A decision-making framework for sedimentation analyses in dammed river corridor impoundments

Ian M. Nesbitt[1], Sean MC Smith[1], Bess G. Koffman[2], Seth W. Campbell[1], Steven Arcone[3]

[1] University of Maine, School of Earth and Climate Sciences
[2] Colby College, Department of Geology
[3] Cold Regions Research and Engineering Laboratory (CRREL), US Army Corps of Engineers

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or

How to pick a coring site for your study

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How do we decide where to core?

- Why are we coring in the first place?
  - Sedimentation effects of damming a corridor
  - Micro- / macrofossils
  - Dating / sedimentation rates
  - Lake level change / paleovegetation / climate proxies

- How do we make sure we know where to core and what we'll be coring into for a given study?

Where would you core?

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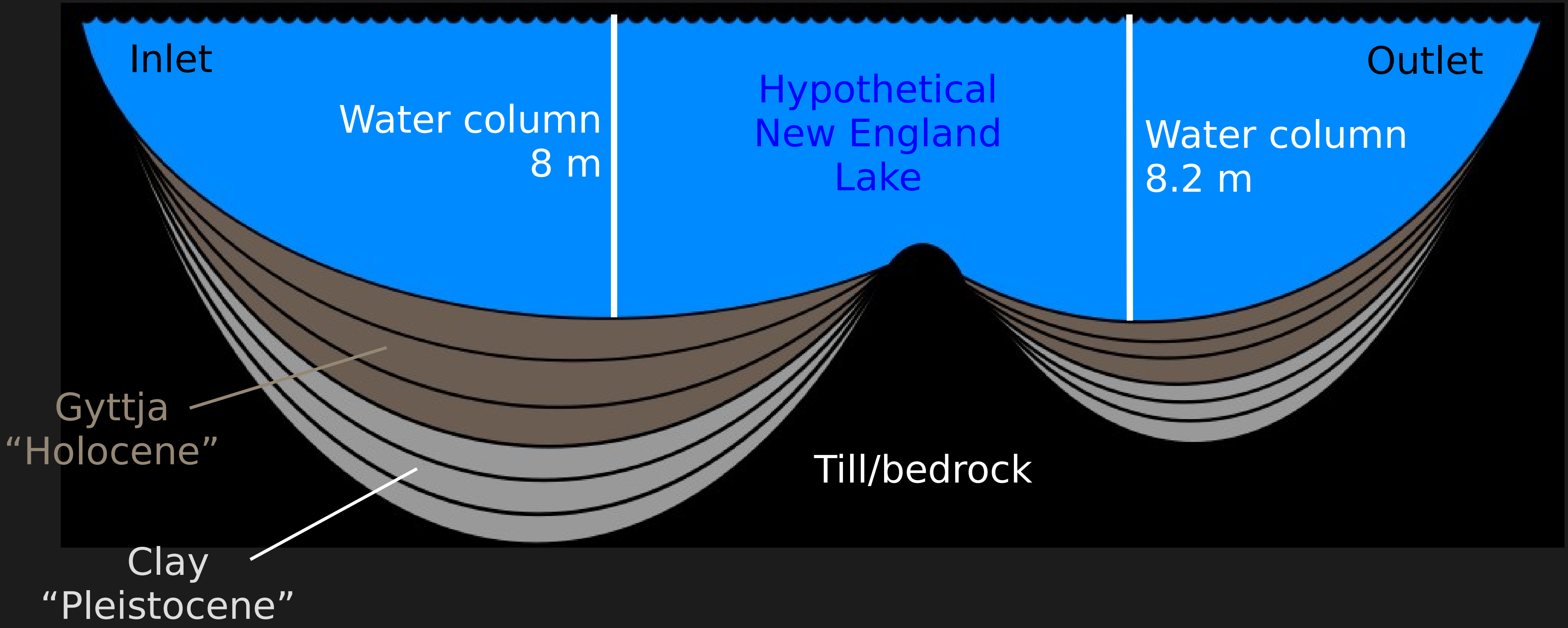

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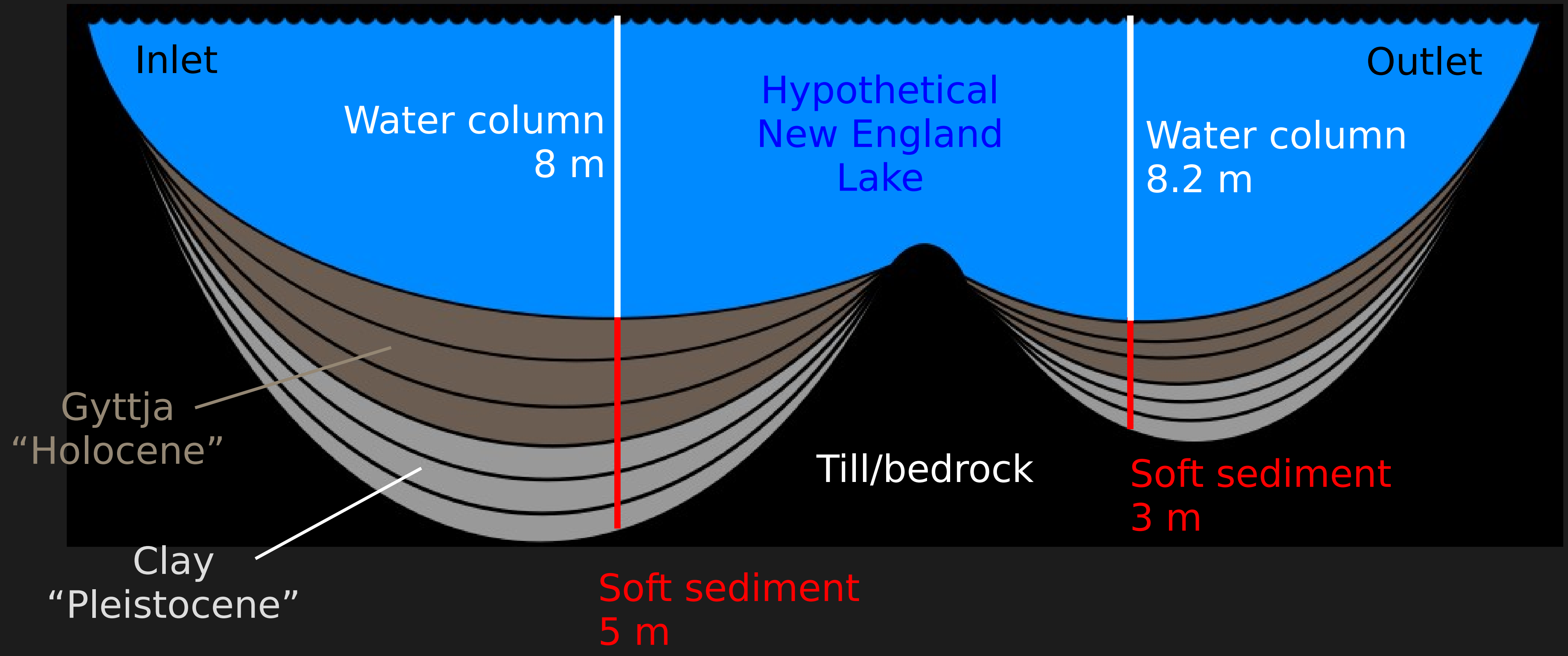

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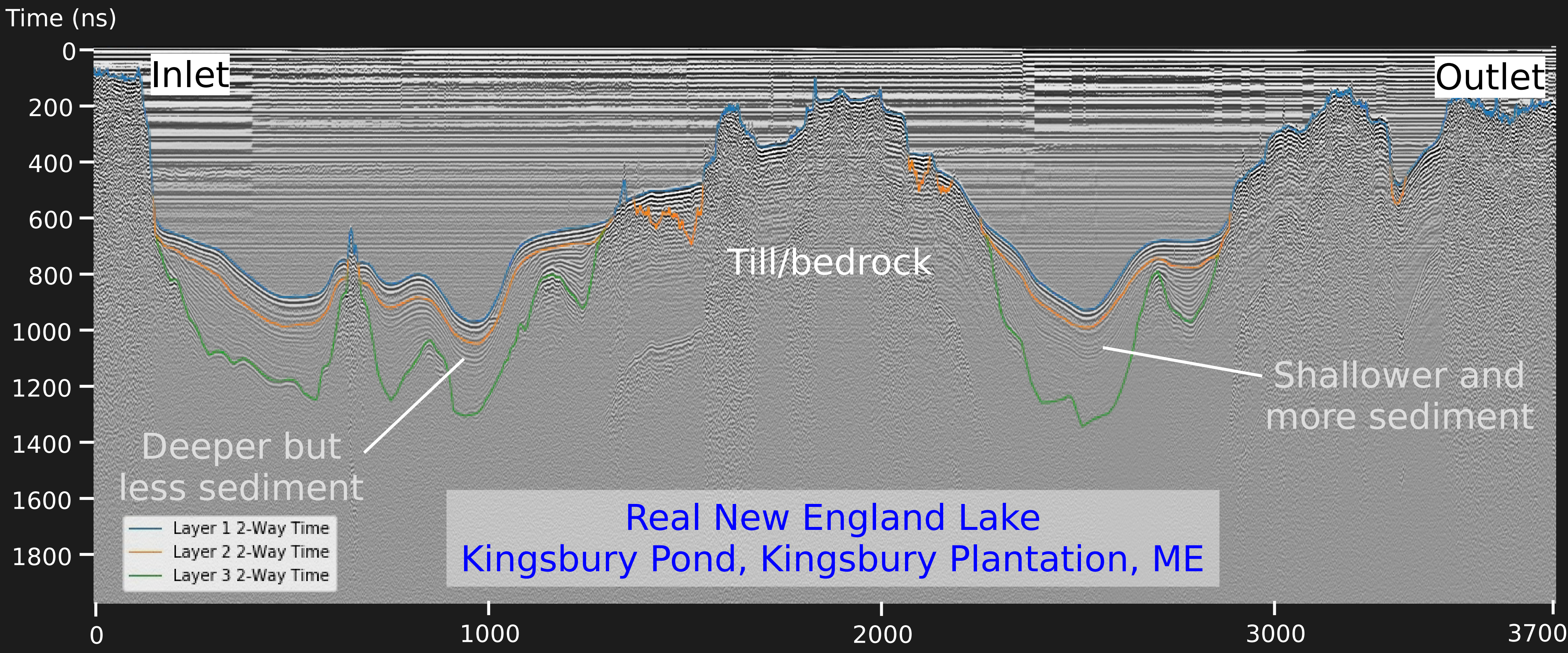

Background

- Coring community has known about problems with spatial variability in New England for decades (Jacobson and Bradshaw, 1981; Davis and Ford, 1982)
- New England shallow lake GPR is not new (Arcone, 2018)
- GPR has been used to find core sites, but infrequently and in two dimensions (ex: Dieffenbacher-Krall and Nurse, 2005)

