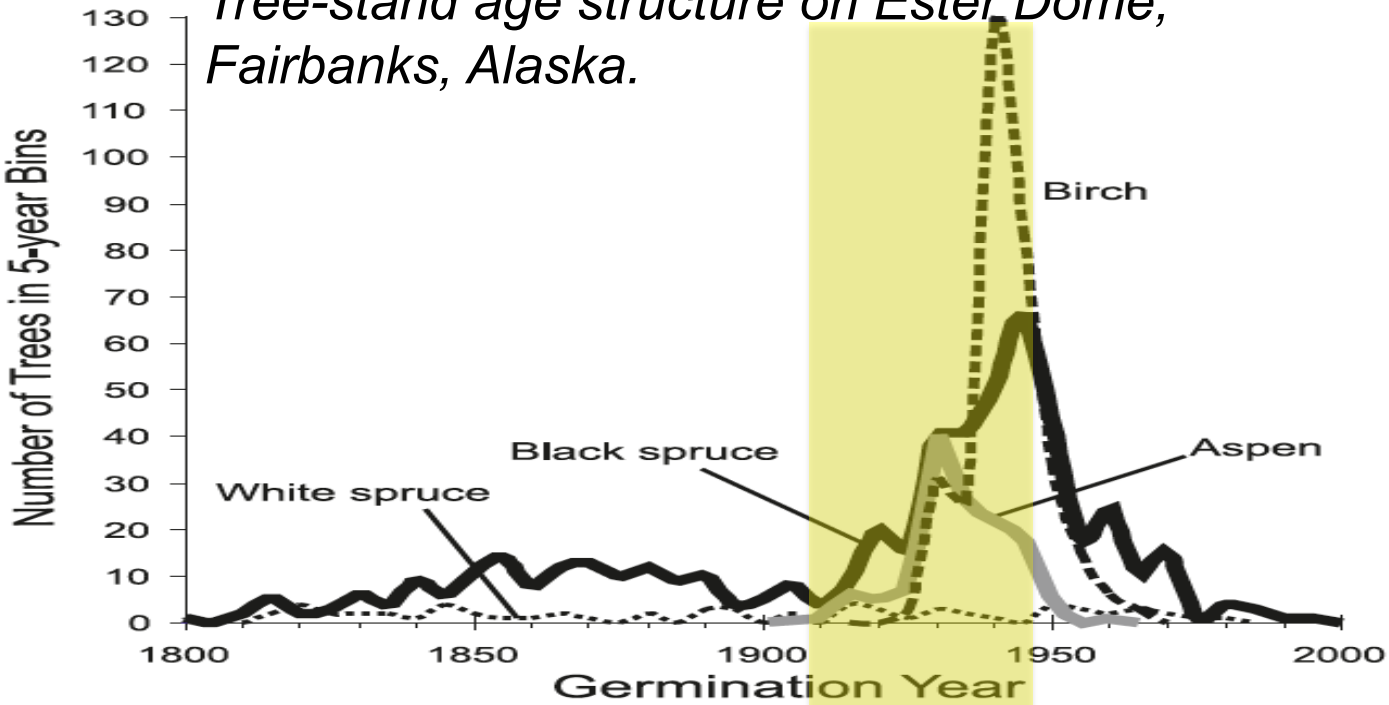


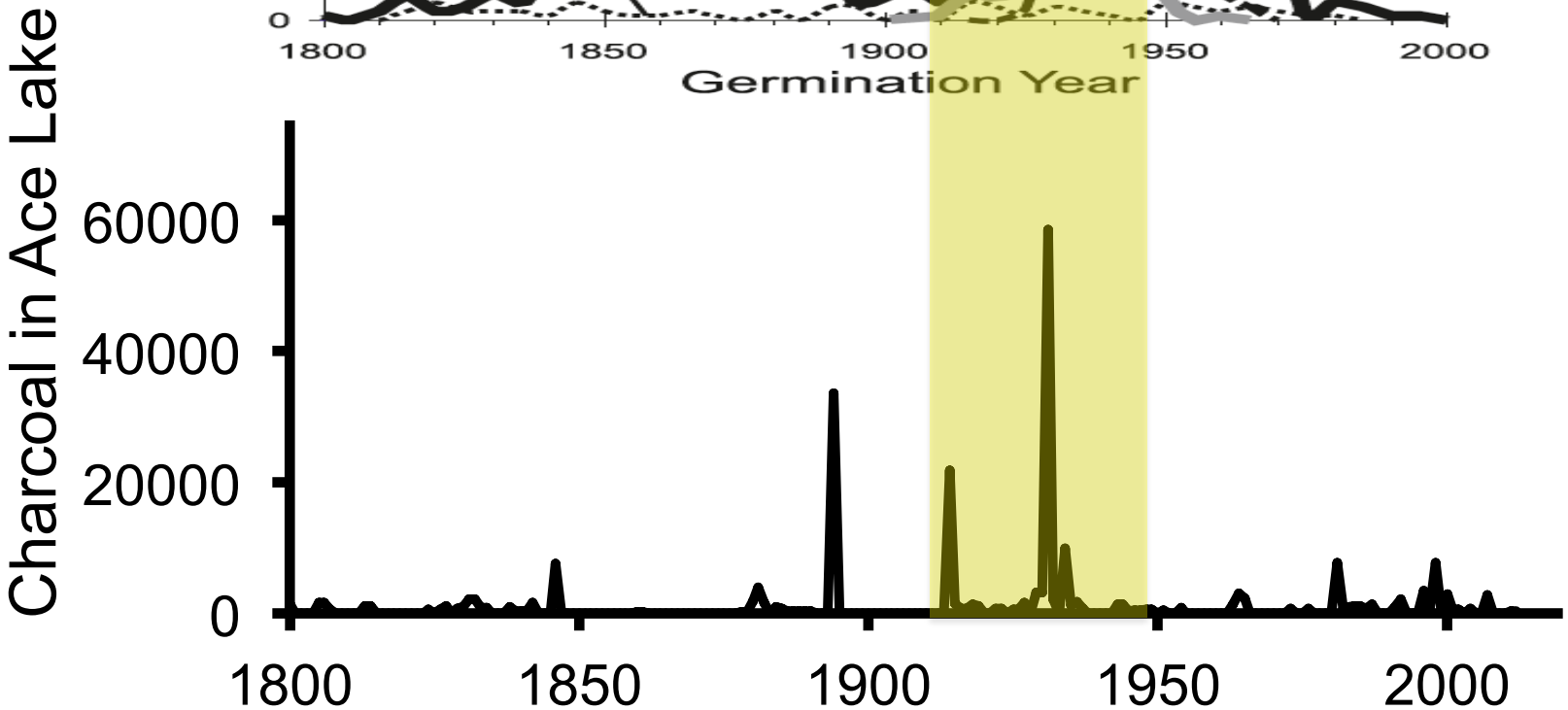
Human context of fire history




AD 1901
Fairbanks
settled
Mining activity
80000
60000
40000
20000
0
μm² of charcoal / year
1800
1850
1900
1950
2000
Year AD

Kurkowski et al., 2008 Can. J. Forest Res.
Tree-stand age structure on Ester Dome, Fairbanks, Alaska.





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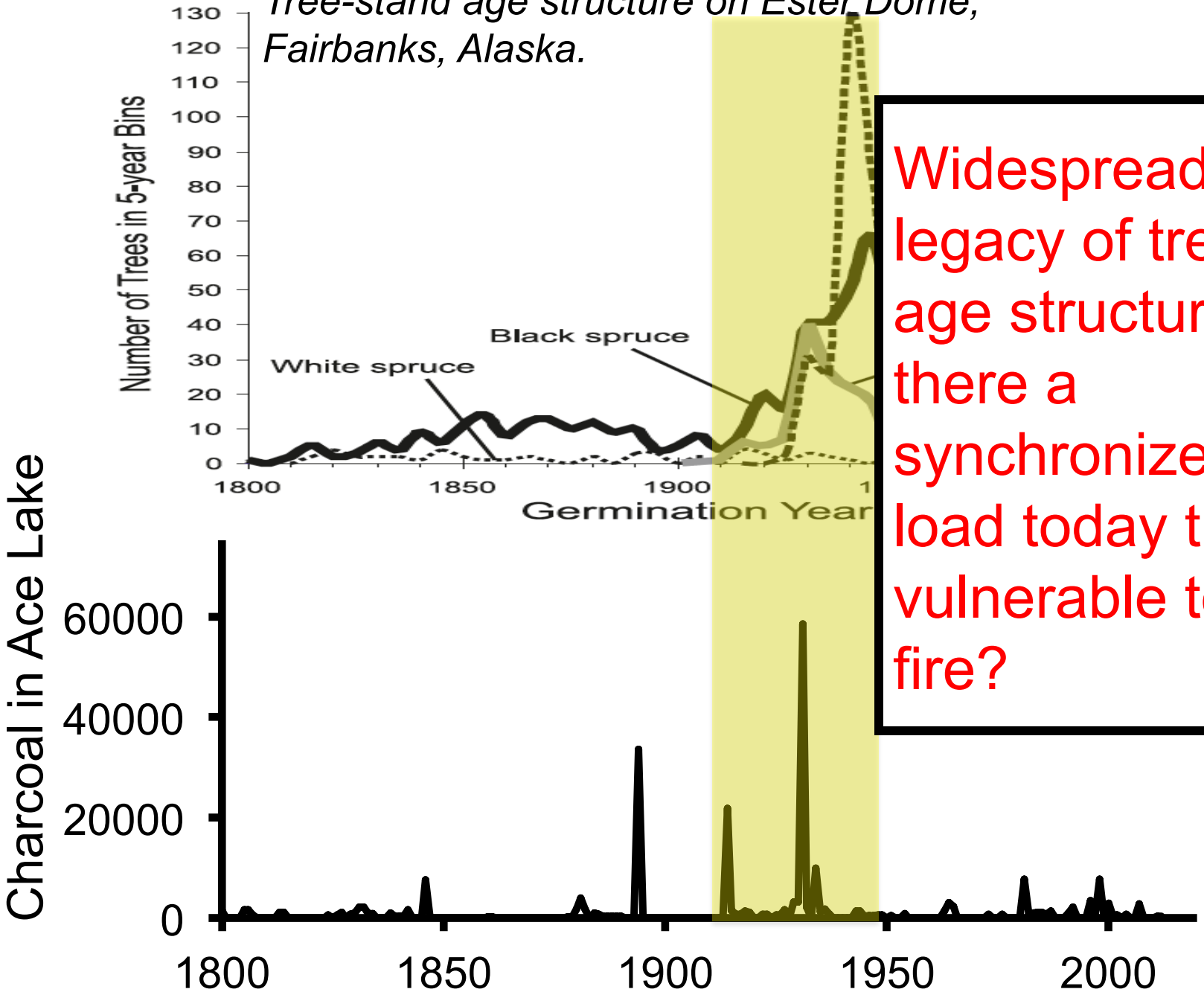

Widespread legacy of tree-age structure: is there a synchronized fuel load today that is vulnerable to fire?

Characteristics of pre/post human fire regimes

Pre-settlement fire return interval: average 69 years (48-99 years, n = 6).

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Settlement period fire return interval: average 23 years (21-24 years, n = 2).

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Pre-settlement fire return interval: average 69 years (48-99 years, n = 6).

Settlement period fire return interval: average 23 years (21-24 years, n = 2).

Time since last Fire in Ace Lake watershed: 74 Years….
AD 2038 will exceed highest FRI over last 600 years.

How did past fire events affect the Ace Lake watershed?

