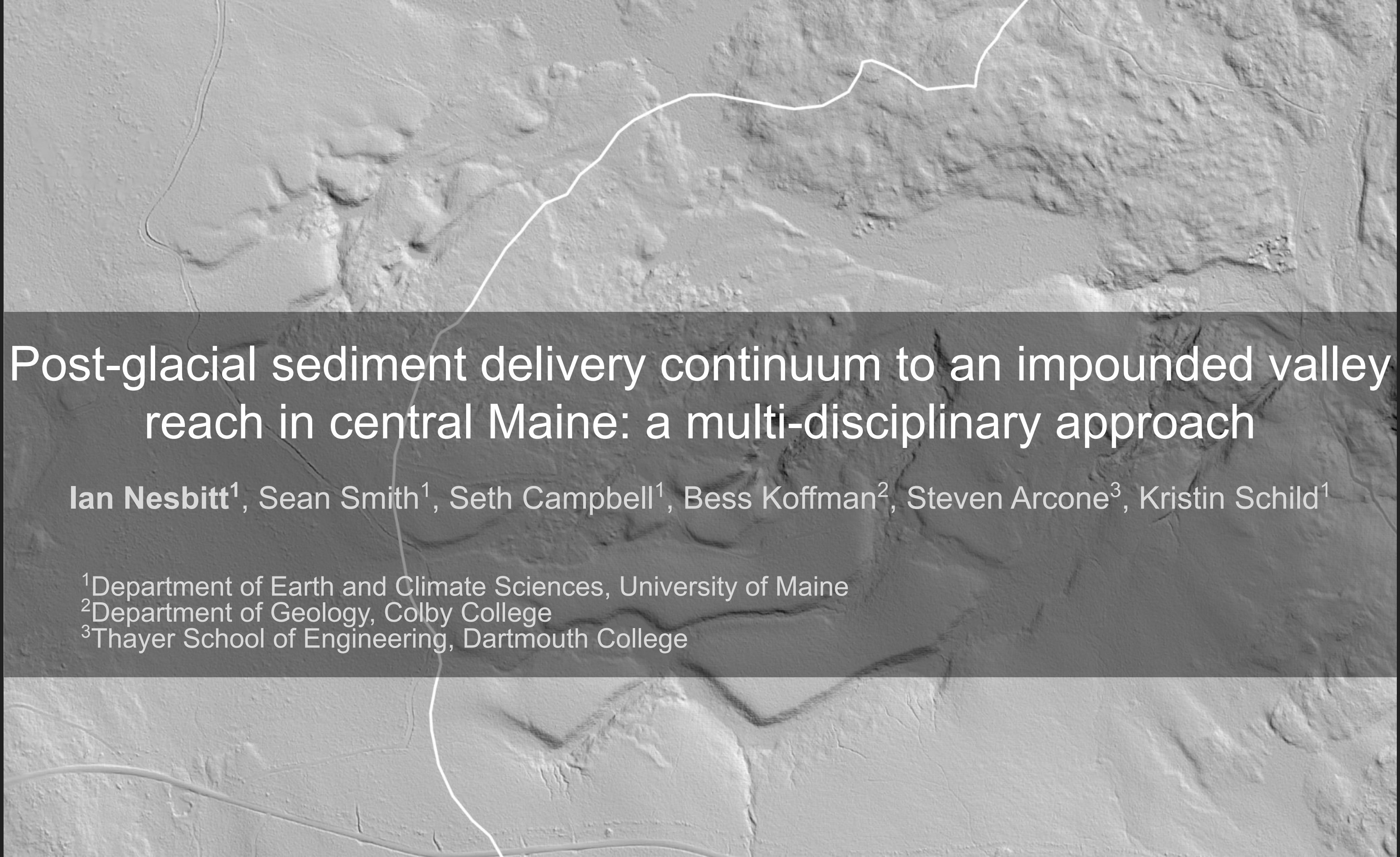

Post-glacial sediment delivery continuum to an impounded valley reach in central Maine: a multi-disciplinary approach

Ian Nesbitt[1], Sean Smith[1], Seth Campbell[1], Bess Koffman[2], Steven Arcone[3], Kristin Schild[1]

[1]Department of Earth and Climate Sciences, University of Maine
[2]Department of Geology, Colby College
[3]Thayer School of Engineering, Dartmouth College

Problems and Importance

Sediment delivery studies are critical to understanding landscape evolution, but:

1. Lack of studies in formerly-glaciated regions
2. Sediment volume is tricky to measure - lakes are complex & not man made
3. Sedimentation time is tricky to measure - ice-off age is not well known

Problem 1

Sedimentation within the North American glacial limit is under-studied.

Especially compared with other regions (e.g. Roehl, 1962; Happ, 1975; Smith and Wilcock, 2015)

SEDIMENT SOURCE AREAS, DELIVERY RATIOS (*) AND INFLUENCING MORPHOLOGICAL FACTORS

JOHN W. ROEHL (**)

Fig. 1 — Approximate Location of Watersheds in which Erosion study was made.

VALLEY SEDIMENTATION AS A FACTOR IN SEDIMENT-YIELD DETERMINATIONS

By Stafford C. Happ[1]

SCS VALLEY SEDIMENT SURVEYS

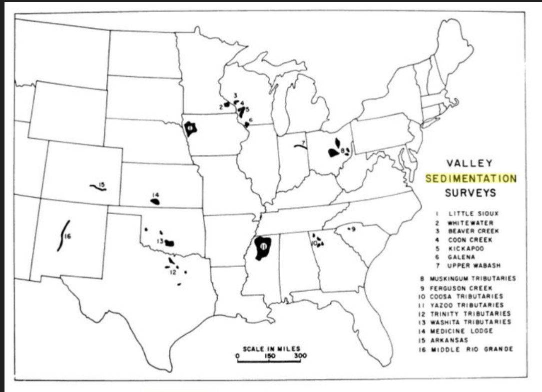

FIGURE 1.—Location of valley sedimentation surveys, 1935–41, for which ranges were profiled and marked for future recovery.

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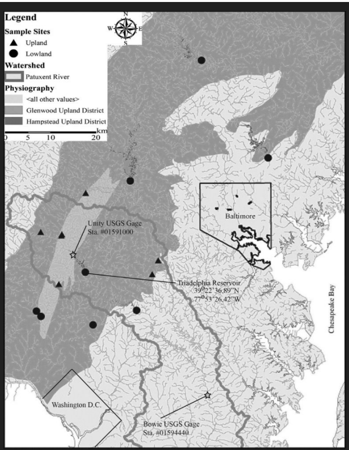
Upland sediment supply and its relation to watershed sediment delivery in the contemporary mid-Atlantic Piedmont (U.S.A.)

S.M.C. Smith [a,*], P.R. Wilcock [b]

[a] University of Maine, School of Earth and Climate Sciences, Bryand Global Science Center, Orono, ME 04473, USA
[b] Johns Hopkins University, Department of Geography and Environmental Engineering, 3400 North Charles Street, Ames Hall 313, Baltimore, MD 21218, USA



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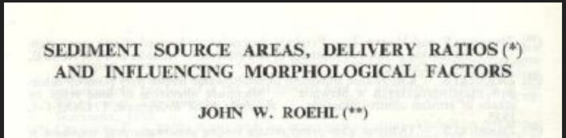
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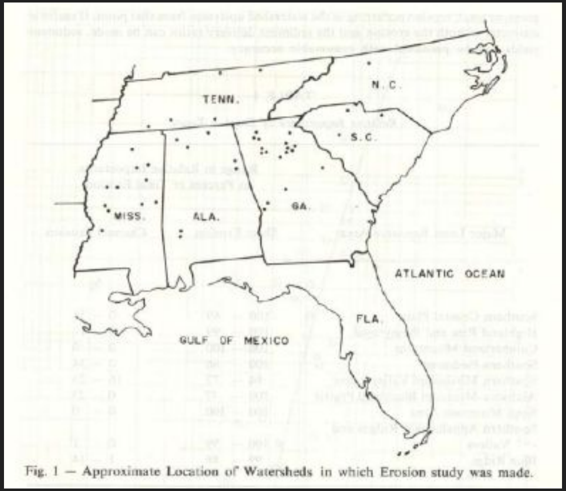
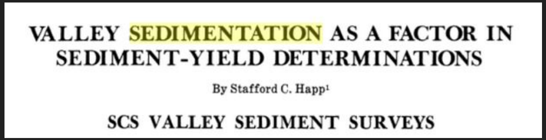