Ground-Penetrating Radar (GPR) or Impulse Radar

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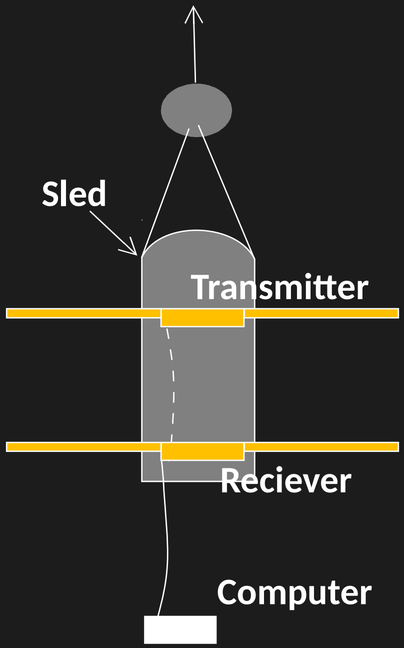
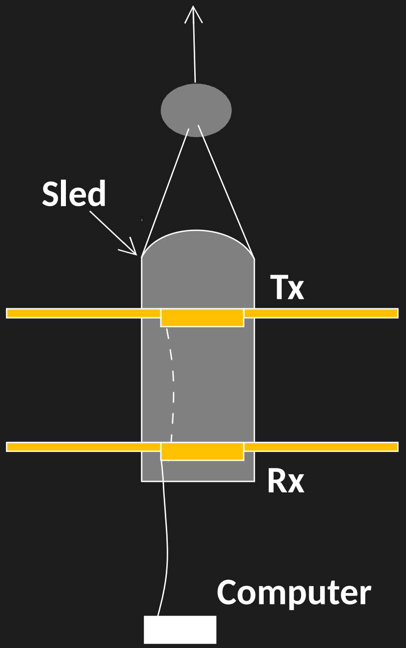
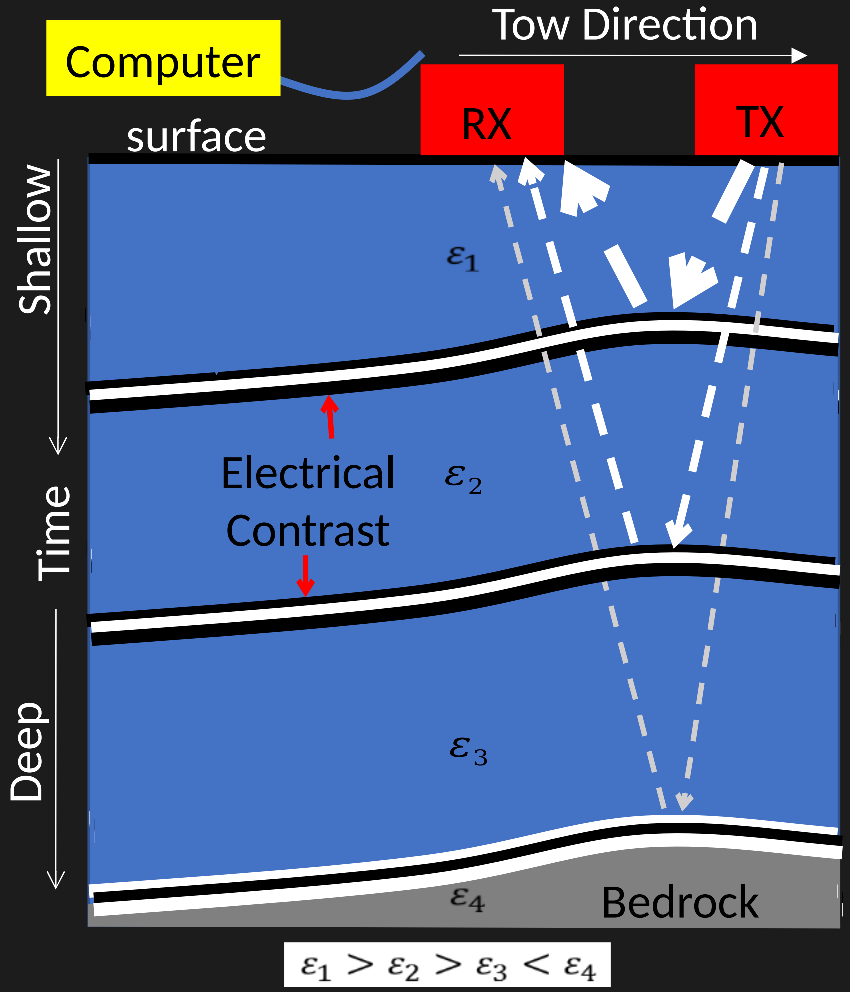


Ground-Penetrating Radar (GPR) or Impulse Radar





Ground-Penetrating Radar (GPR) or Impulse Radar

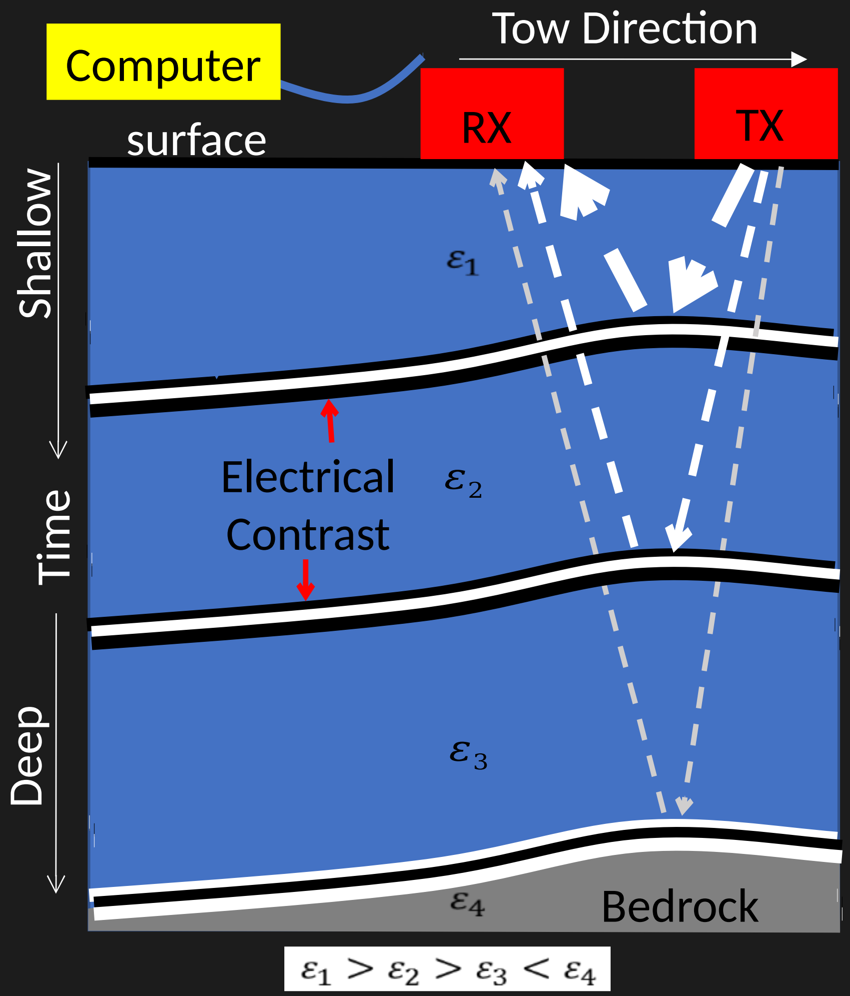
Permittivity (ε) - Material ability to store or release EM energy

$$\varepsilon_r = \frac{\varepsilon_{material}}{\varepsilon_{vacuum}} \propto \frac{c_{material}}{c_{vacuum}}$$

ε_r values:

Air = 1
Dry snow = 1.4
Dry Firn = 2.2-2.6
Ice = 3.0-3.2
Wet snow = 4-6
Granite = 6-12
Permafrost = 5-6
Till = 12-32
Sands = 12-32
Water = 80-88