1) Is silt deposition enhanced after fire?

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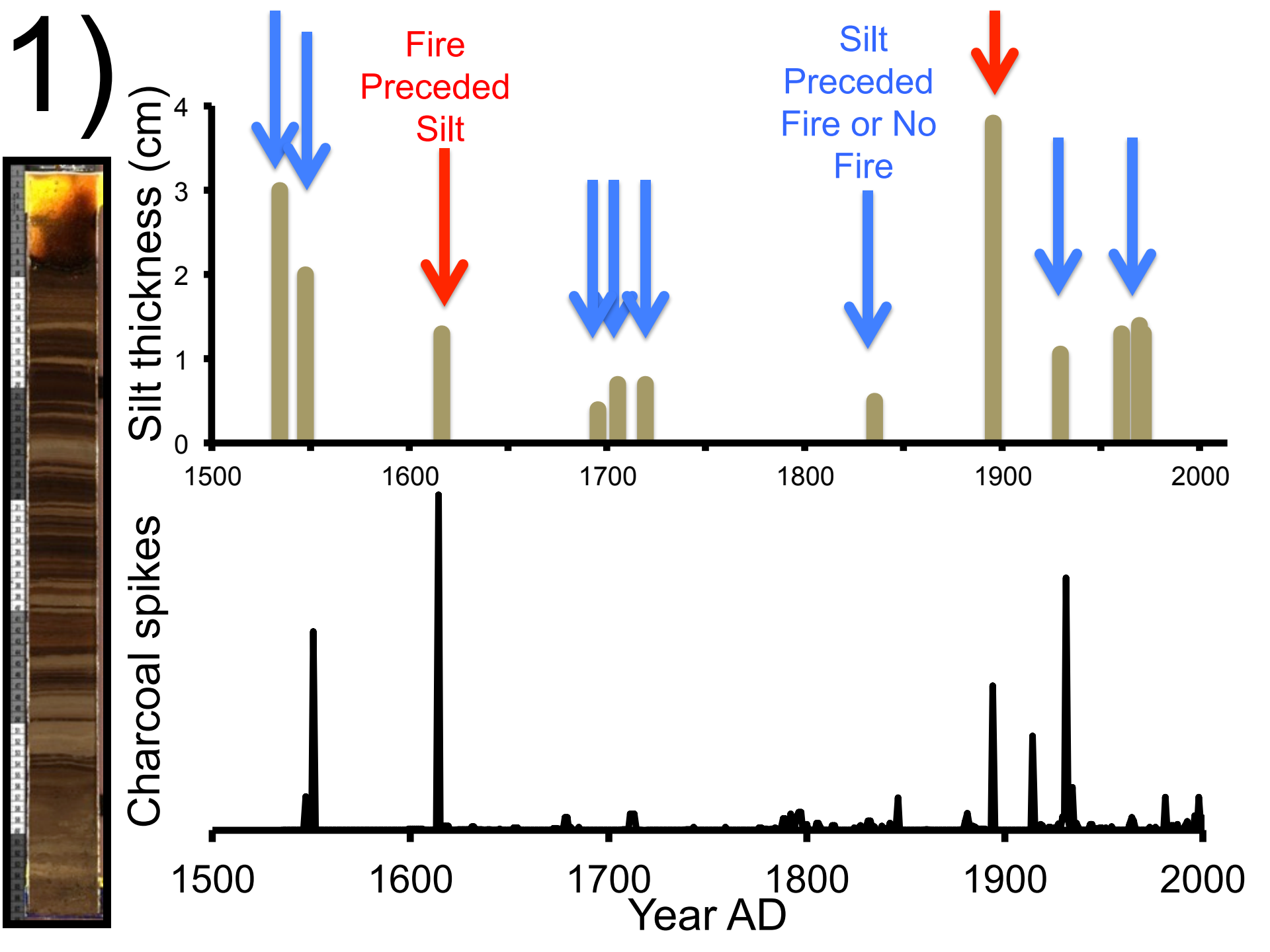