Fig. 1 — Approximate Location of Watersheds in which Erosion study was made.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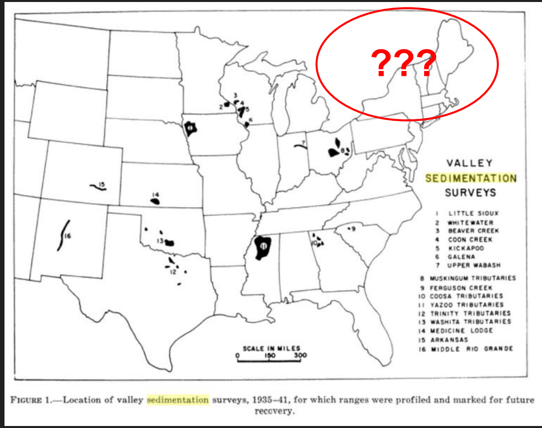
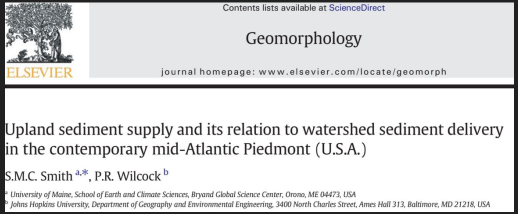


FIGURE 1.—Location of valley sedimentation surveys, 1935–41, for which ranges were profiled and marked for future recovery.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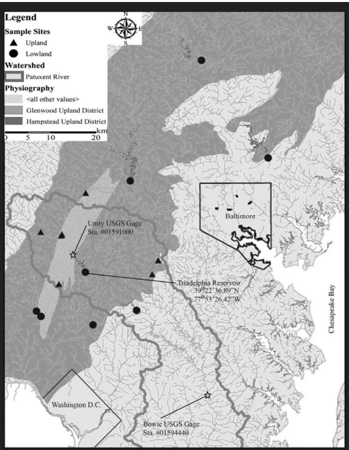
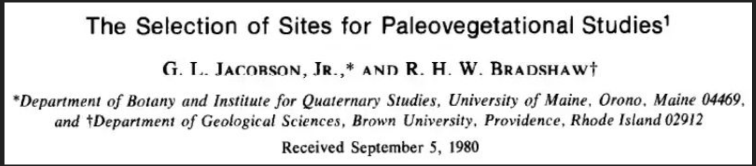


Problem 2

Most studies use point-source methods (cores, probes) for volume estimates.

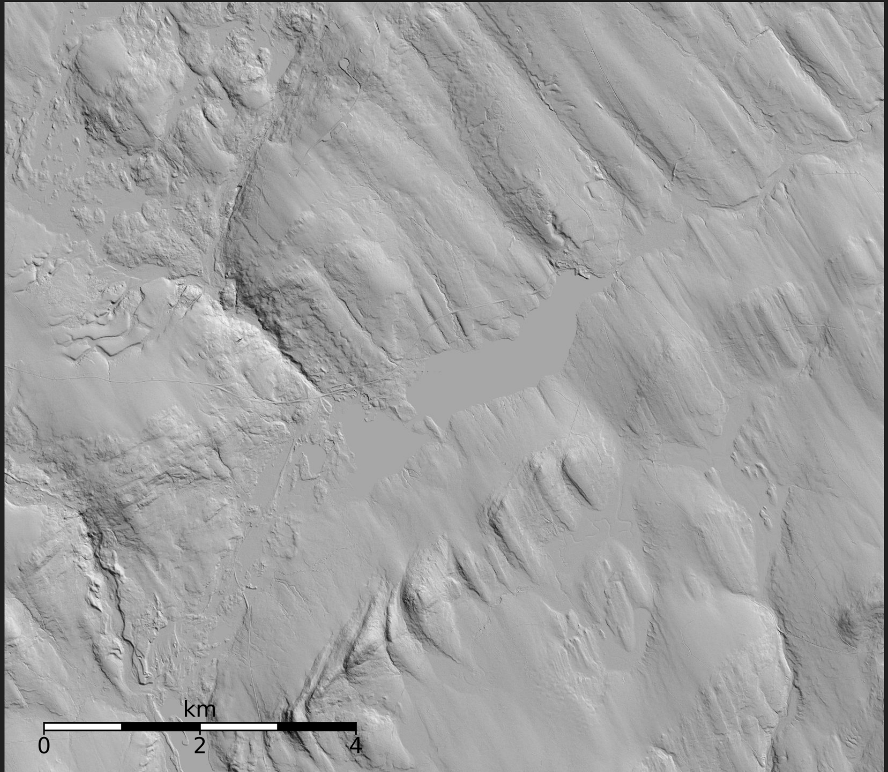
Assumes spatial predictability in highly variable landscapes (Jacobson and Bradshaw, 1982)


The Selection of Sites for Paleovegetational Studies[1]

G. L. Jacobson, Jr.,* and R. H. W. Bradshaw†

*Department of Botany and Institute for Quaternary Studies, University of Maine, Orono, Maine 04469, and †Department of Geological Sciences, Brown University, Providence, Rhode Island 02912

Received September 5, 1980



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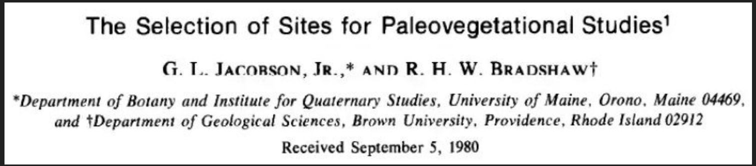
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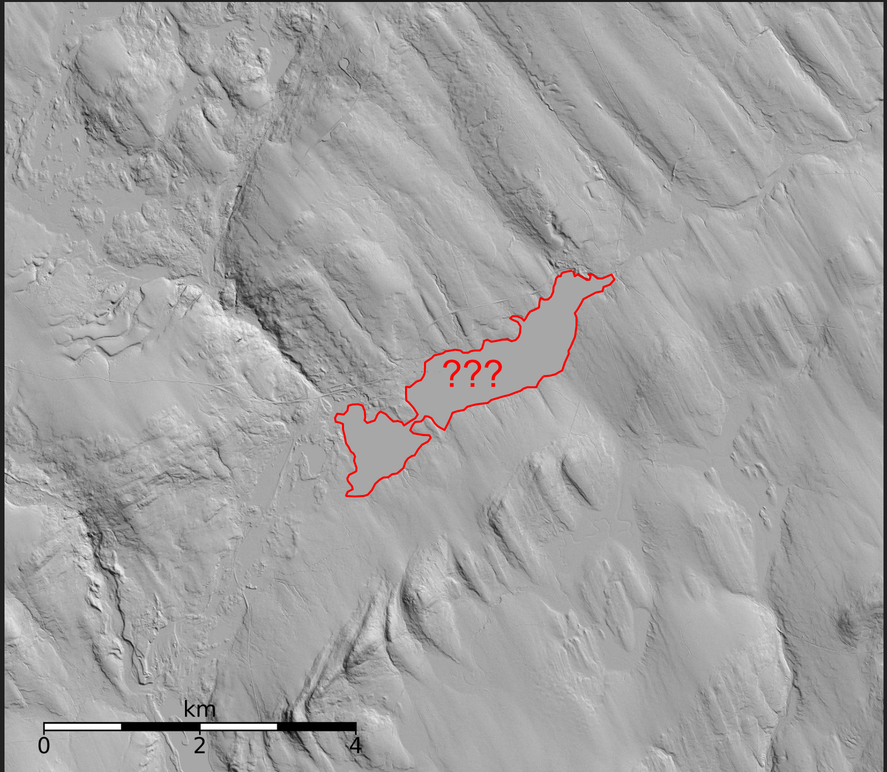


Need many cores to create a decent volume model here!