$$z = \frac{t_n - t_{n-1}}{2} * \frac{c}{\sqrt{\varepsilon_{r(n)}}}$$



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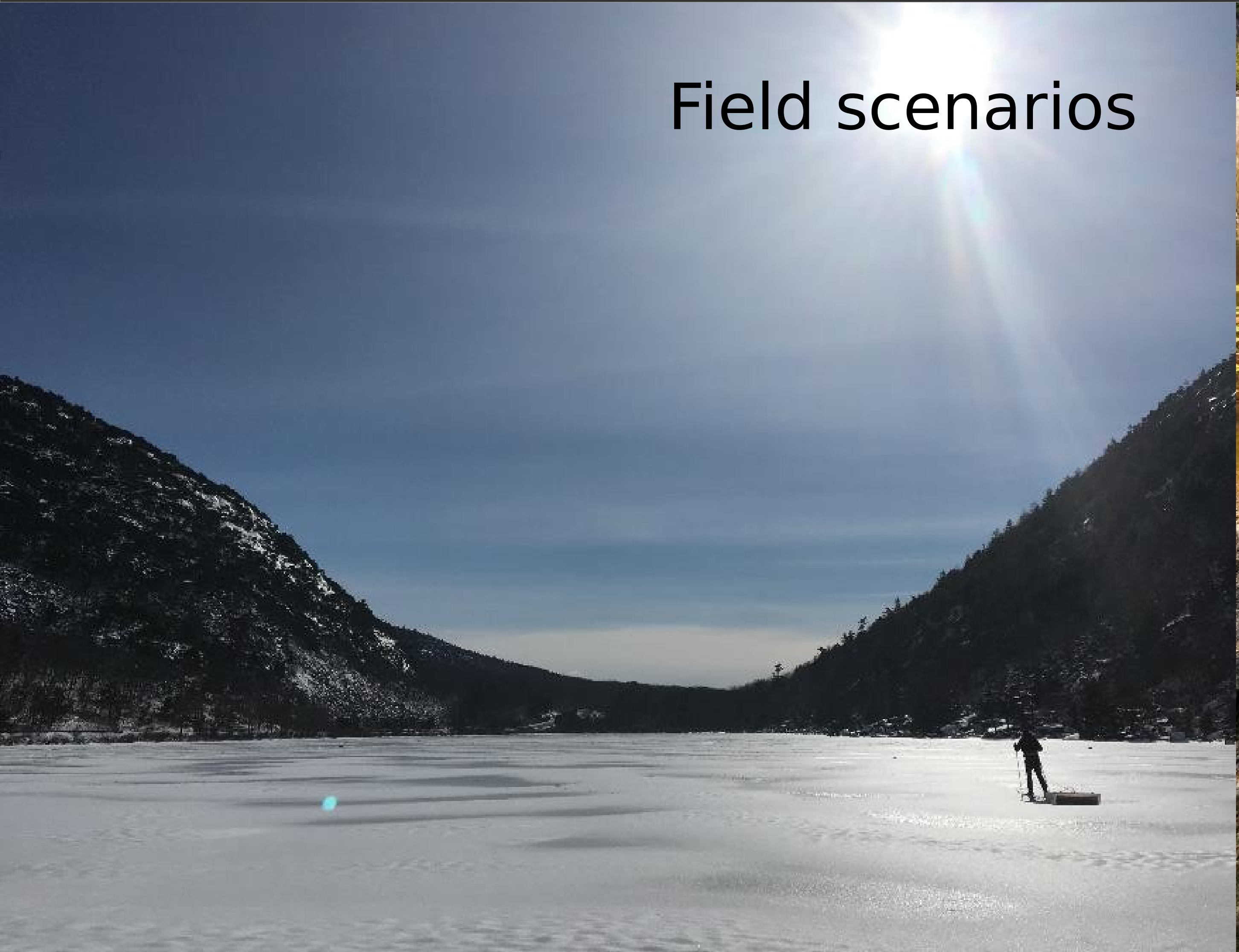
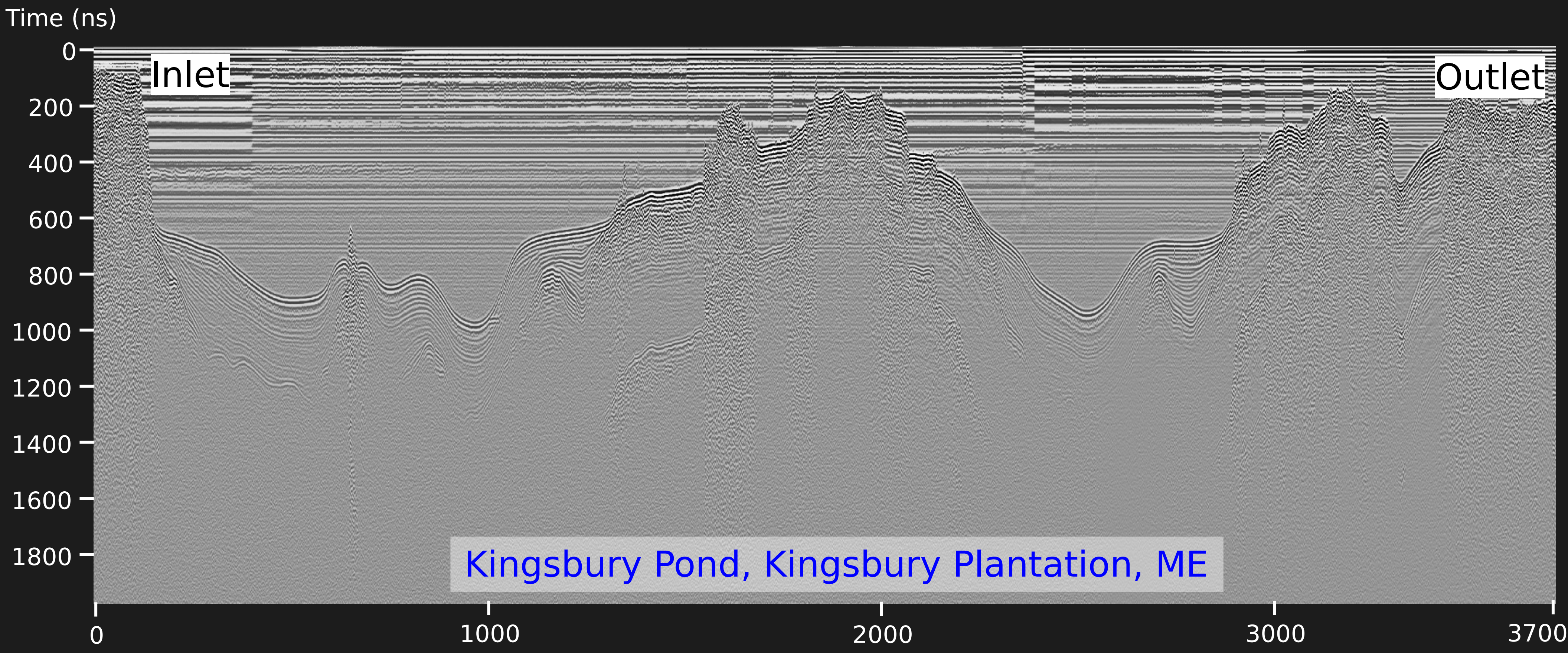
- Cons:
  - Water must be very fresh (typically <50 µs/m)
  - Shallow bathrmetry works best (<20 m)
  - Doesn’t do well in hydrocarbon-rich layers (but better than sub-bottom acoustic)
- Pros:
  - Portable, unlike sub-bottom acoustic (walk, ski, paddle, motor)
  - Can resolve stratigraphic detail
  - “Relatively inexpensive”

Field scenarios



Picking and depth calibration



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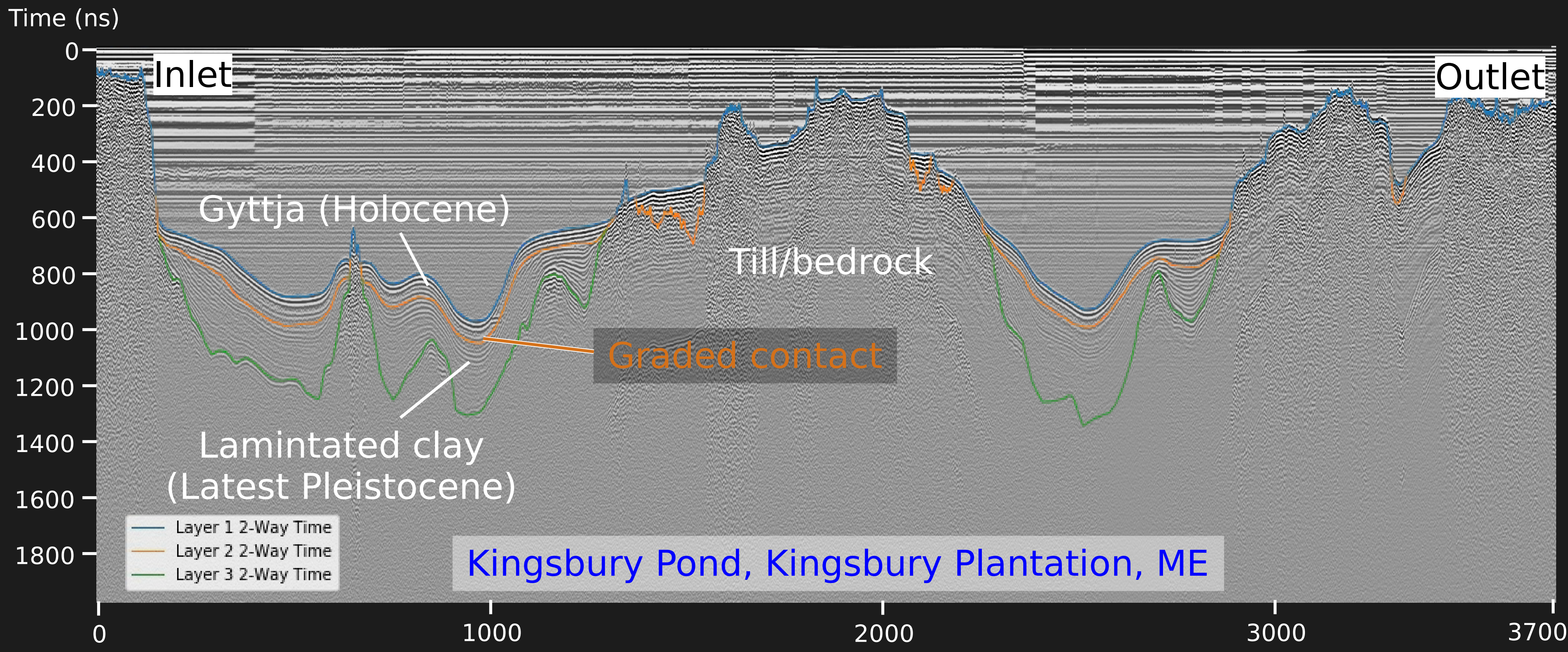
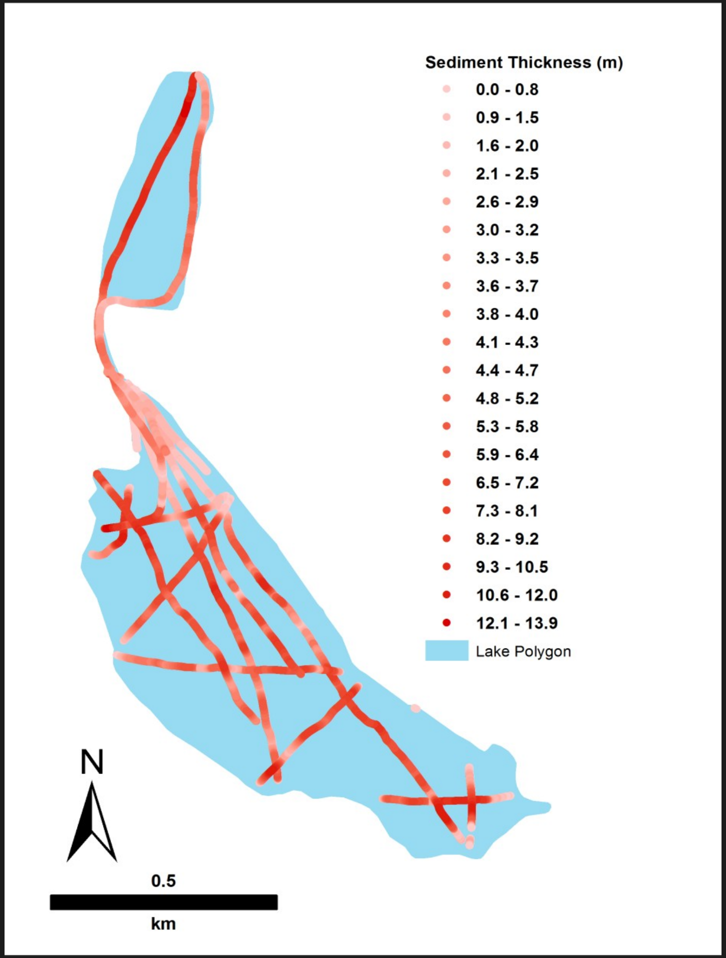
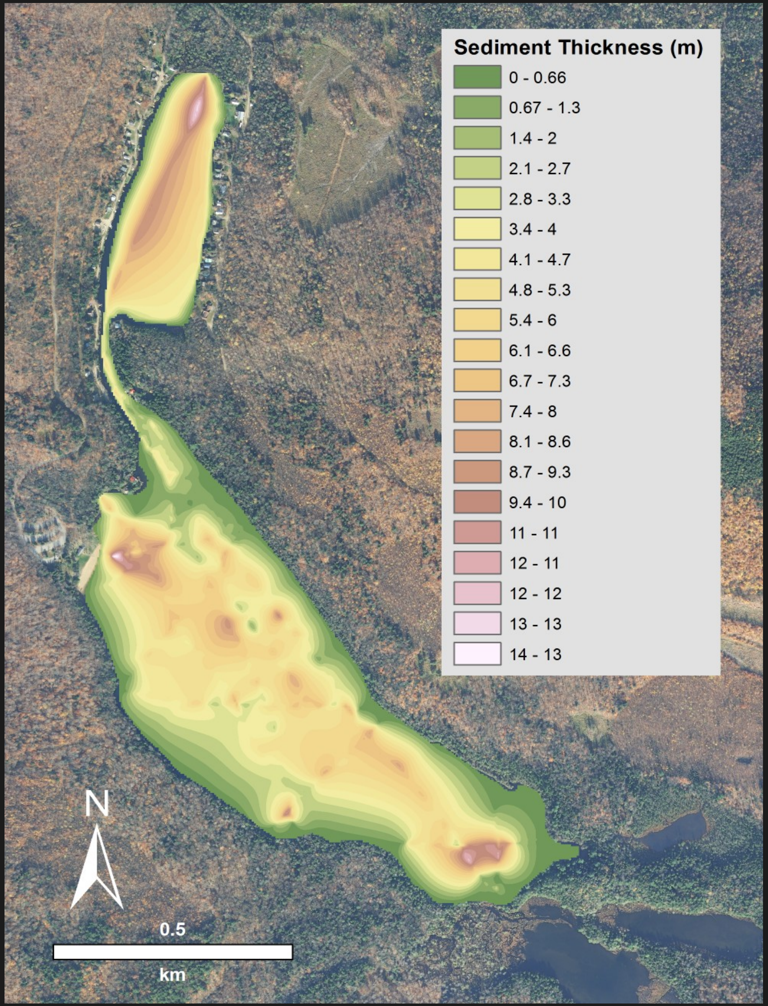
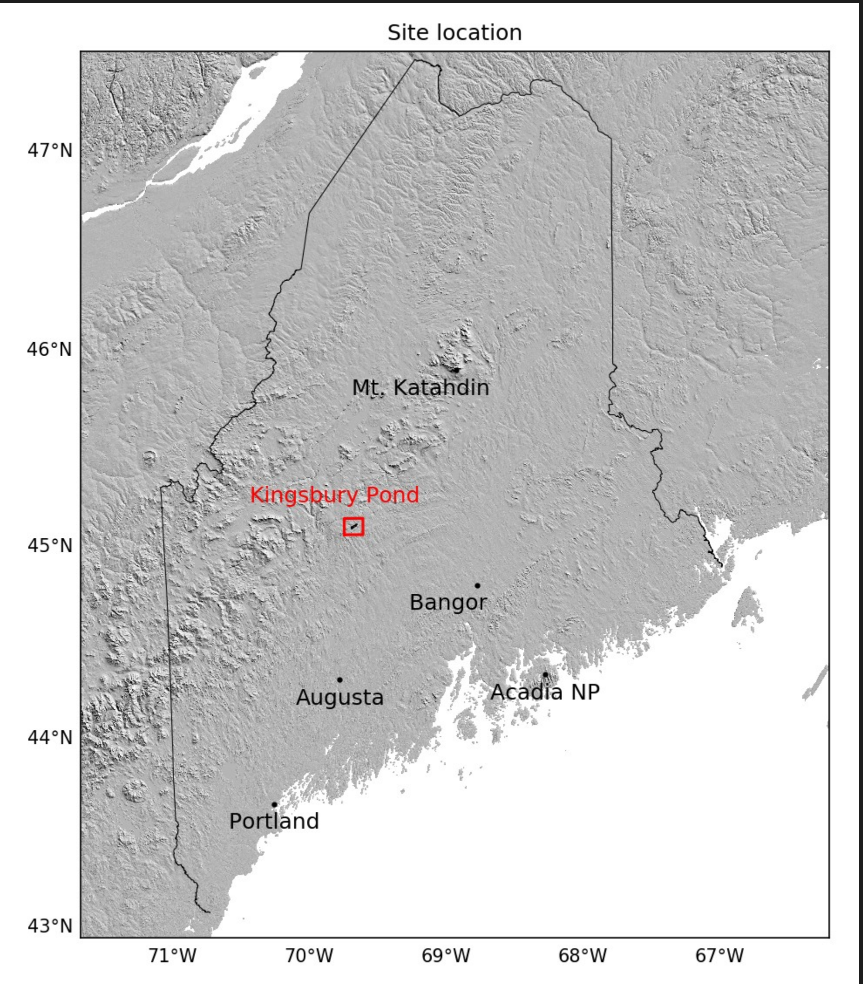