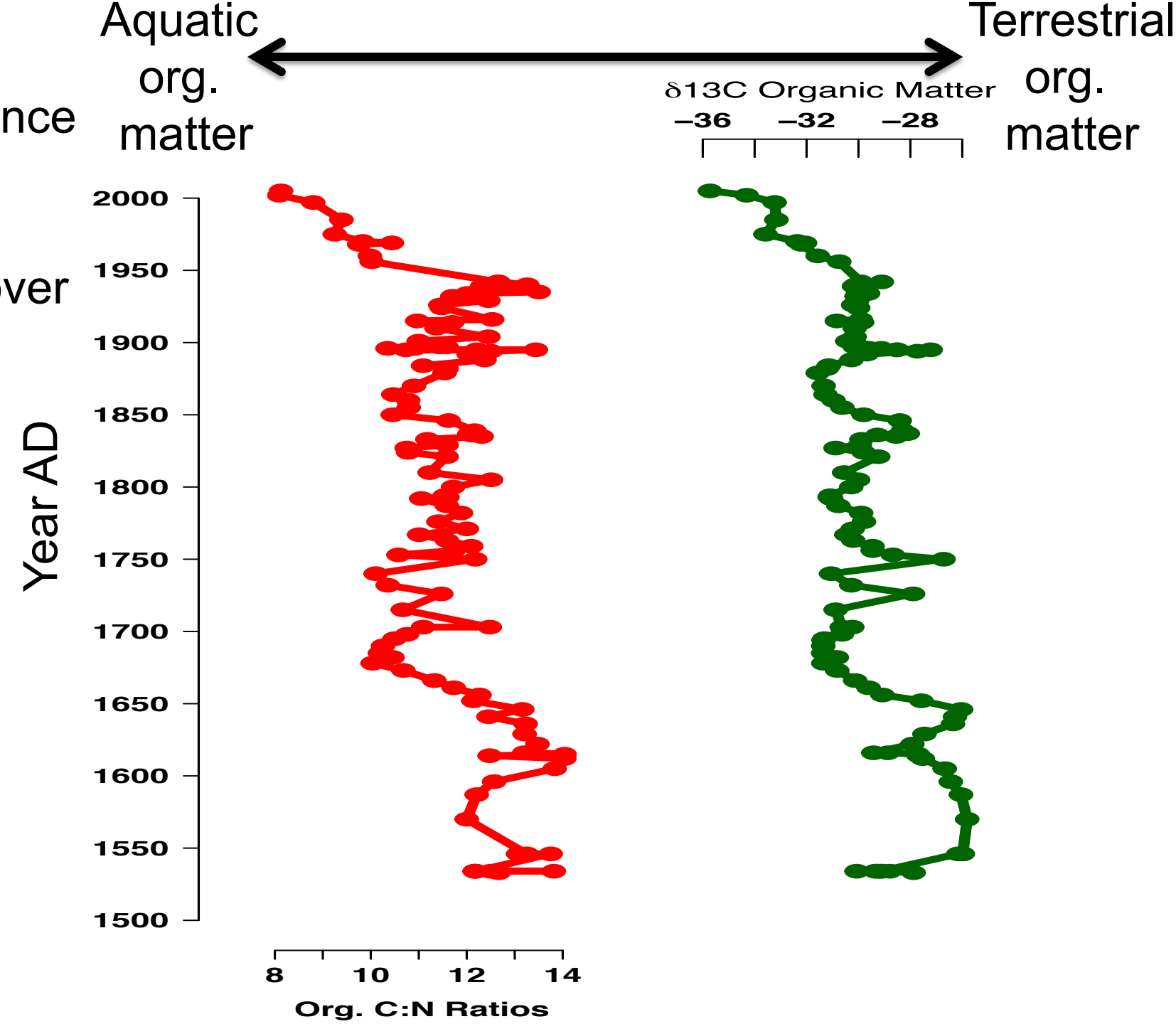
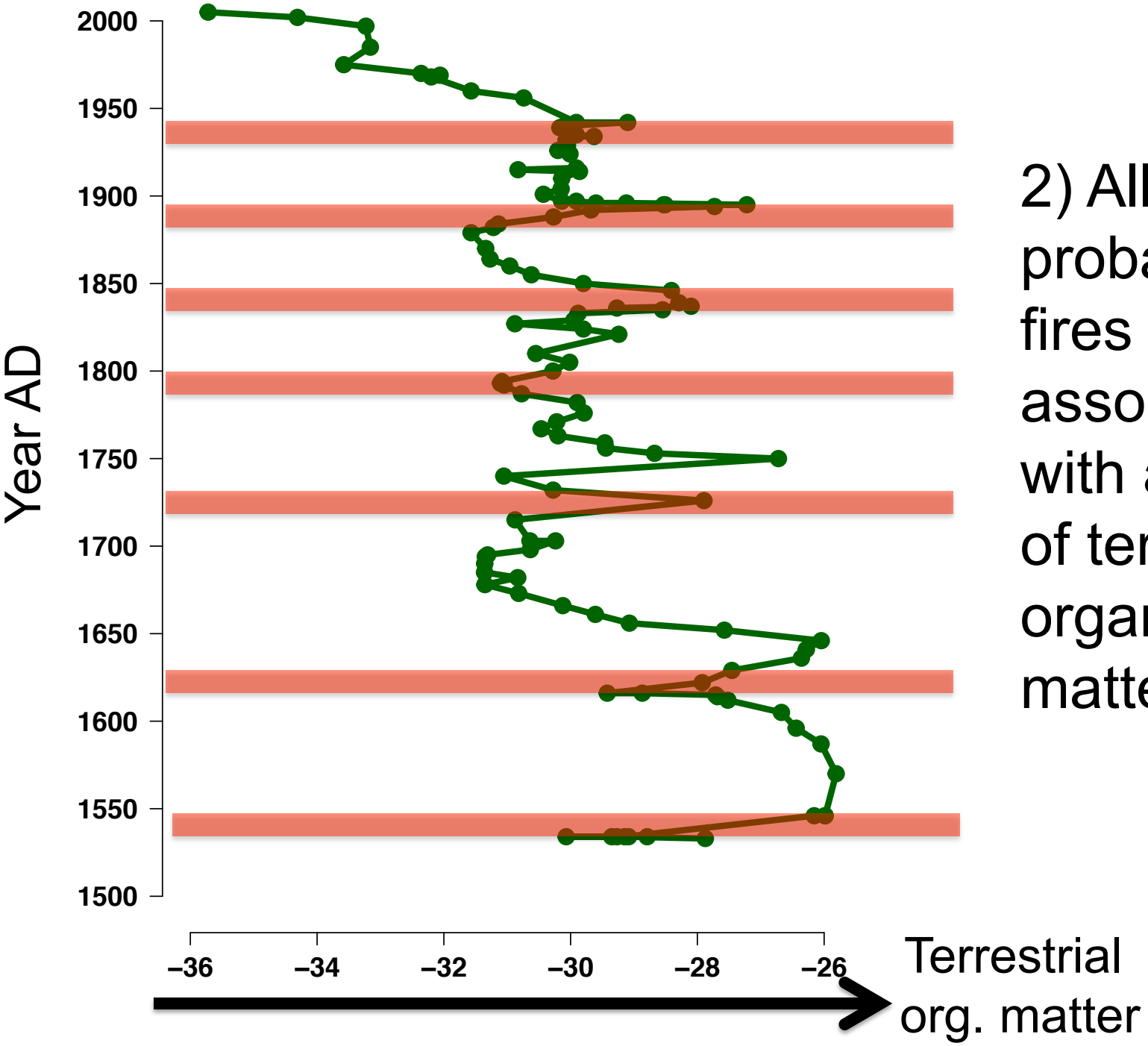
3) Have C sources for algae changed in Ace Lake?