Objectives

1. Use core analysis and geophysics to estimate sediment delivery rate and volume for deglaciated period

2. Establish a delivery rate continuum

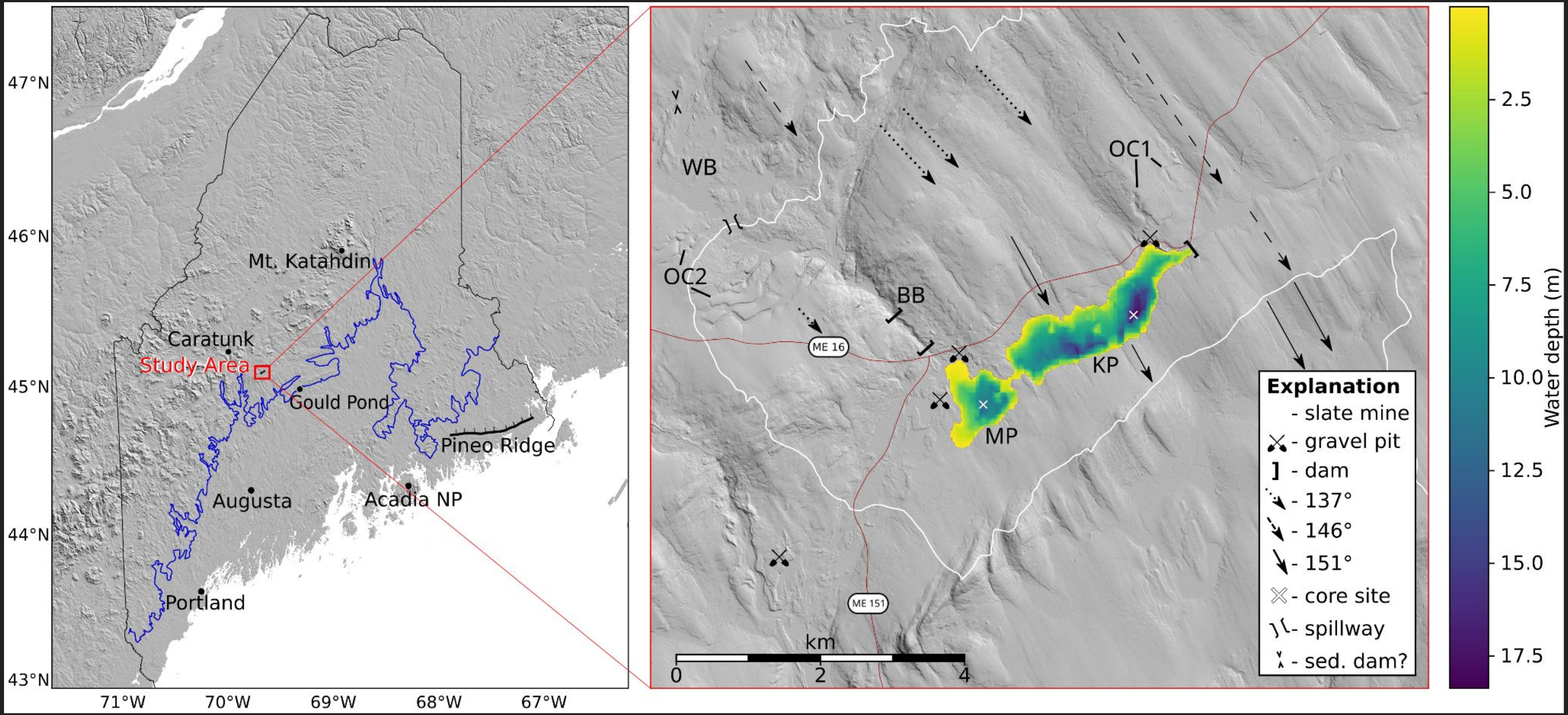
3. Attempt to use landscape features to help explain events in the continuum

4. Quantify the effects of human influence (dams, logging, development, etc.)

Study location - selection criteria

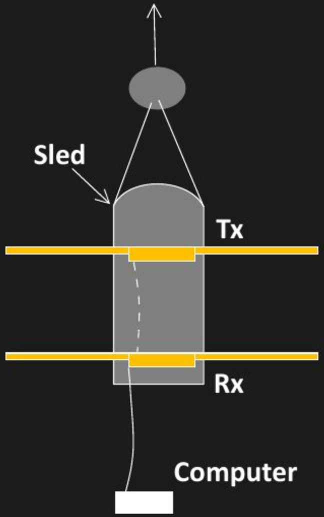
- Low-mid Strahler order watershed in western Penobscot
- Above marine transgression
- Shallow and fresh enough to measure sediment column with radar
- Deep enough to be oligotrophic
- Dam on lake outlet

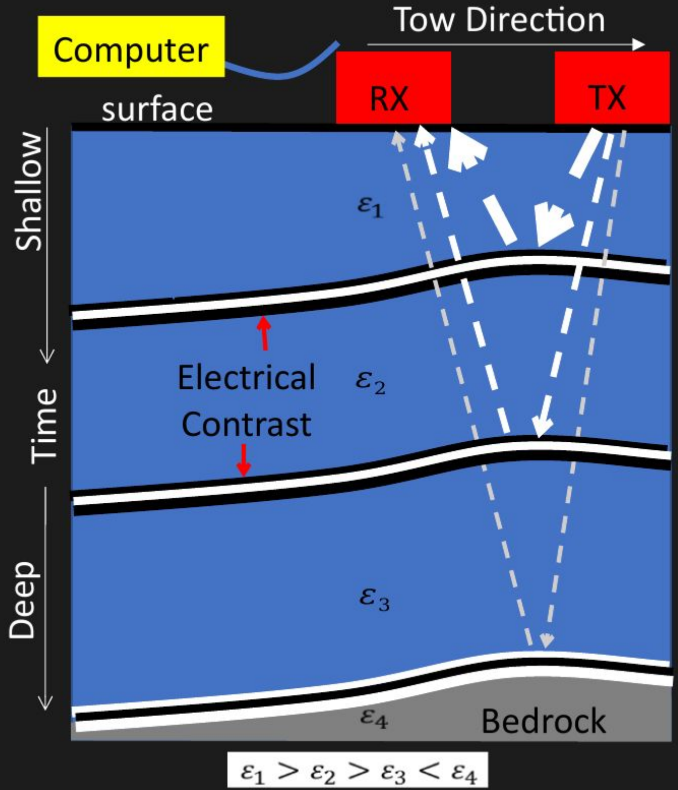
Study location - Kingsbury/Mayfield Ponds (K-M)