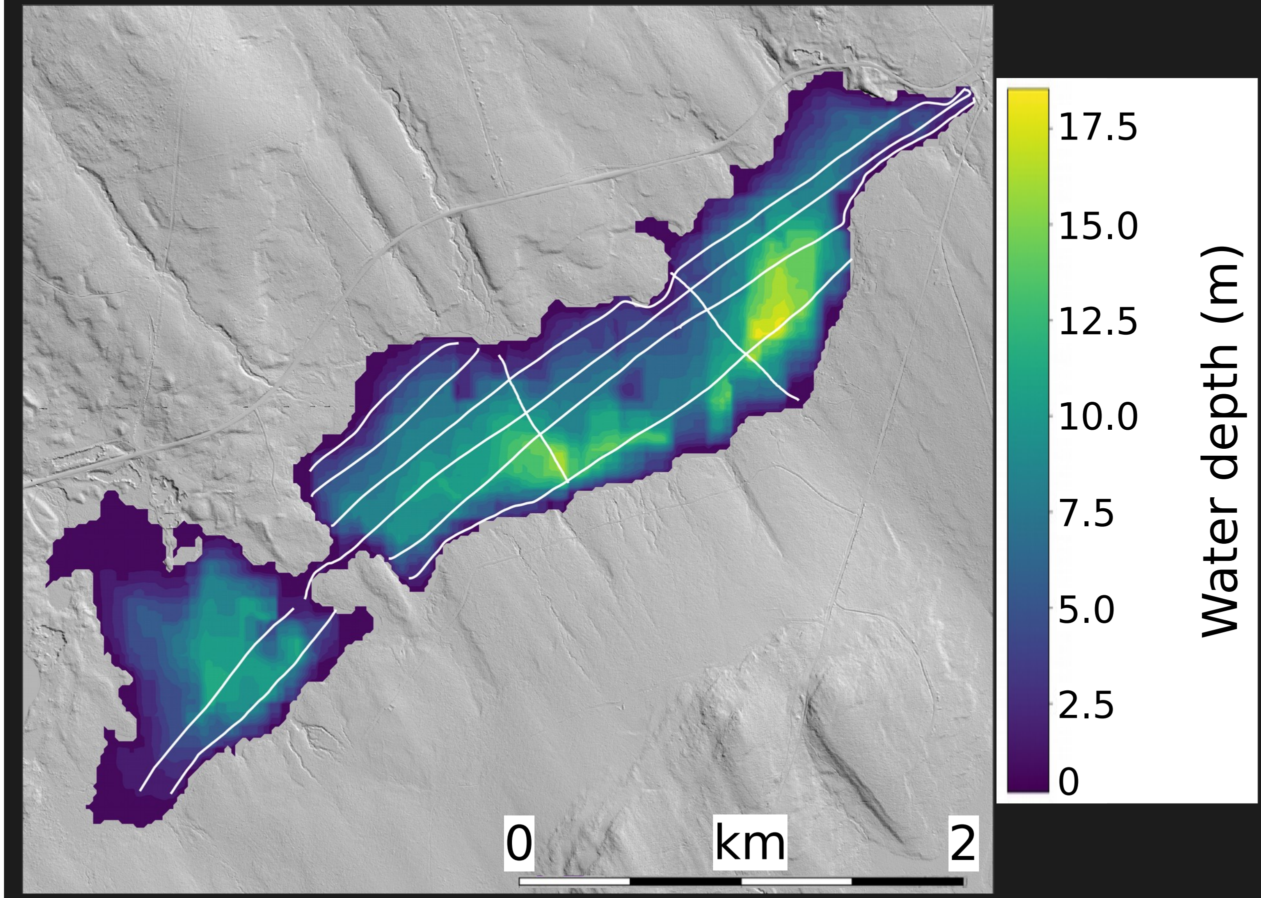
Thickness map creation



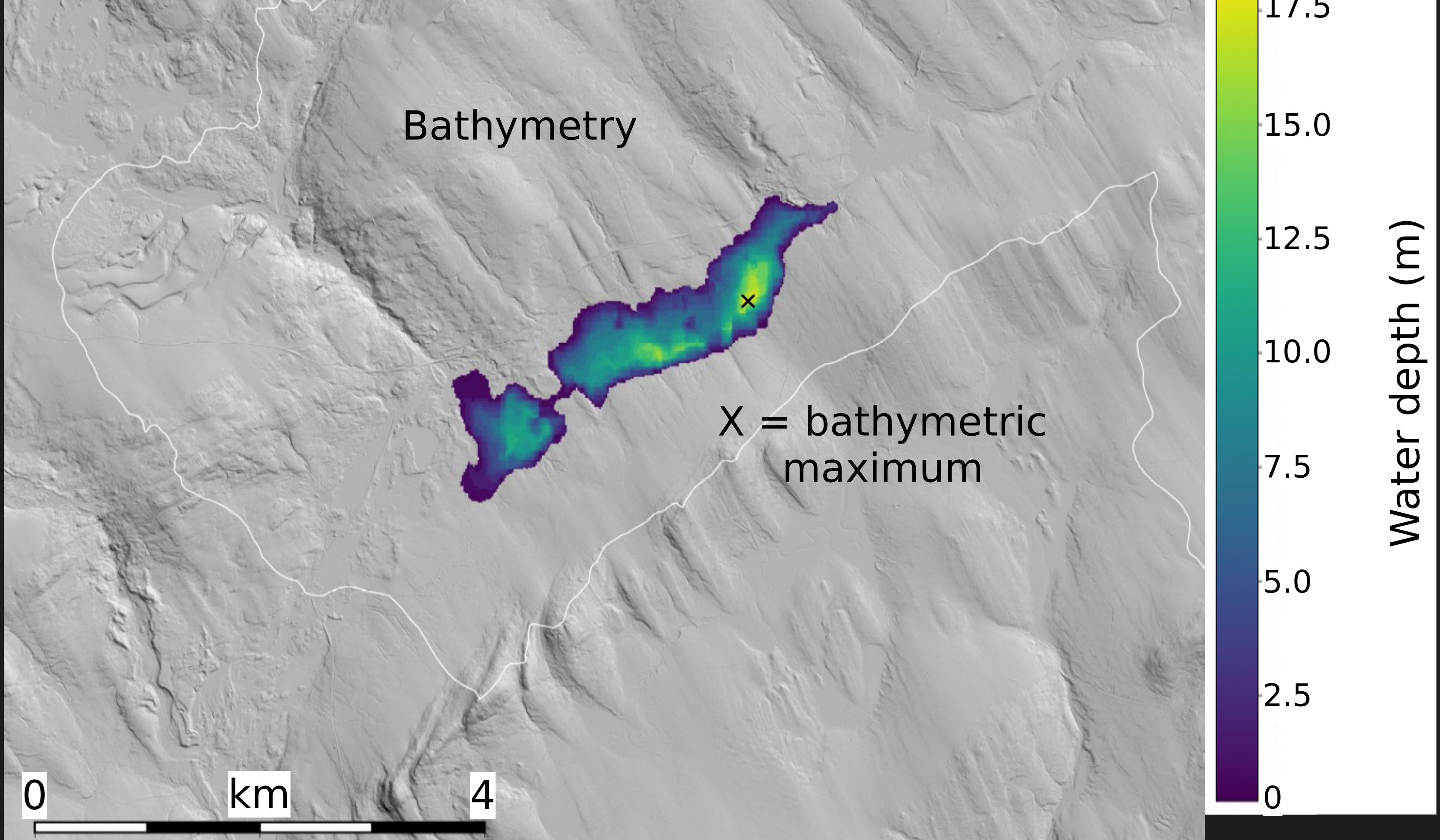


Study site


Site location
47°N
46°N
45°N
44°N
43°N
71°W
70°W
69°W
68°W
67°W
Mt. Katahdin
Kingsbury Pond
Bangor
Augusta
Acadia NP
Portland


0
km
2
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0