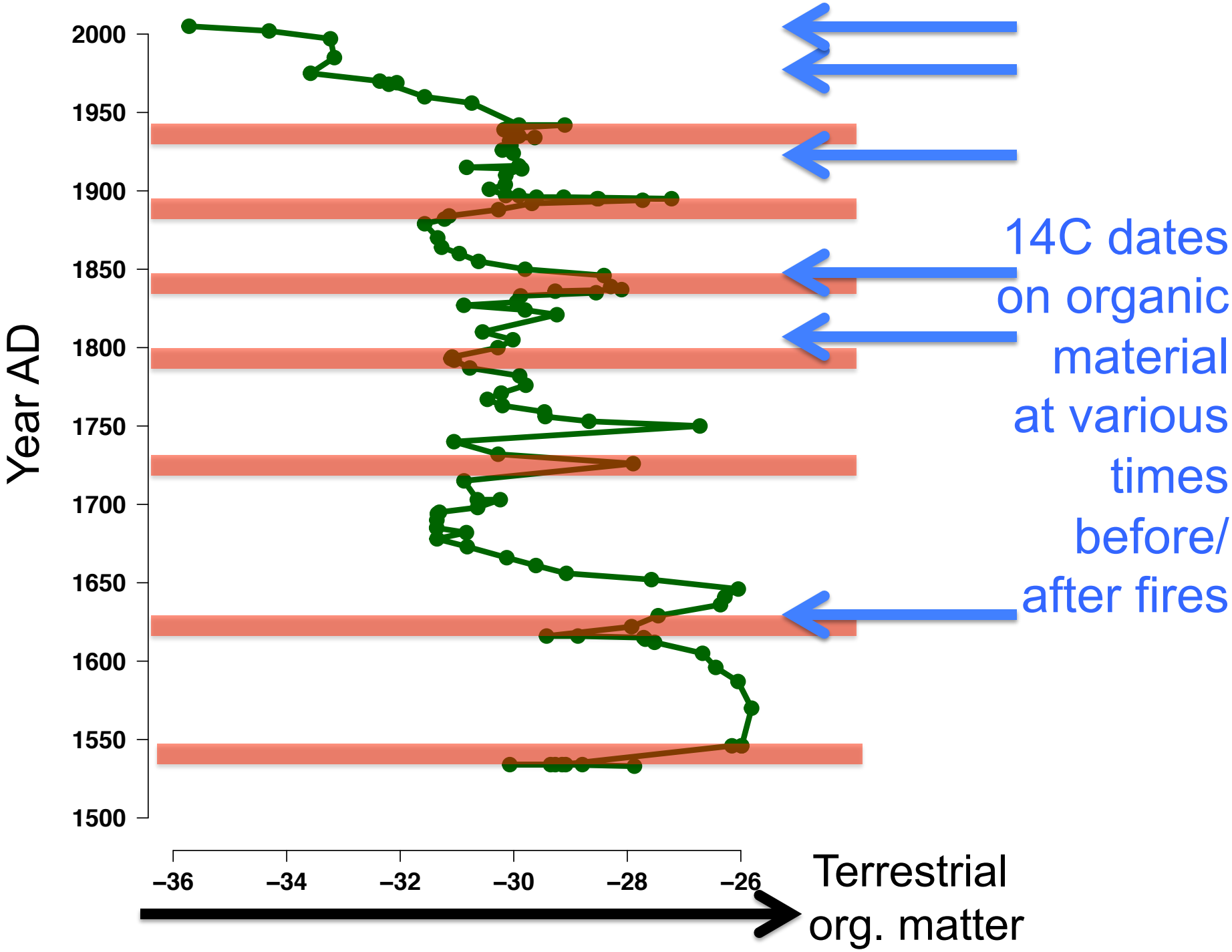

1)
Fire Preceded Silt
Silt Preceded Fire or No Fire
Silt thickness (cm)
0
1
2
3
4
1500
1600
1700
1800
1900
2000
Charcoal spikes
1500
1600
1700
1800
1900
2000
Year AD