White line = Penobscot-Kennebec watershed boundary

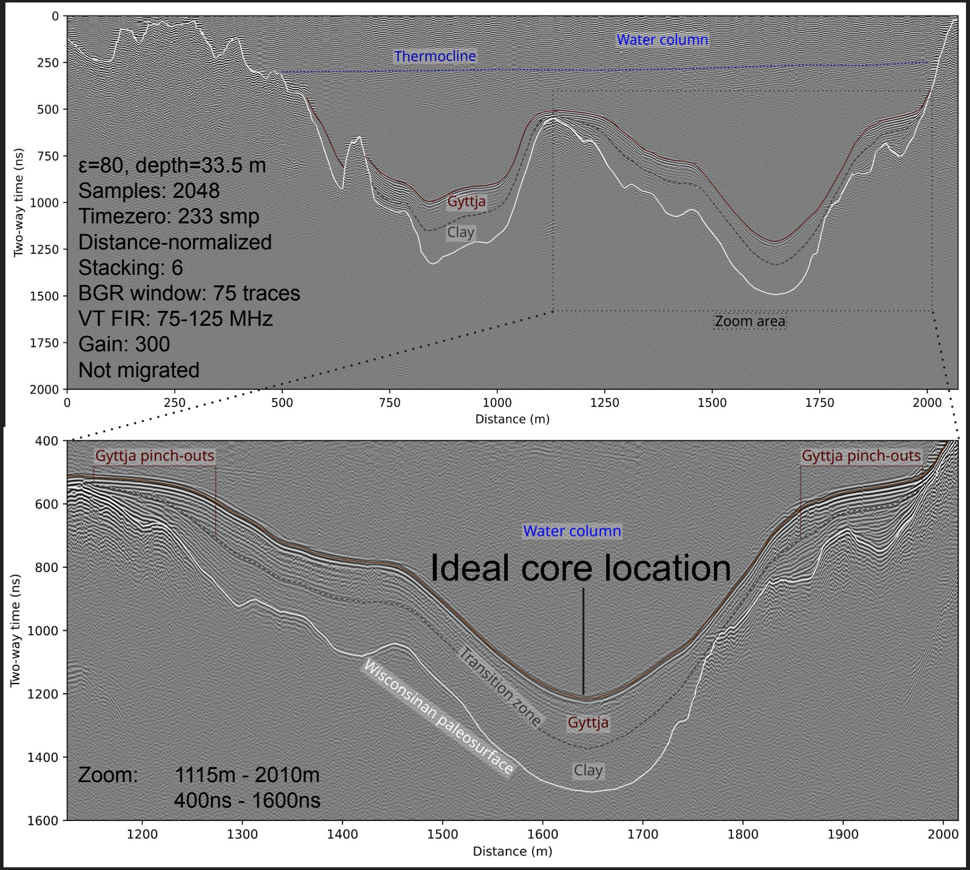
Methods - ground-penetrating radar





Radar processing & core location selection

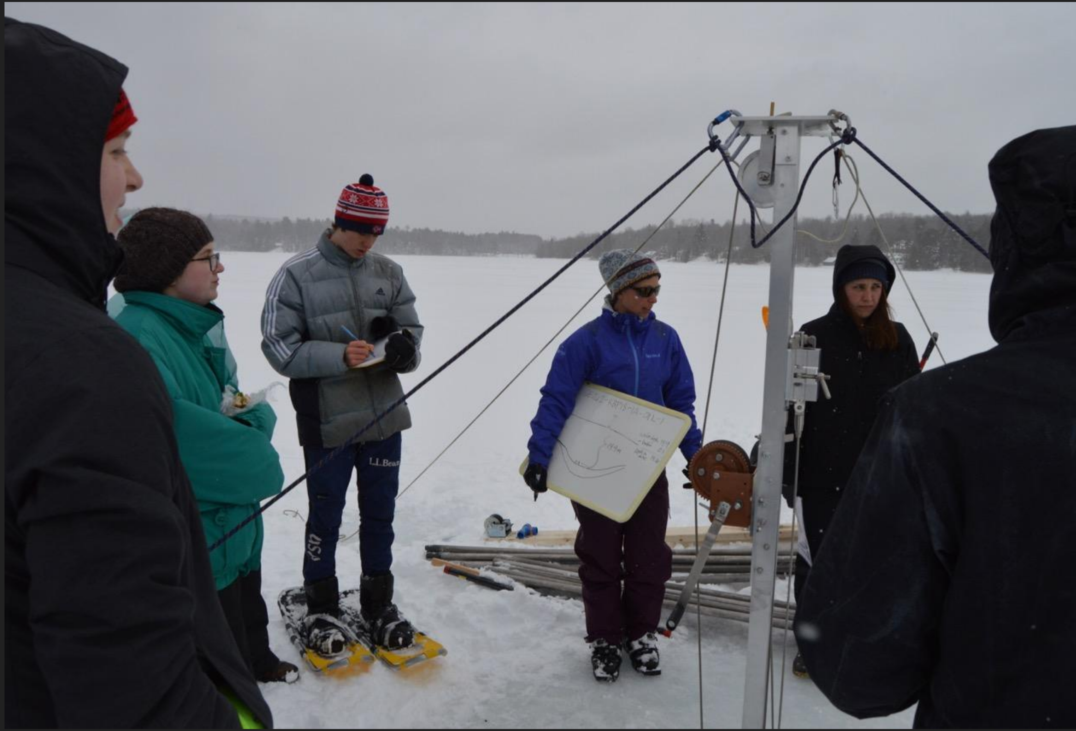
- readgssi (Nesbitt et al. 2021) for distance normalization
- RADAN 7 for filtering and picking
- XYZ of picks to surfaces in QGIS



Coring and analysis

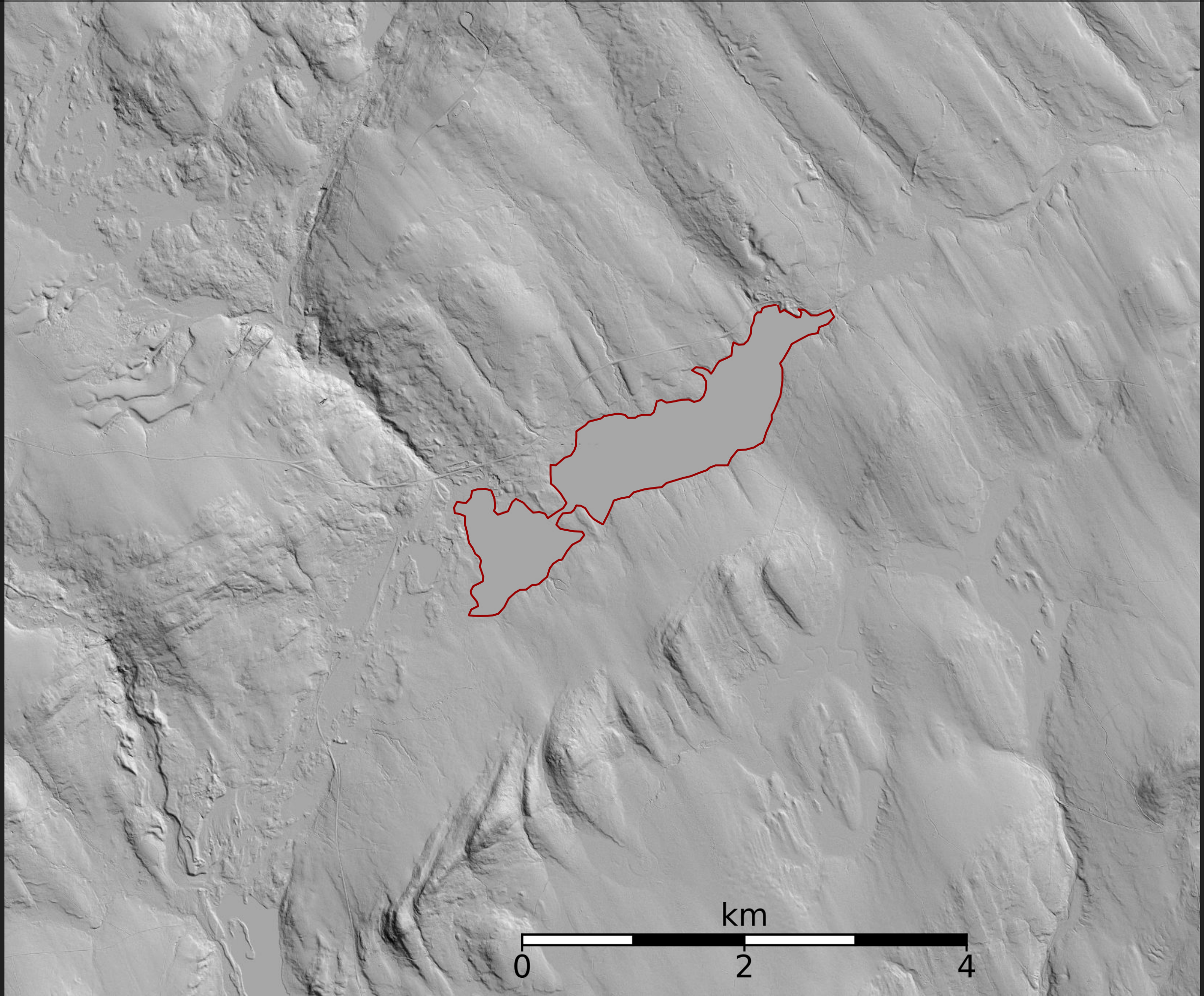
- Livingstone (1955) style piston corer (pictured)

- Standard core analysis
- ^{14}C dates
- ^{210}Pb activity
- Matched core features with radar reflections