Water depth (m)

Subglacial paleosurface is complex!



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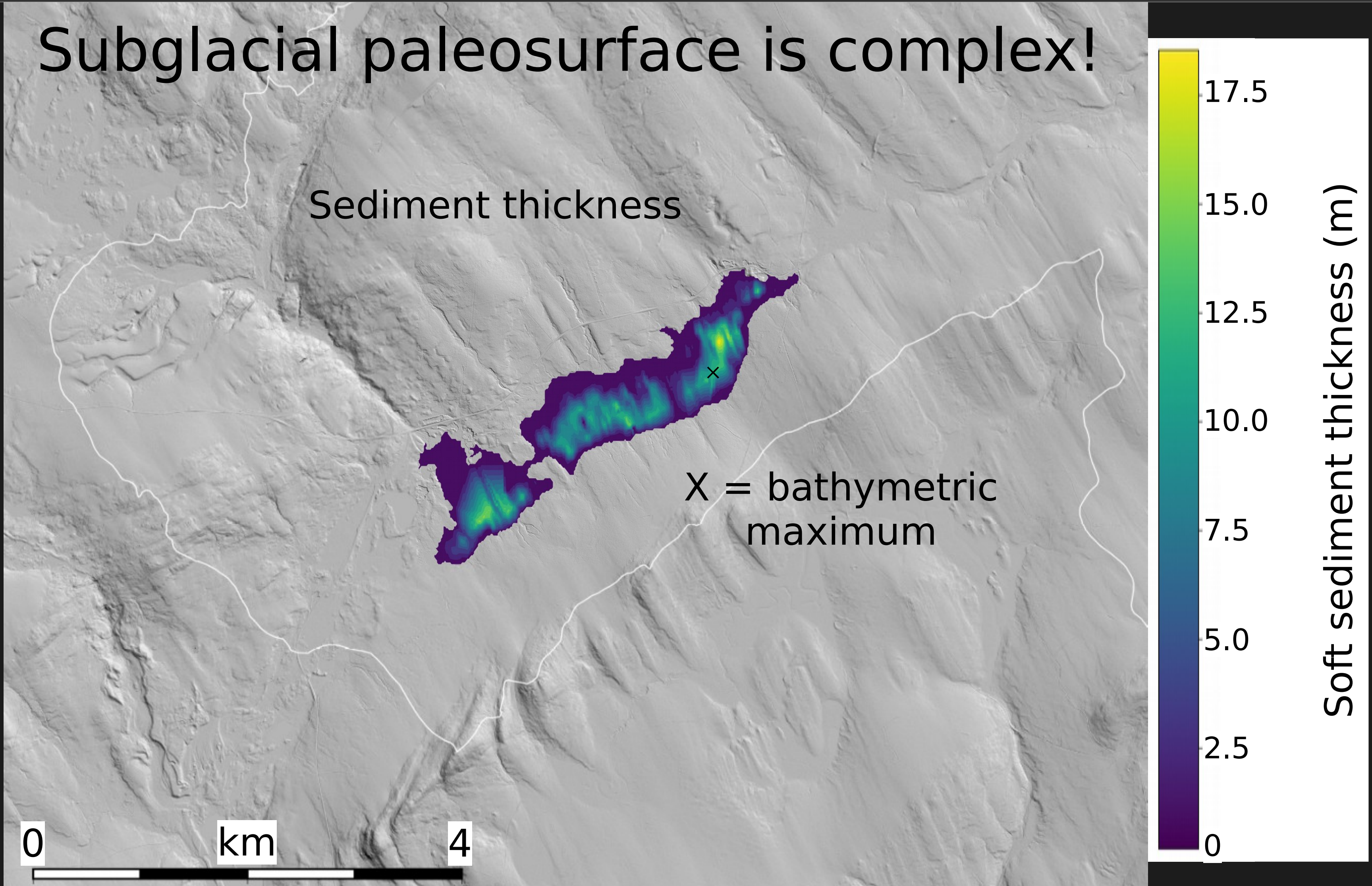
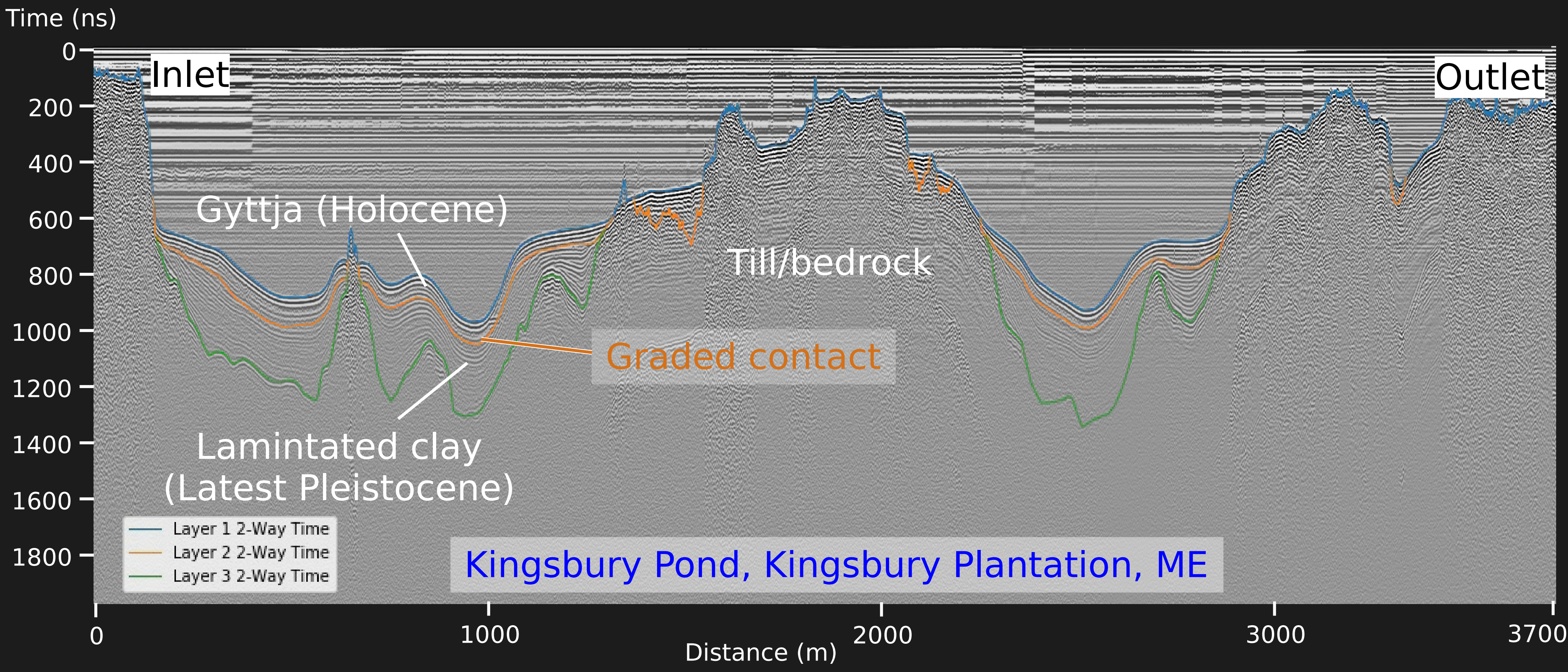
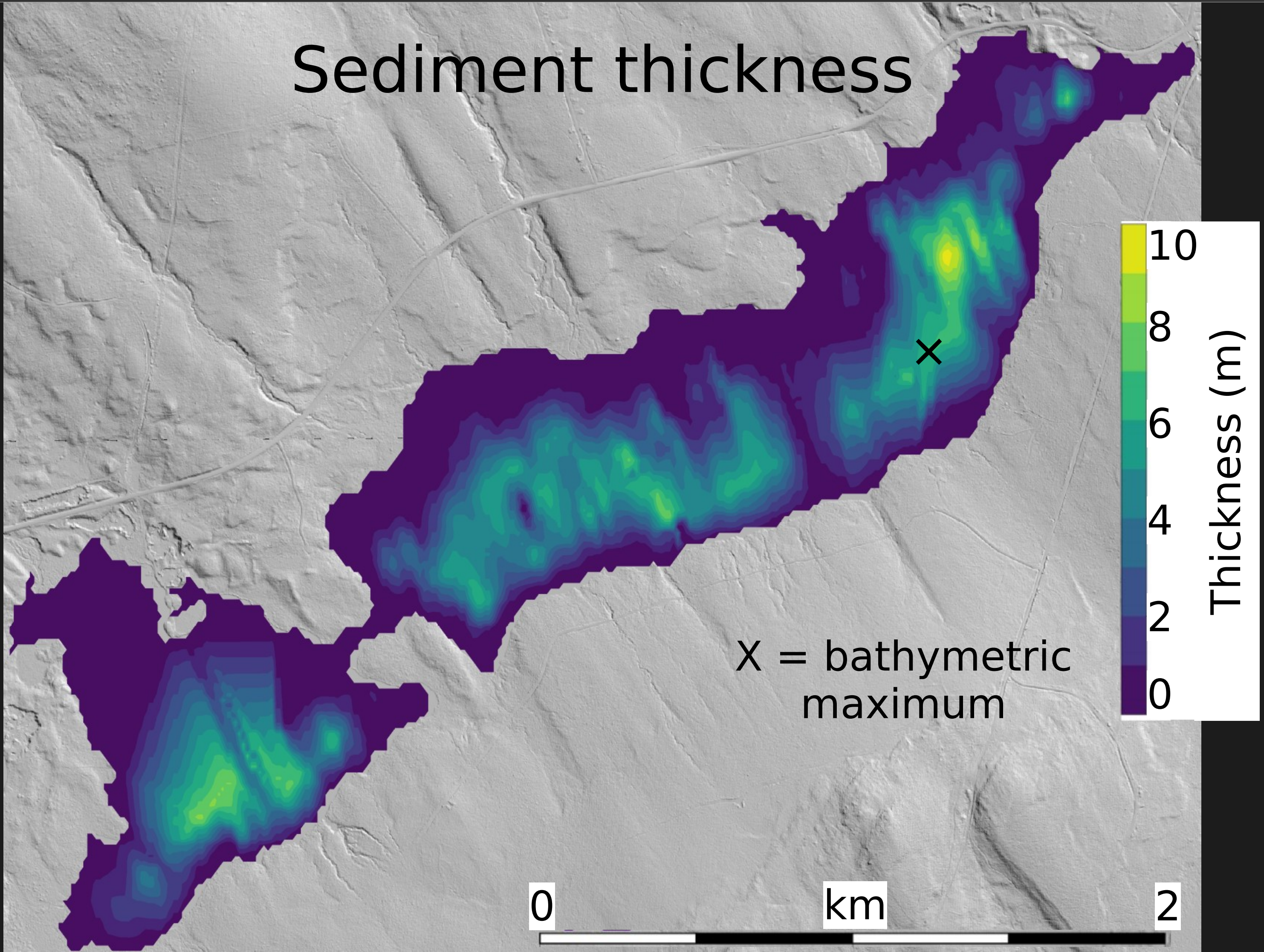
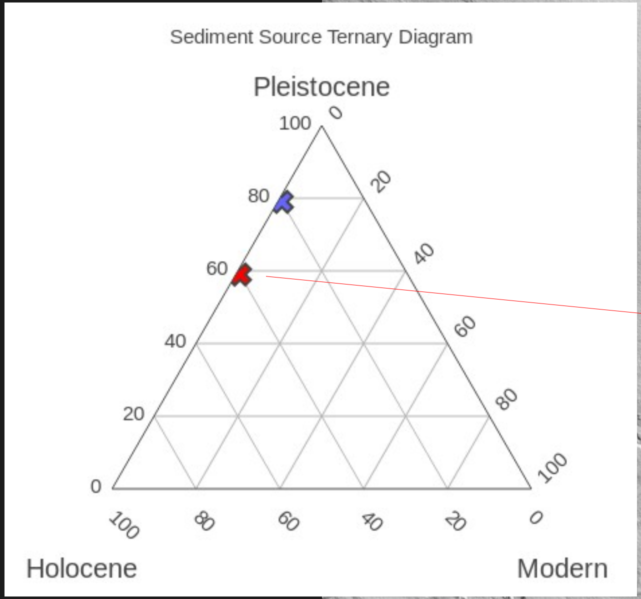