2)The provenance of lake organic matter over time

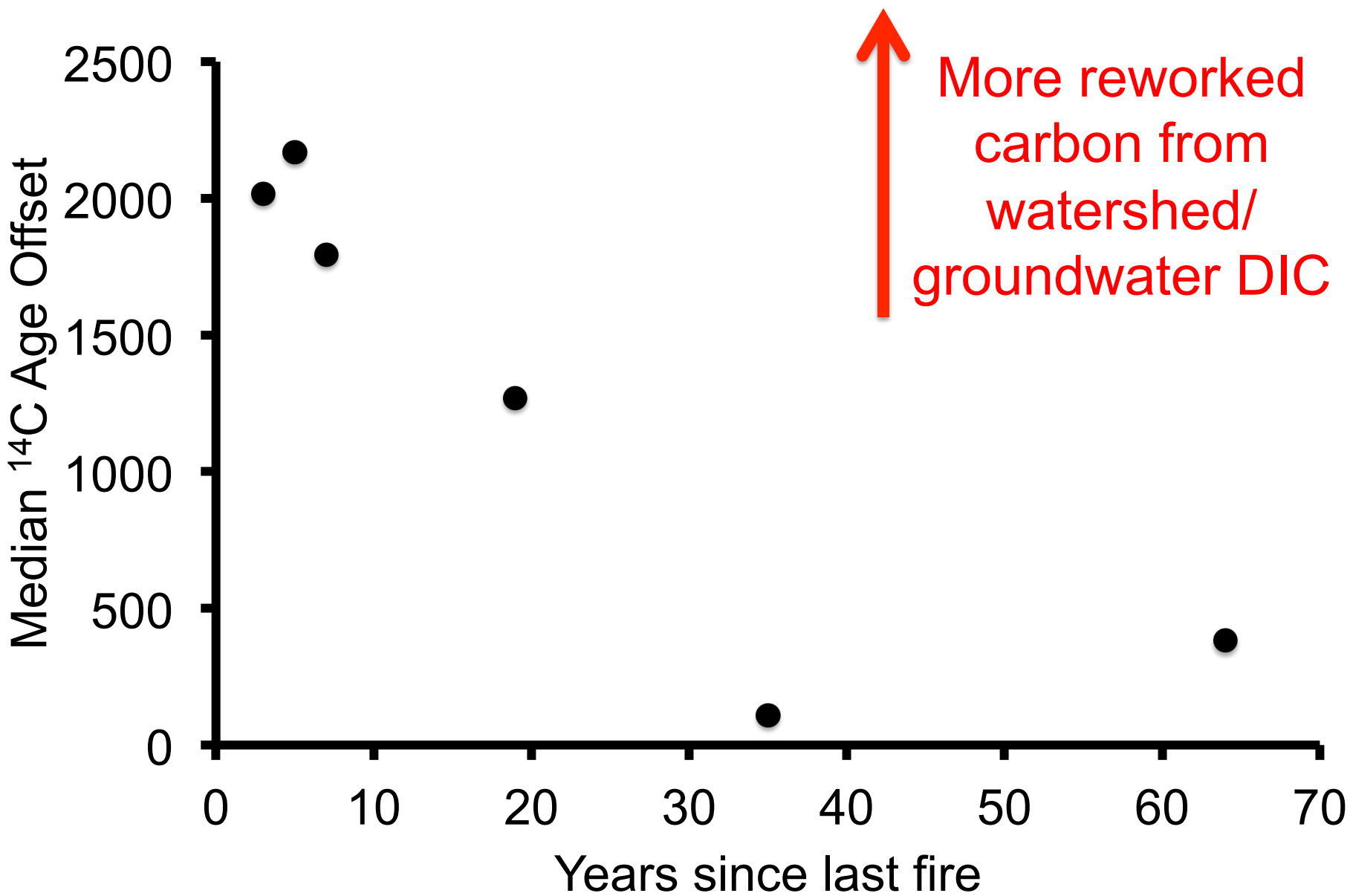




2) All probable fires associated with a pulse of terrestrial organic matter


Year AD
2000
1950
1900
1850
1800
1750
1700
1650
1600
1550
1500
–36
–34
–32
–30
–28
–26
Terrestrial org. matter
14C dates on organic material at various times before/ after fires