LiDAR

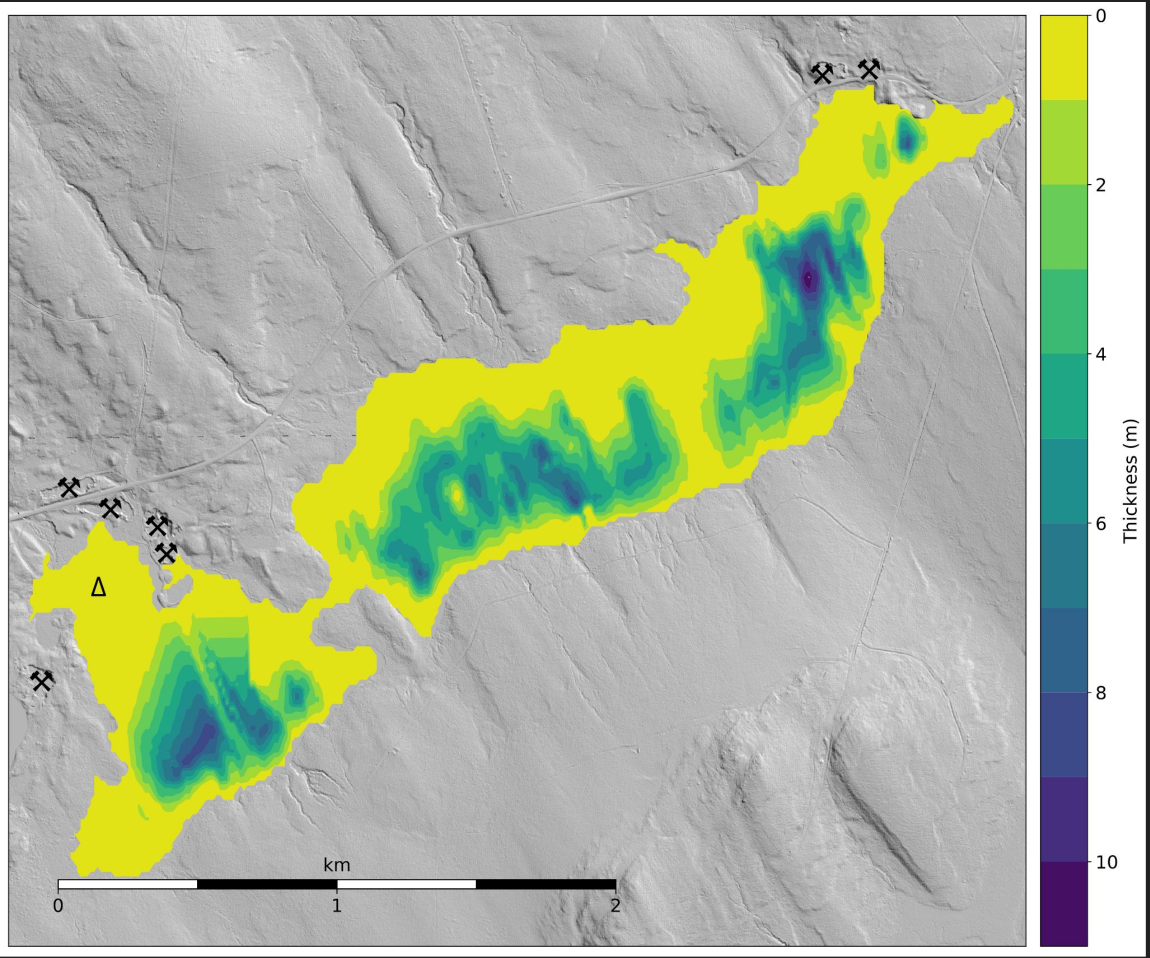
Key takeaway:
complex surface!



Radar pick analysis

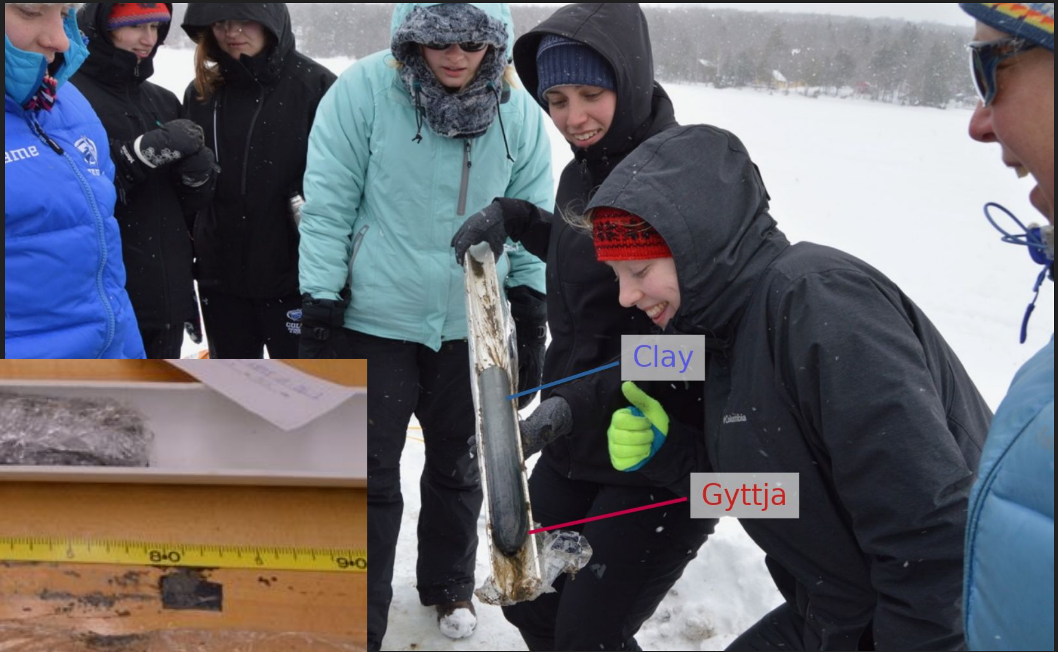
Key takeaways:
complex surface
+ sediment focusing
= complex sedimentation pattern

Note: Bigelow Brook delta sediments (symbolized as Δ) are too thick to evaluate with radar and are excluded here