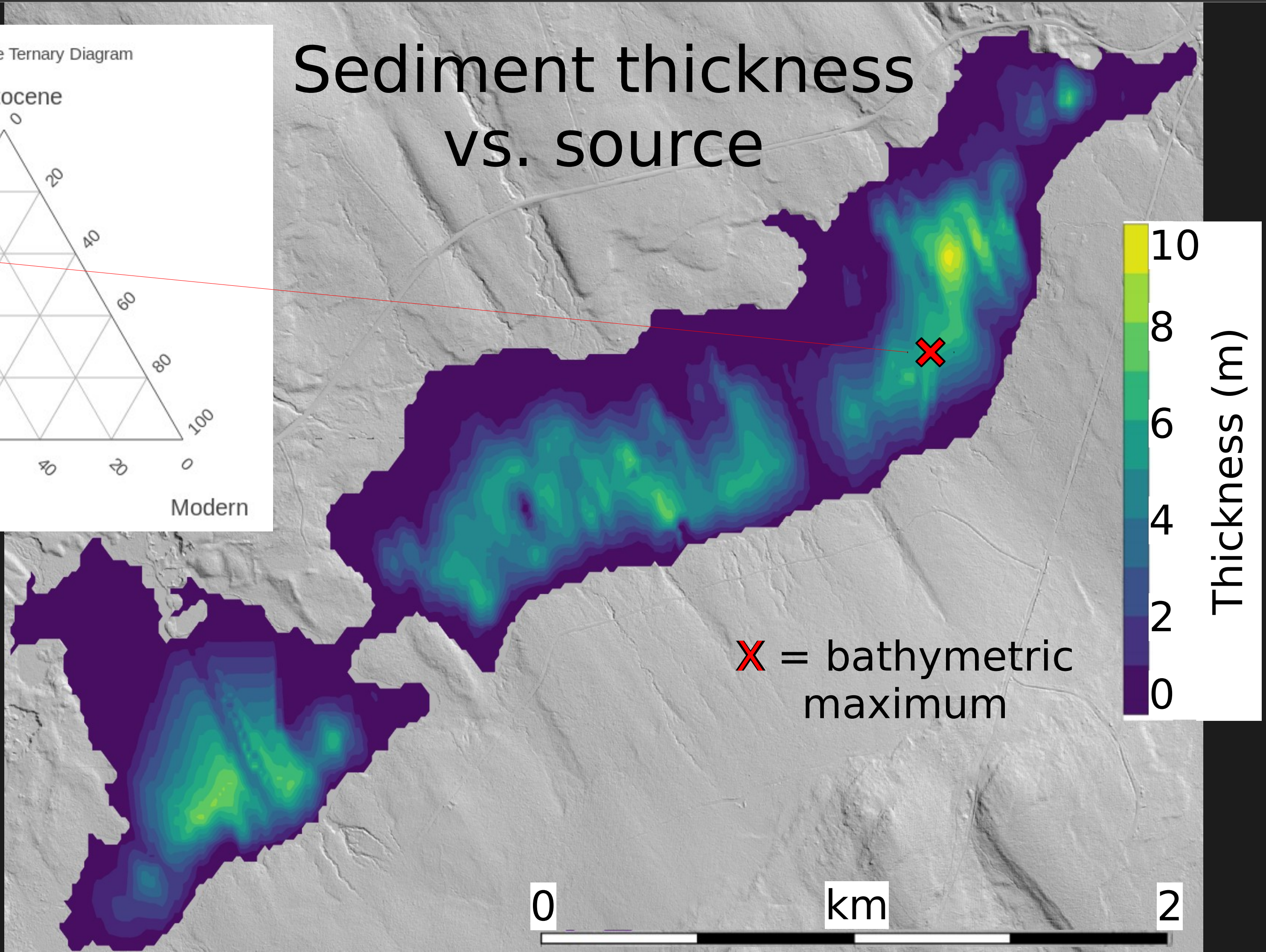
Typical Kingsbury Pond radar transect



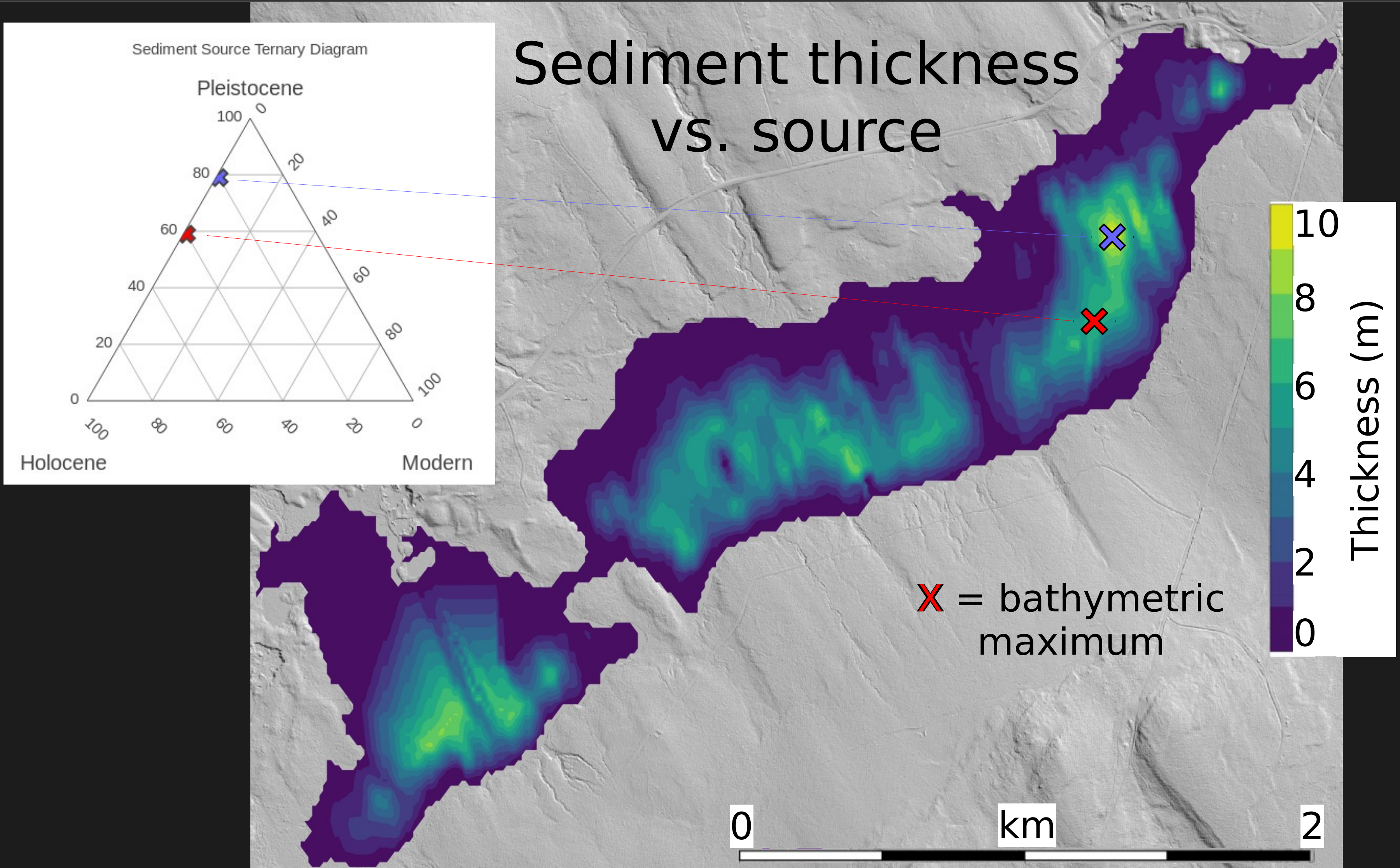

Sediment thickness
X = bathymetric maximum
Thickness (m)
0
2
4
6
8
10
0
km
2

Sediment thickness vs. source





Sediment thickness vs. source



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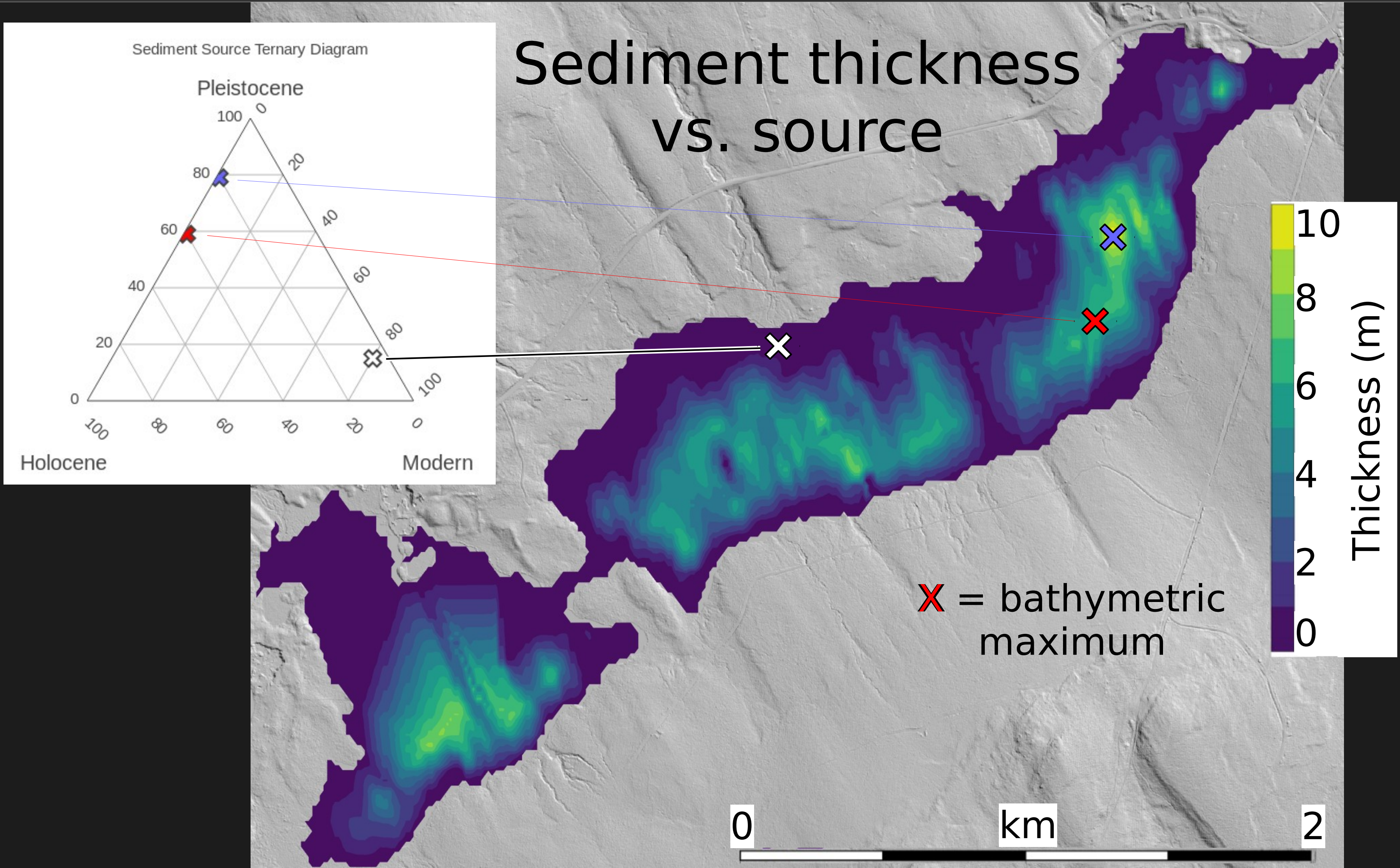
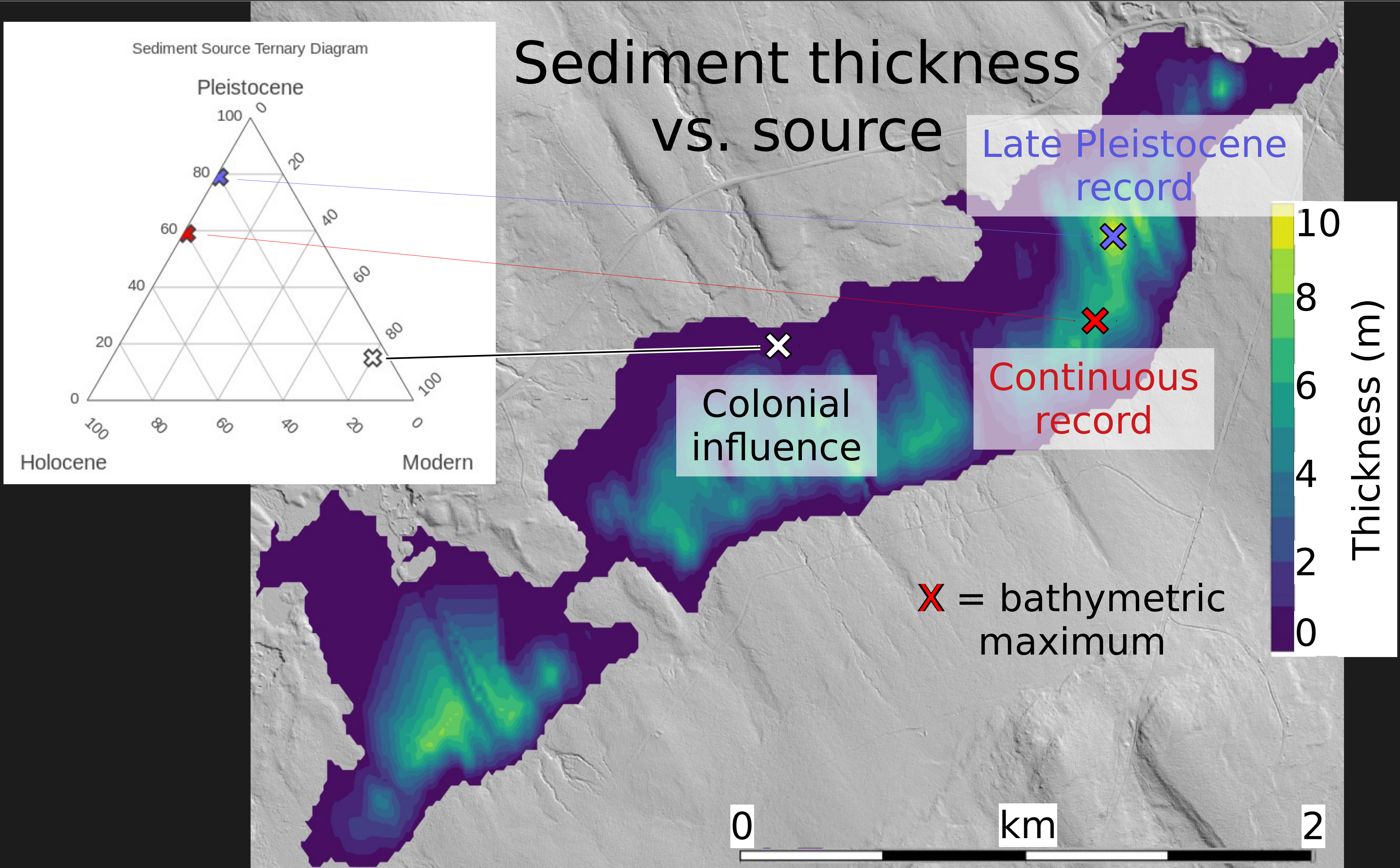


Sediment thickness vs. source



Summary

- Complexity has traditionally been a challenge in the lake coring community
- GPR can help establish:
  - Where to place core sites
  - Stratigraphic context for sites