3) Age of organic matter sources



Permafrost-Lake Response to Fires: A Working Hypothesis From Ace Lake

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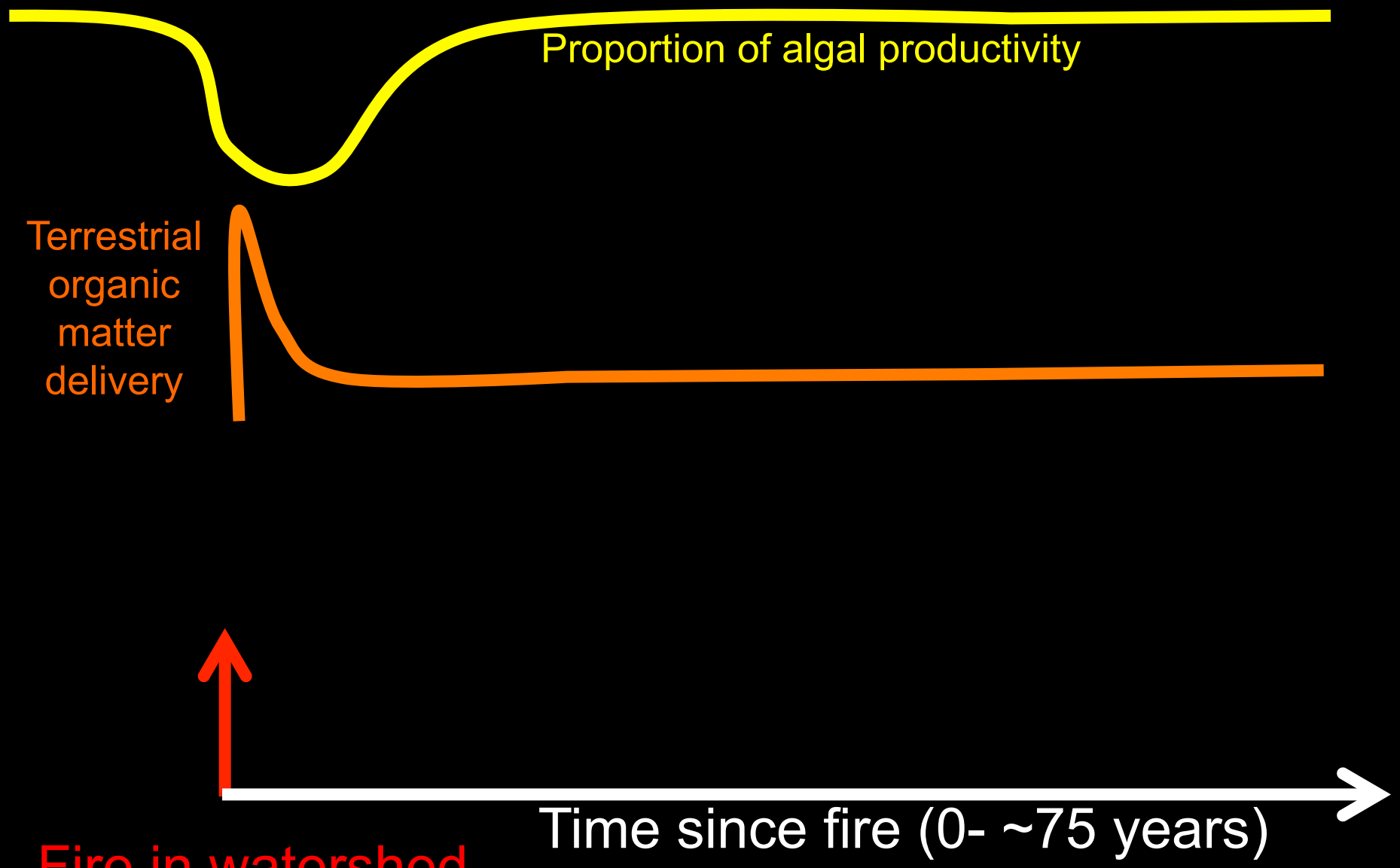
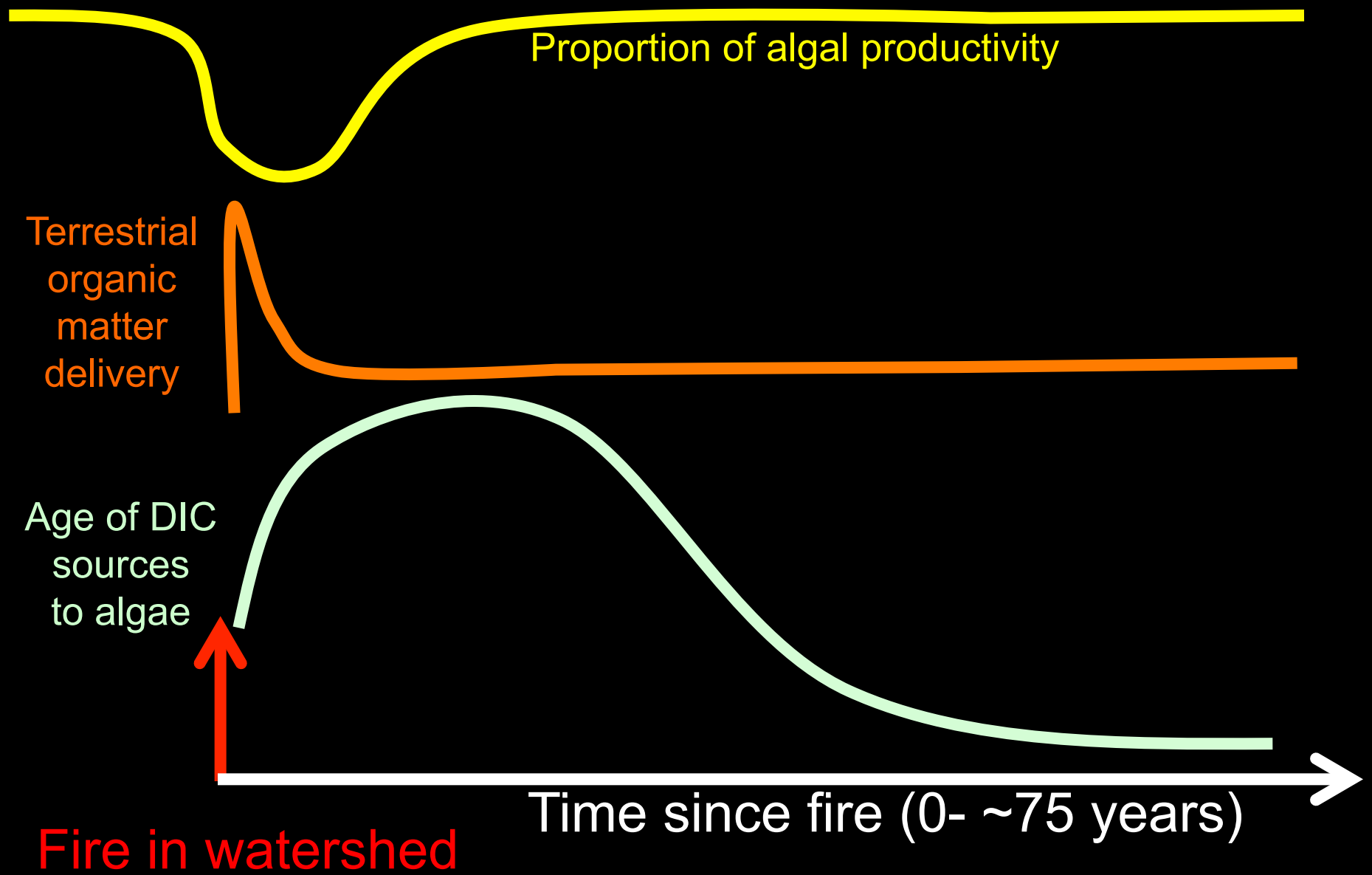
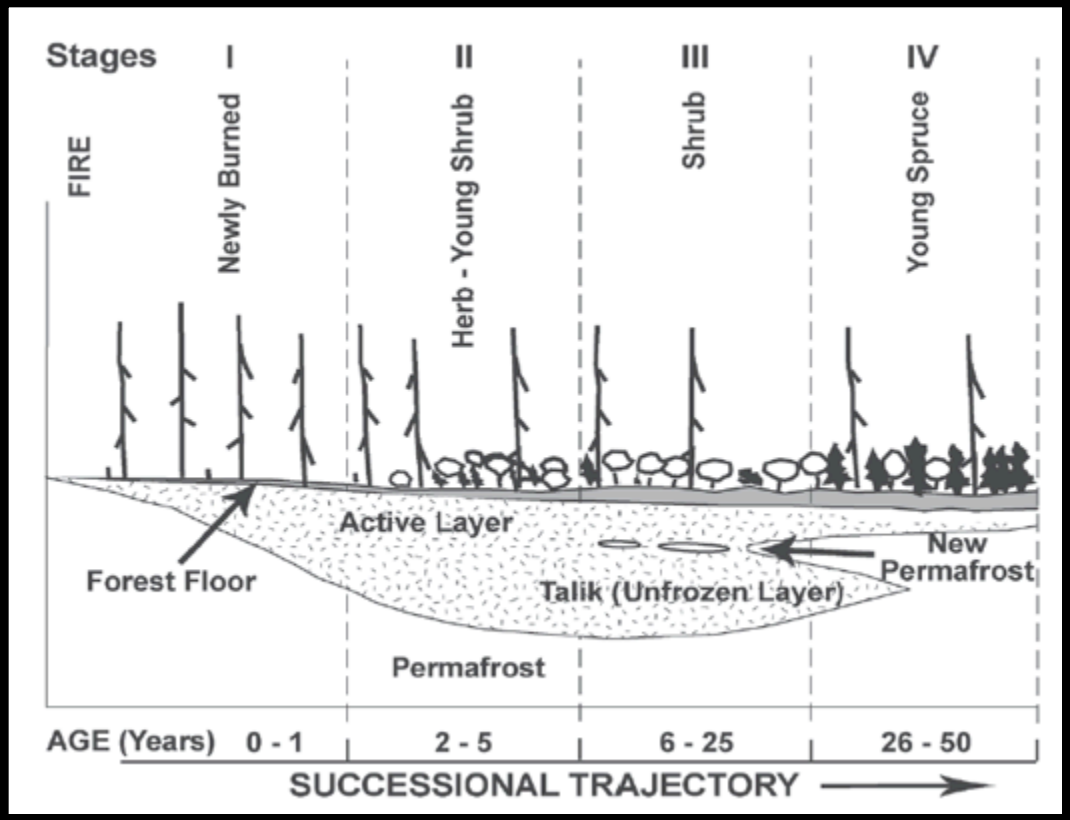