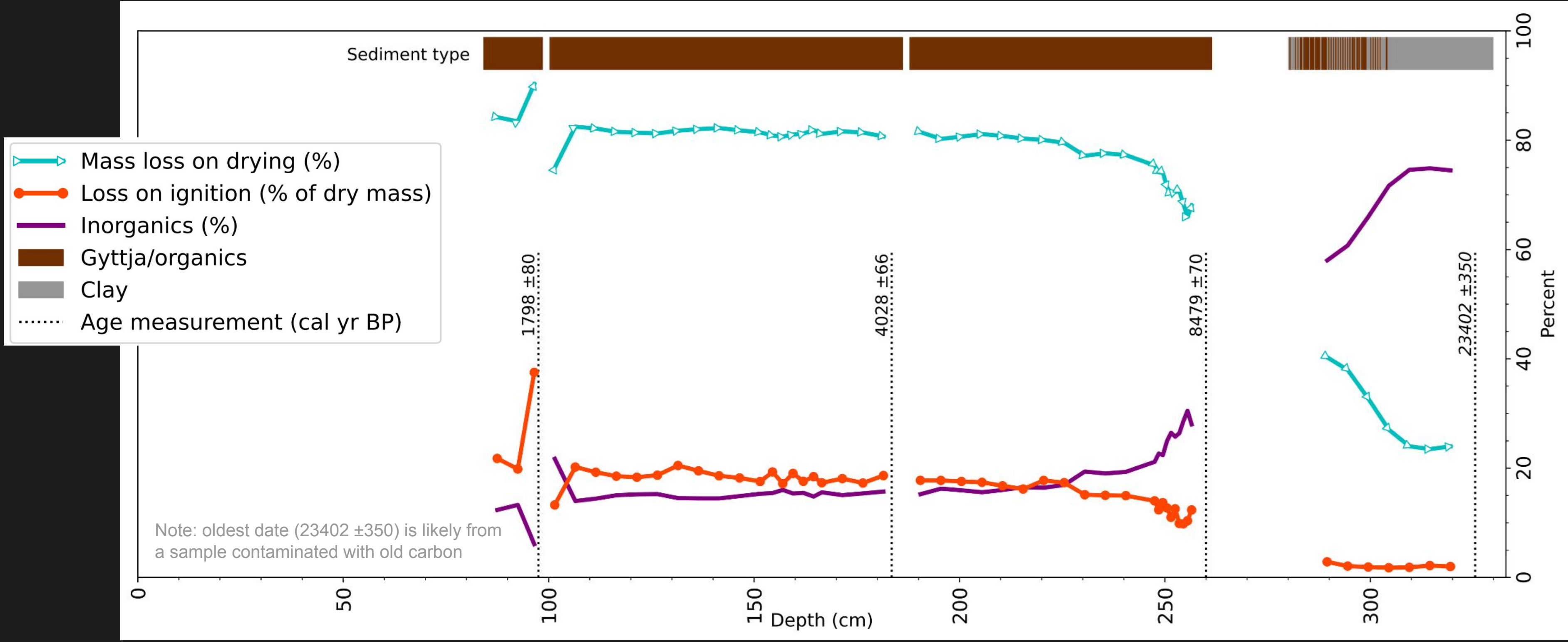
Gyttja-clay transition

Key takeaway:
Transition zone between gyttja and clay at 2.7-3.1 m



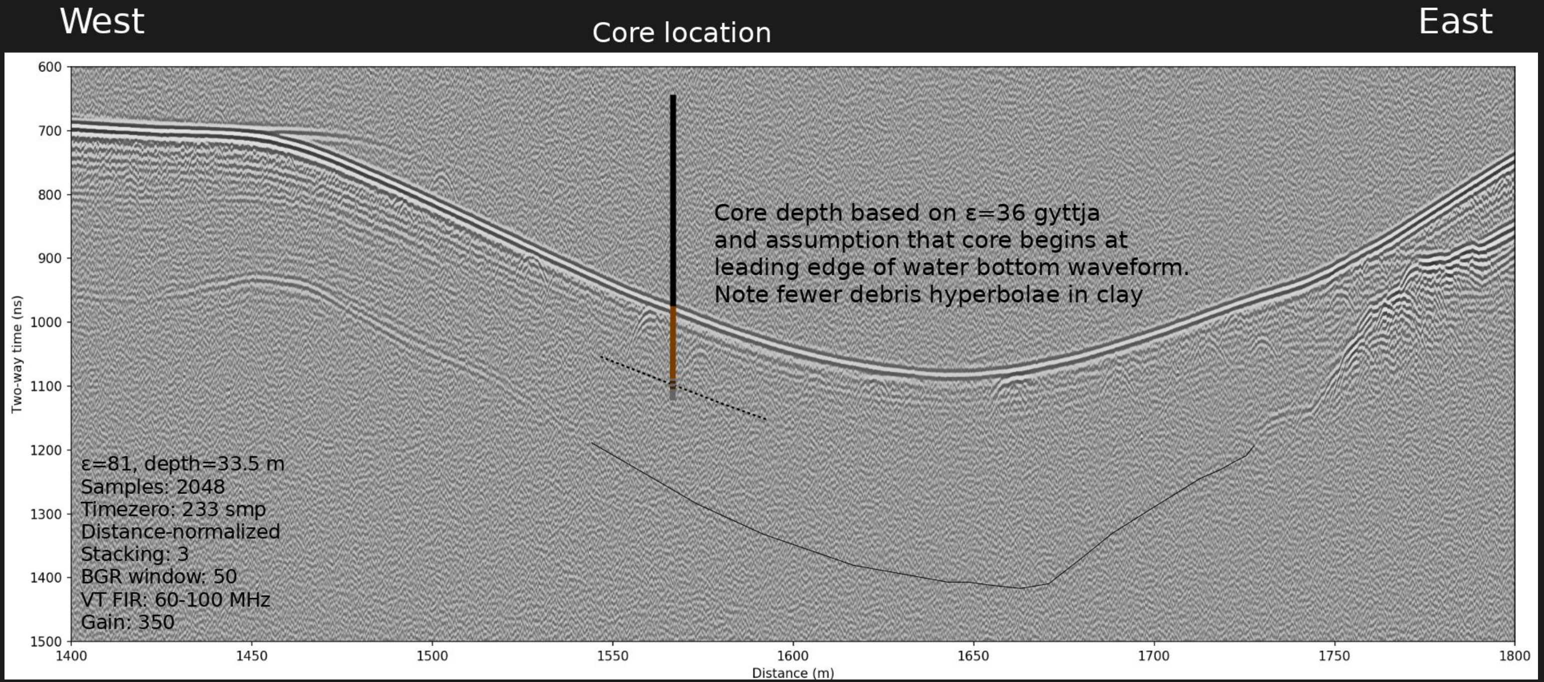
Core results and ^{14}C

Key takeaways:
- Major difference in water and organic content between pre- and post-transition
- Transition at around 8500 cal yr BP