Coring

Acknowledgments (Questions?)

- University of Maine Geodynamics and Watershed Processes & Sustainability Research groups (coring)
- Colby College Geology Department (coring & analysis)
- University of Maine Physics Department (analysis)
- George Jacobsen (advice)
- Mariama Dryak, Kate Hruby, Aaron Chesler (advice & moral support)

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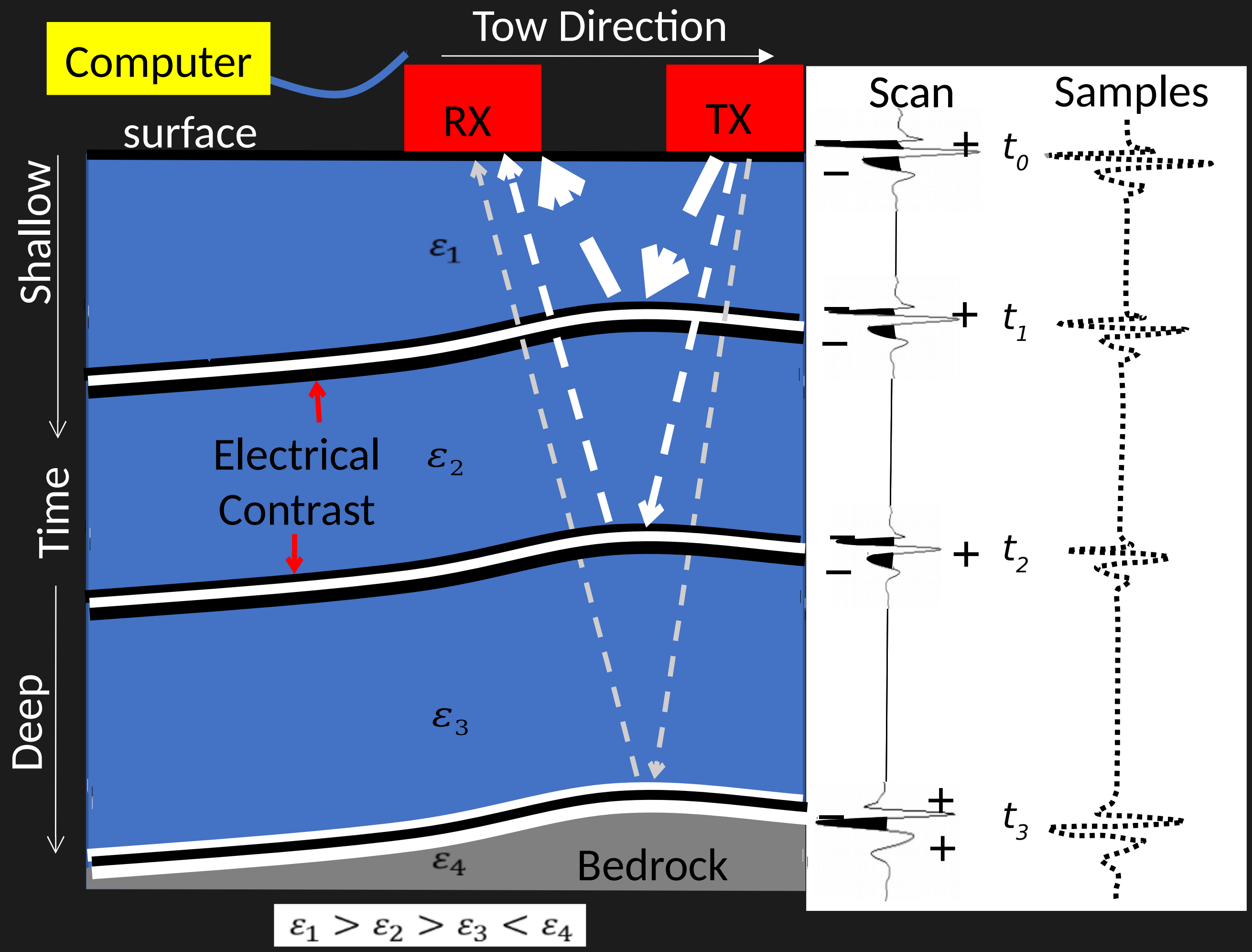
Jacobson, G.L., Bradshaw, R.H.W., 1981. The Selection of Sites for Paleovegetational Studies. *Quaternary Research* 16, 80–96. https://doi.org/10.1016/0033-5894(81)90129-0