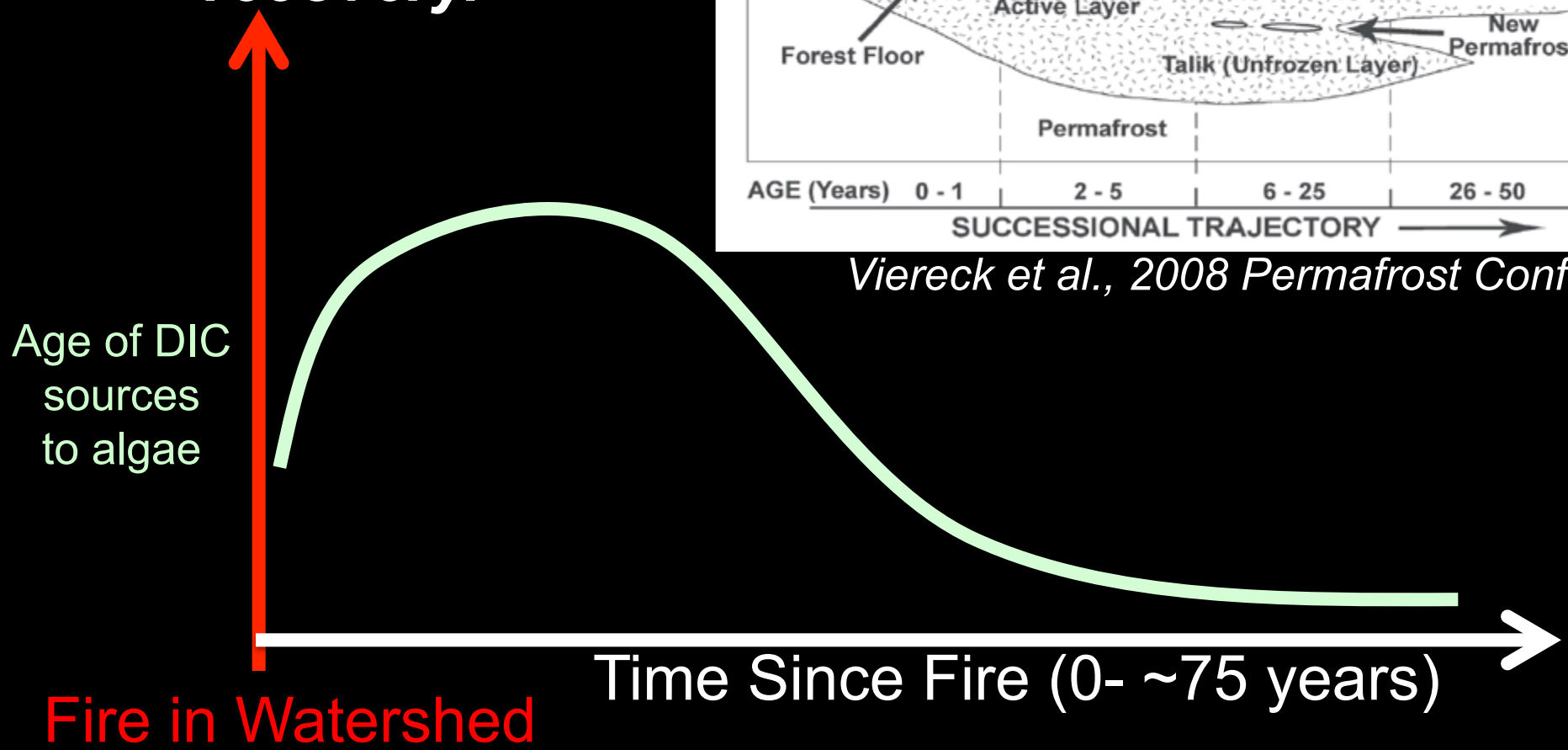
Permafrost-Lake Response to Fires: A Working Hypothesis From Ace Lake



Hyp: Enhanced decomposition in watershed soils after a fire and before recovery.



Viereck et al., 2008 Permafrost Conf.



Conclusions

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Conclusions

1) Ace Lake records a precise fire history
2) Fire return intervals lowered during settlement period.
3) Within pre-historic FRI range today, but not for long.
4) Fire does not enhance lake expansion and silt deposition
5) A range of permafrost/lake Responses after a fire

Questions

Acknowledgements: Carson Baughman, Ben Jones, Woods Hole.