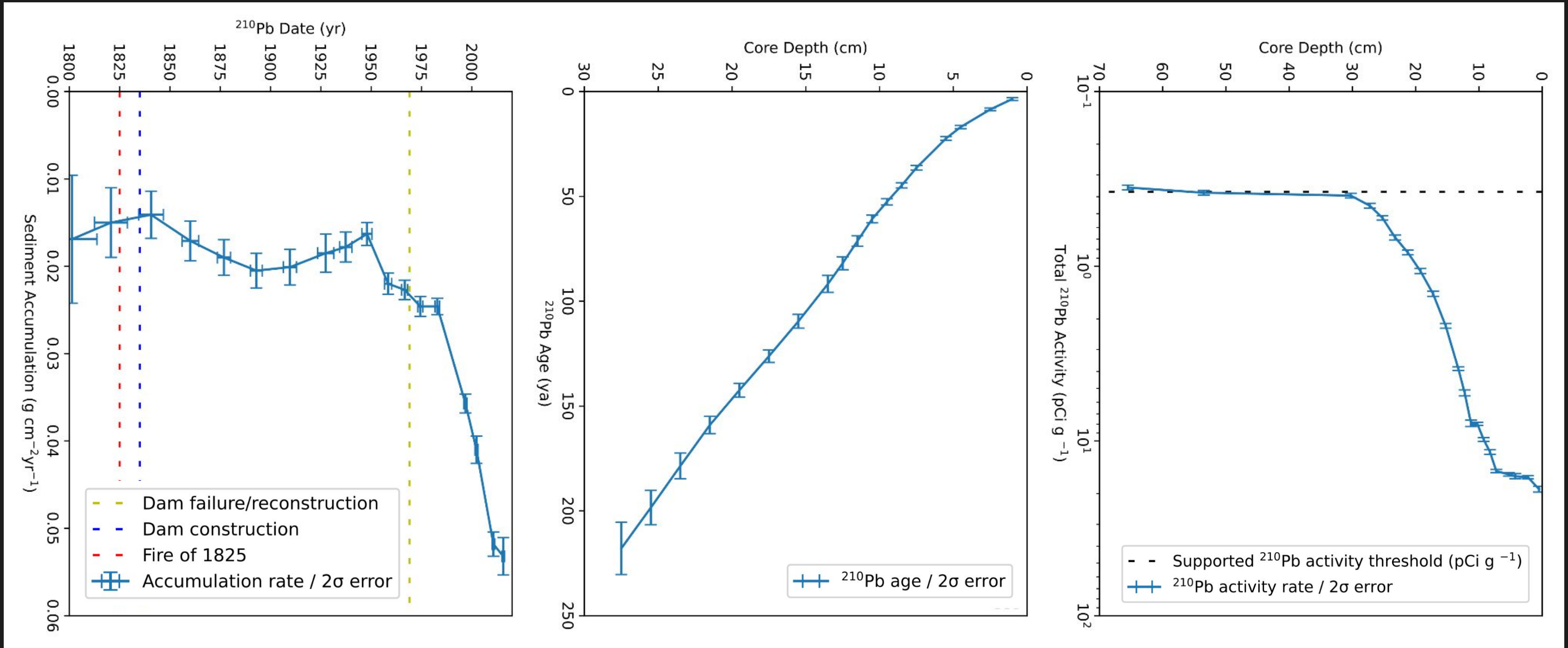
Core-radar comparison

Key takeaways:
- Core did not reach till surface



^{210}Pb results

Key takeaways:
- Major increase in sedimentation rate in mid 20th century



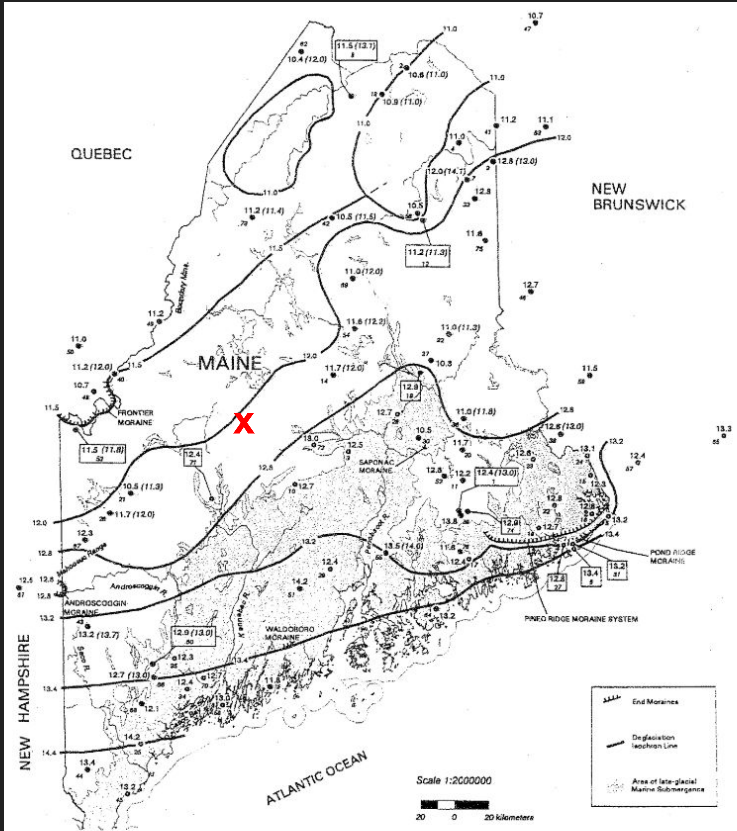
Deglaciation timing

Deglaciation age is probably between 13.0 and 14.2 cal ka BP

The deglaciation of Maine, U.S.A.

Harold W. Borns, Jr. [1], Lisa A. Doner [3], Christopher C. Dorion [1], George L. Jacobson Jr. [1], Michael R. Kaplan [4], Karl J. Kreutz, [1], Thomas V. Lowell [5], Woodrow B. Thompson [2] and Thomas K. Weddle, [2]

[1] *Institute for Quaternary and Climate Studies, University of Maine, Orono, Maine 04469, U.S.A.*
[2] *Maine Geological Survey, Augusta, Maine 04333-0022, U.S.A.*
[3] *Institute of Arctic and Alpine Research, University of Colorado, Boulder, Colorado 80309-0450, U.S.A.*
[4] *Department of Geology and Geophysics, University of Wisconsin, Madison, Wisconsin 53706, U.S.A.*
[5] *Department of Geology, University of Cincinnati, Cincinnati, Ohio 45221, U.S.A.*



X = study location

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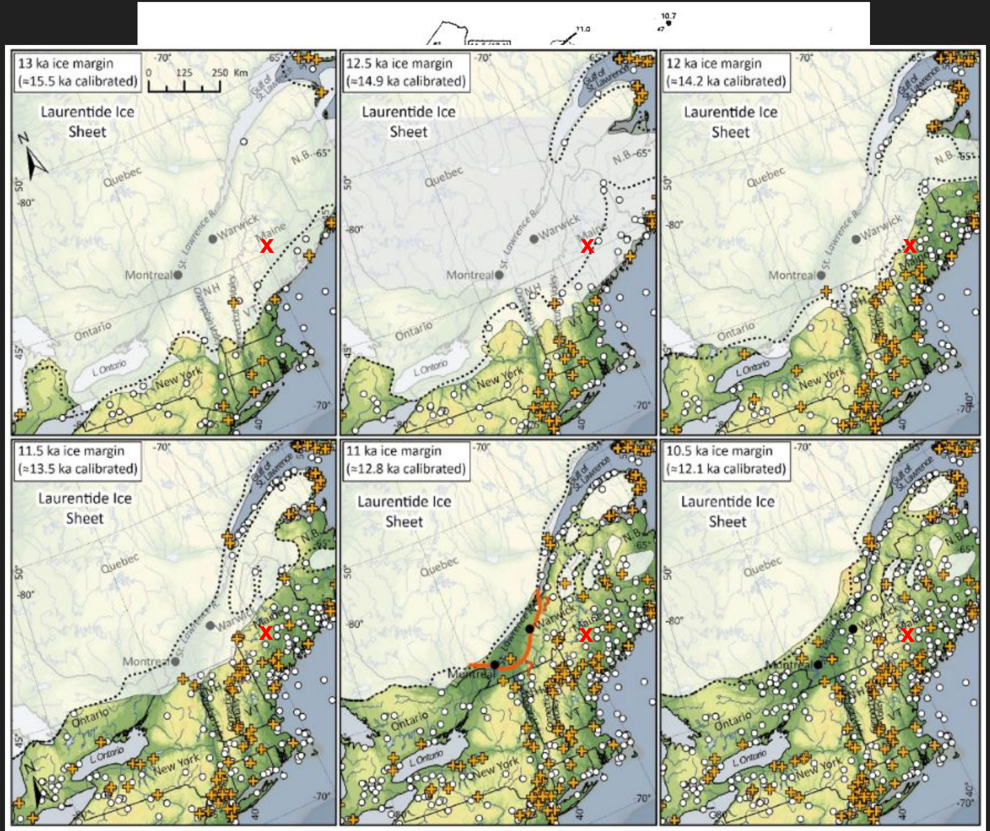
Invited review

An updated radiocarbon-based ice margin chronology for the last deglaciation of the North American Ice Sheet Complex

April S. Dalton [a, b, *], Martin Margold [b], Chris R. Stokes [a], Lev Tarasov [c], Arthur S. Dyke [d, e], Roberta S. Adams [f], Serge Allard [g], Heather E. Arends [h], Nigel Atkinson [i], John W. Attig [j], Peter J. Barnett [k], Robert L. Barnett [l, m], Martin Batterson [n], Pascal Bernatchez [l], Harold W. Borns Jr. [o], Andy Breckenridge [p], Jason P. Briner [q], Etienne Brouard [r, s], Janet E. Campbell [t], Anders E. Carlson [u], John J. Clague [v], B. Brandon Curry [w], Robert-André Daigneault [x], Hugo Dubé-Loubert [y, z], Don J. Easterbrook [aa], David A. Franzi [bb], Hannah G. Friedrich [h, 1], Svend Funder [cc], Michelle S. Gauthier [dd], Angela S. Gowan [ee], Ken L. Harris [ff], Bernard Hétu [l], Tom S. Hooyer [gg, 1], Carrie E. Jennings [hh], Mark D. Johnson [ii], Alan E. Kehew [jj], Samuel E. Kelley [kk], Daniel Kerr [t], Edward L. King [ll], Kristian K. Kjeldsen [mm], Alan R. Knaeble [ee], Patrick Lajeunesse [r], Thomas R. Lakeman [nn], Michel Lamothe [s], Phillip Larson [oo], Martin Lavoie [r], Henry M. Loope [pp], Thomas V. Lowell [qq], Barbara A. Lusardi [ee], Lorraine Manz [ff], Isabelle McMartin [t], F. Chantel Nixon [rr], Serge Occhietti [x], Michael A. Parkhill [ss], David J.W. Piper [ll], Antonius G. Pronk [g], Pierre J.H. Richard [uu], John C. Ridge [vv], Martin Ross [ww], Martin Roy [z], Allen Seaman [g], John Shaw [ll], Rudolph R. Stea [xx], James T. Teller [yy], Woodrow B. Thompson [zz], L. Harvey Thorleifson [ee], Daniel J. Utting [aaa], Jean J. Veillette [t], Brent C. Ward [v], Thomas K. Weddle [zz], Herbert E. Wright Jr. [hh, 1]