Ground-Penetrating Radar (GPR) or Impulse Radar



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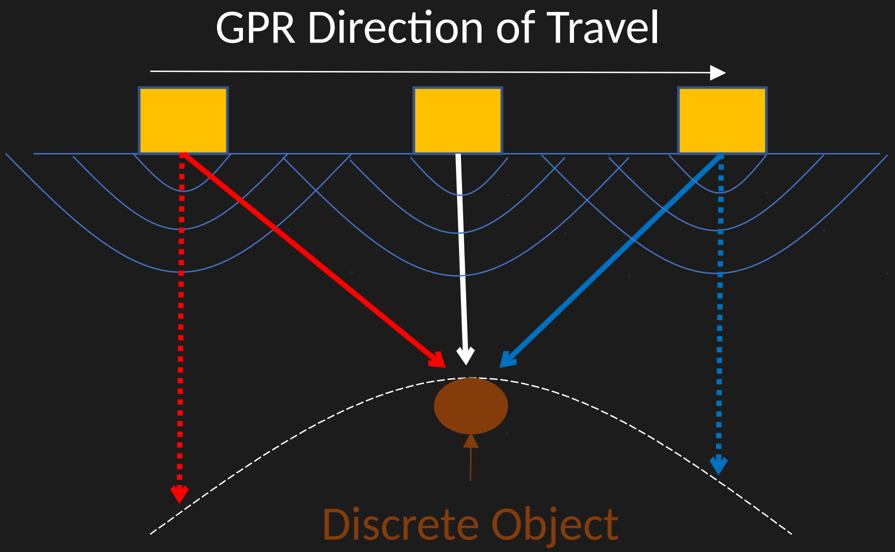
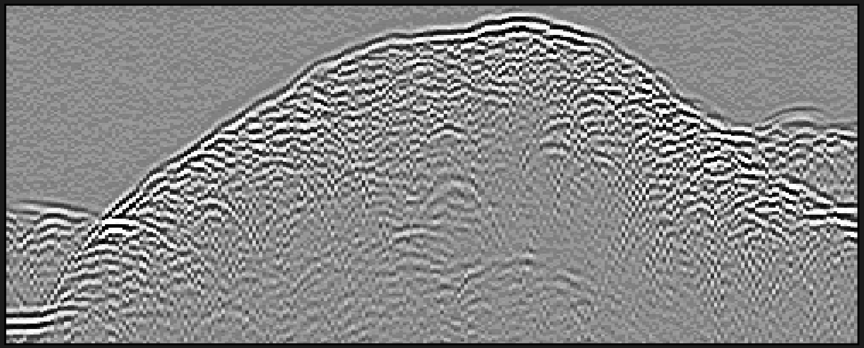
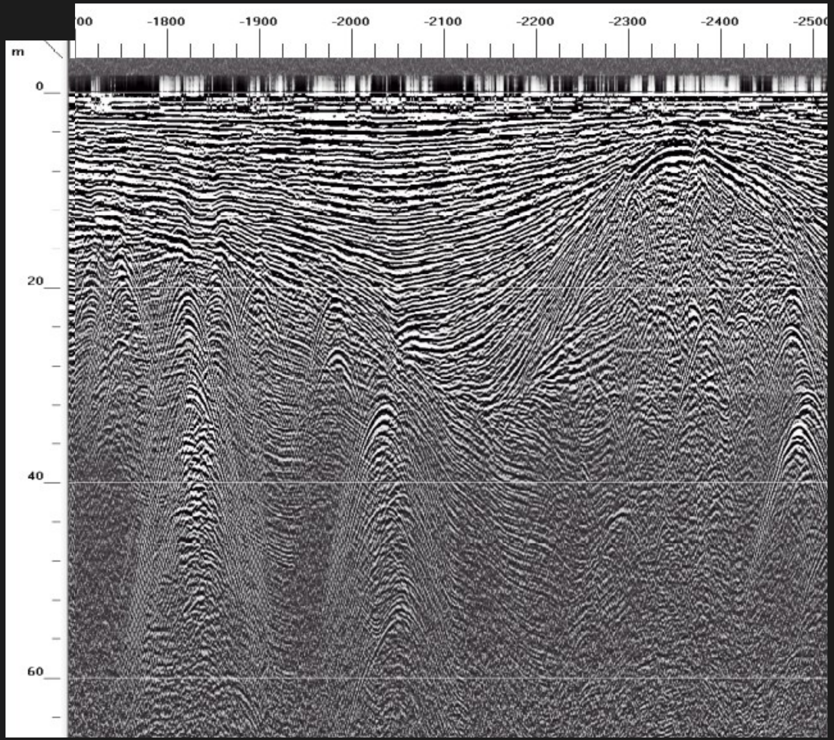
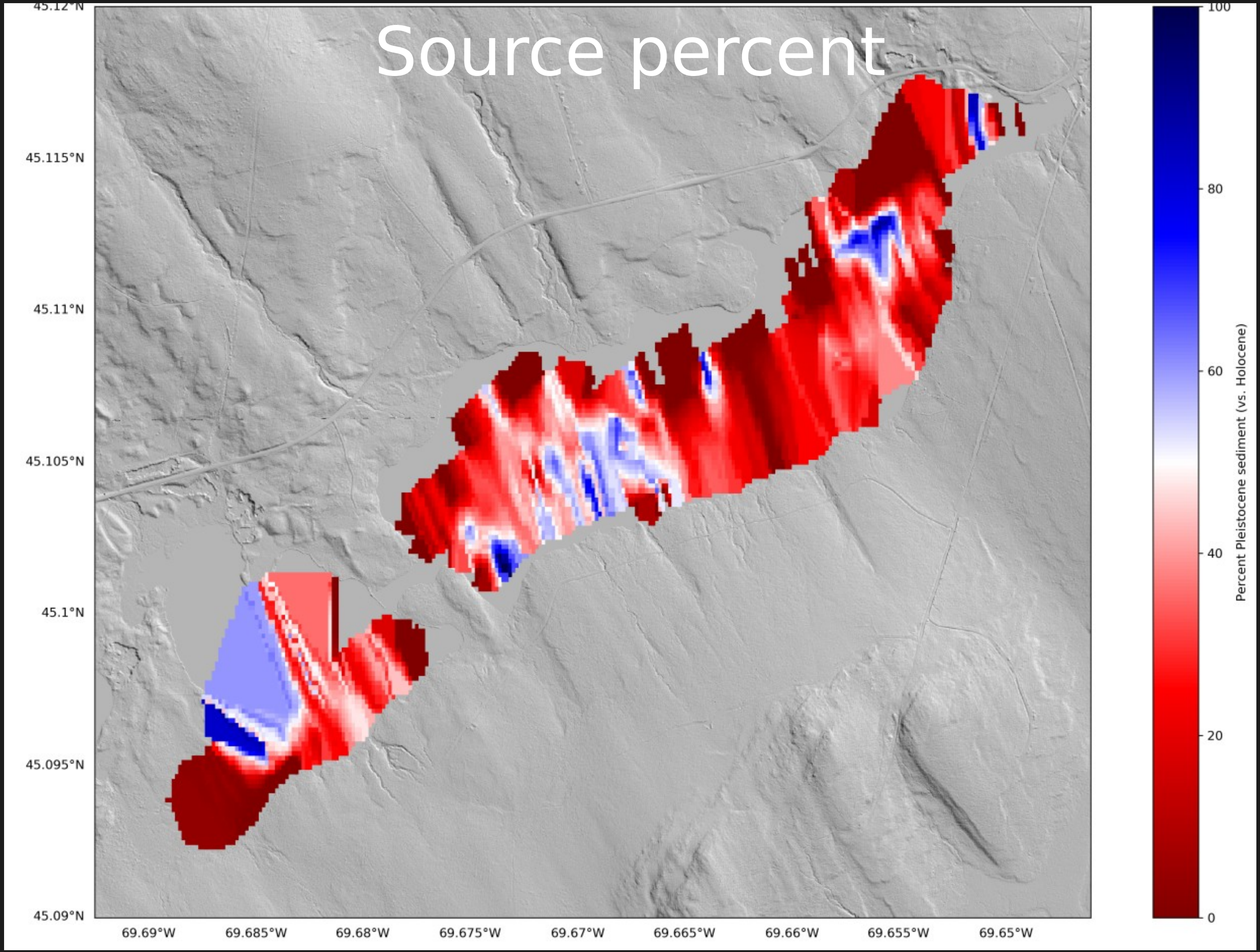




Key Points:

- Hyperbolas
- Off-Axis Reflections




Source percent
45.12°N
45.115°N
45.11°N
45.105°N
45.1°N
45.095°N
45.09°N
69.69°W
69.685°W
69.68°W
69.675°W
69.67°W
69.665°W
69.66°W
69.655°W
69.65°W
Percent Pleistocene sediment (vs. Holocene)
100
80
60
40
20
0