[a] Department of Geography, Durham University, Durham, United Kingdom
[b] Department of Physical Geography and Geoecology, Charles University, Prague, Czech Republic
[c] Department of Physics and Physical Oceanography, Memorial University, St. John's, Newfoundland, Canada
[d] Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia, Canada
[e] Department of Anthropology, McGill University, Montreal, Quebec, Canada
[f] Madrone Environmental Services Ltd, Abbotsford, British Columbia, Canada
[g] New Brunswick Geological Survey, New Brunswick Department of Energy and Resource Development, Fredericton, New Brunswick, Canada
[h] Division of Lands and Mineral, Minnesota Department of Natural Resources, St. Paul, Minnesota, USA
[i] Alberta Geological Survey, Edmonton, Alberta, Canada
[j] Wisconsin Geological and Natural History Survey, Madison, WI, USA
[k] Harquail School of Earth Sciences, Laurentian University, Sudbury, Ontario, Canada
[l] Département de biologie, chimie et géographie & Centre for Northern Studies (CEN), Université du Québec à Rimouski, Rimouski, Québec, Canada
[m] Geography, College of Life and Environmental Sciences, University of Exeter, Exeter, United Kingdom
[n] Geological Survey of Newfoundland and Labrador, St. John's, Newfoundland, Canada
[o] School of Earth and Climate Sciences, University of Maine, Orono, ME, USA
[p] Natural Sciences Department, University of Wisconsin–Superior, Superior, WI, USA
[q] Department of Geology, University at Buffalo, Buffalo, NY, USA
[r] Département de géographie and Centre d'études nordiques, Université Laval, Québec, Québec, Canada
[s] Département des sciences de la Terre et de l'atmosphère, Université du Québec à Montréal, Montréal, Québec, Canada
[t] Geological Survey of Canada, Natural Resources Canada, Ottawa, Ontario, Canada
[u] College of Earth, Ocean, and Atmospheric Science, Oregon State University, Corvallis, OR, USA
[v] Department of Earth Sciences, Simon Fraser University, Burnaby, British Columbia, Canada
[w] Illinois State Geological Survey, Prairie Research Institute, University of Illinois at Urbana-Champaign, Champaign, IL, USA
[x] Département de géographie, Université du Québec à Montréal, Montréal, Québec, Canada
[y] Ministry of Energy and Natural Resources of Quebec, Val-d'Or, Quebec, Canada

X = study location

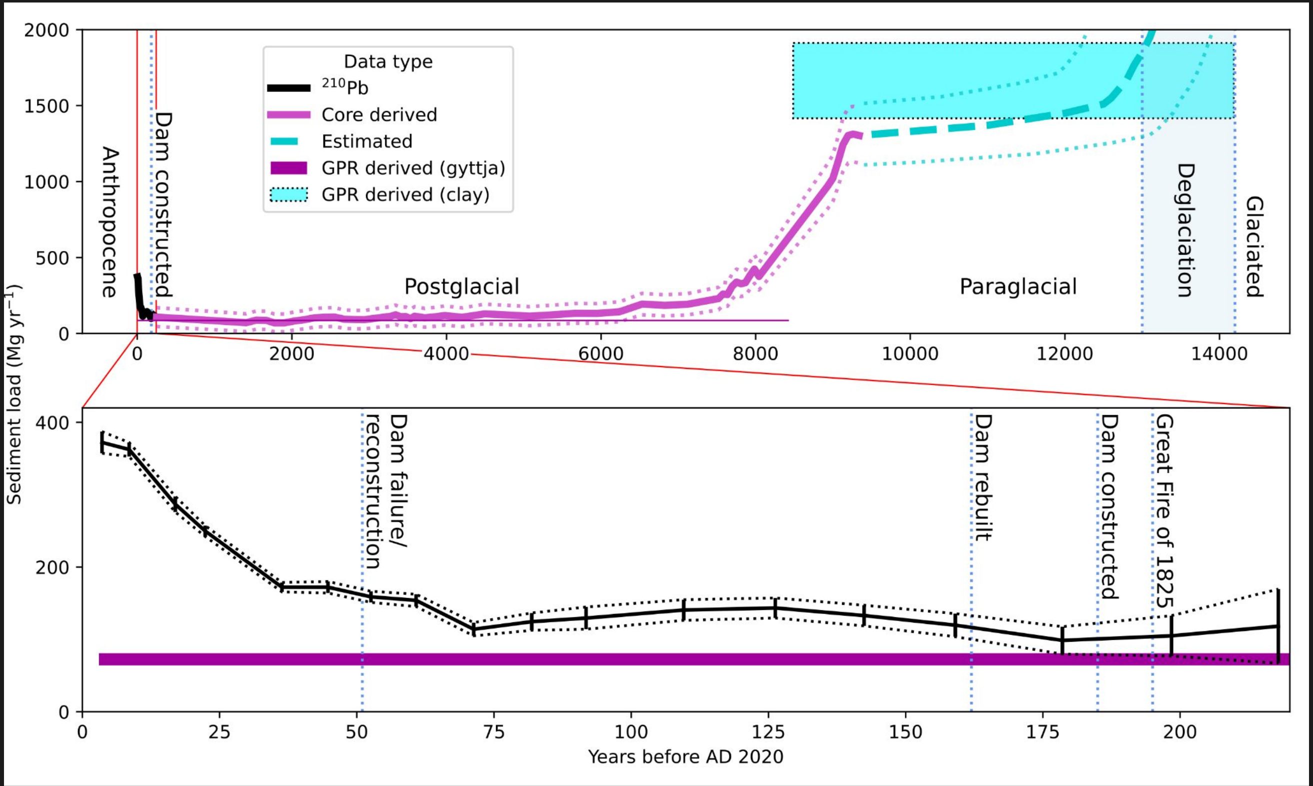


Discussion - sediment delivery continuum

Key takeaways:

- Sediment mass delivery to K-M decreased by an order of magnitude around 8500 cal yr BP
- Pre-transition sediment mass delivery rate greatly exceeds that of modern
- Modern rates are highest in more than 7000 years

- WEPP sediment delivery estimate for this watershed: 67 Mg/yr (within purple bar)



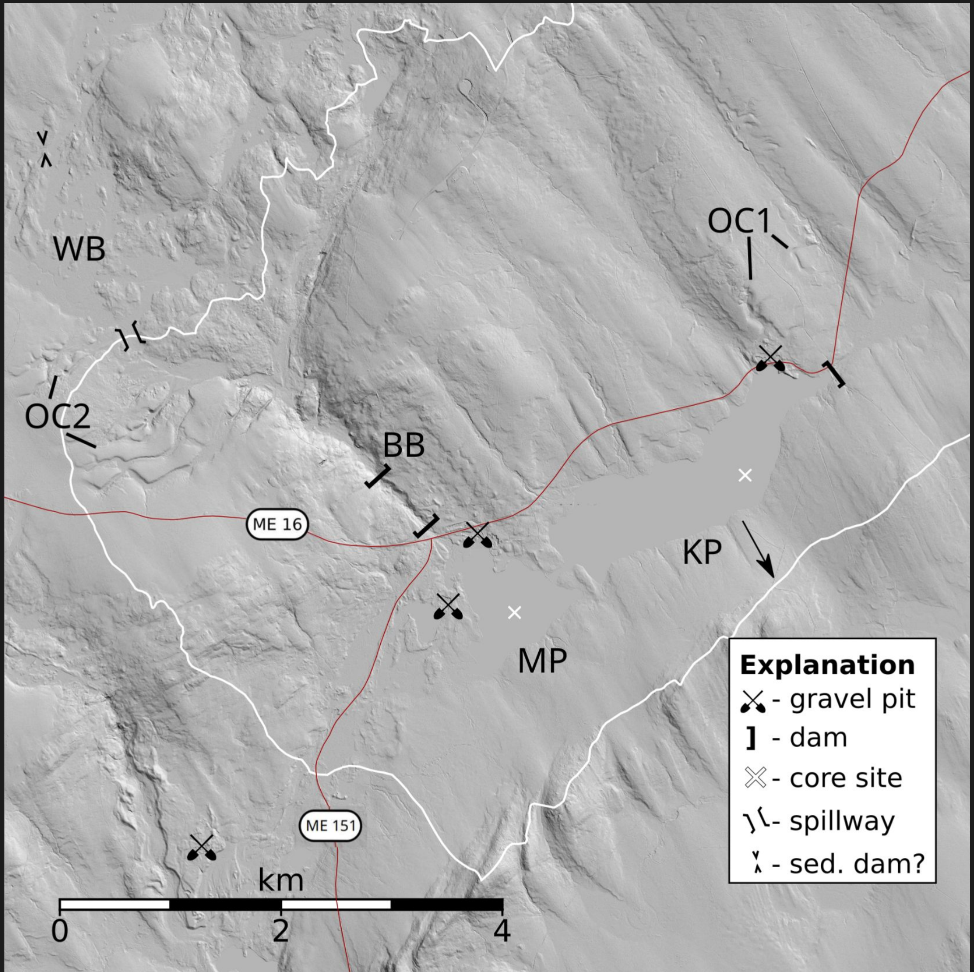
Note: error ranges are symbolized with dotted lines

LiDAR analysis

Key takeaways:

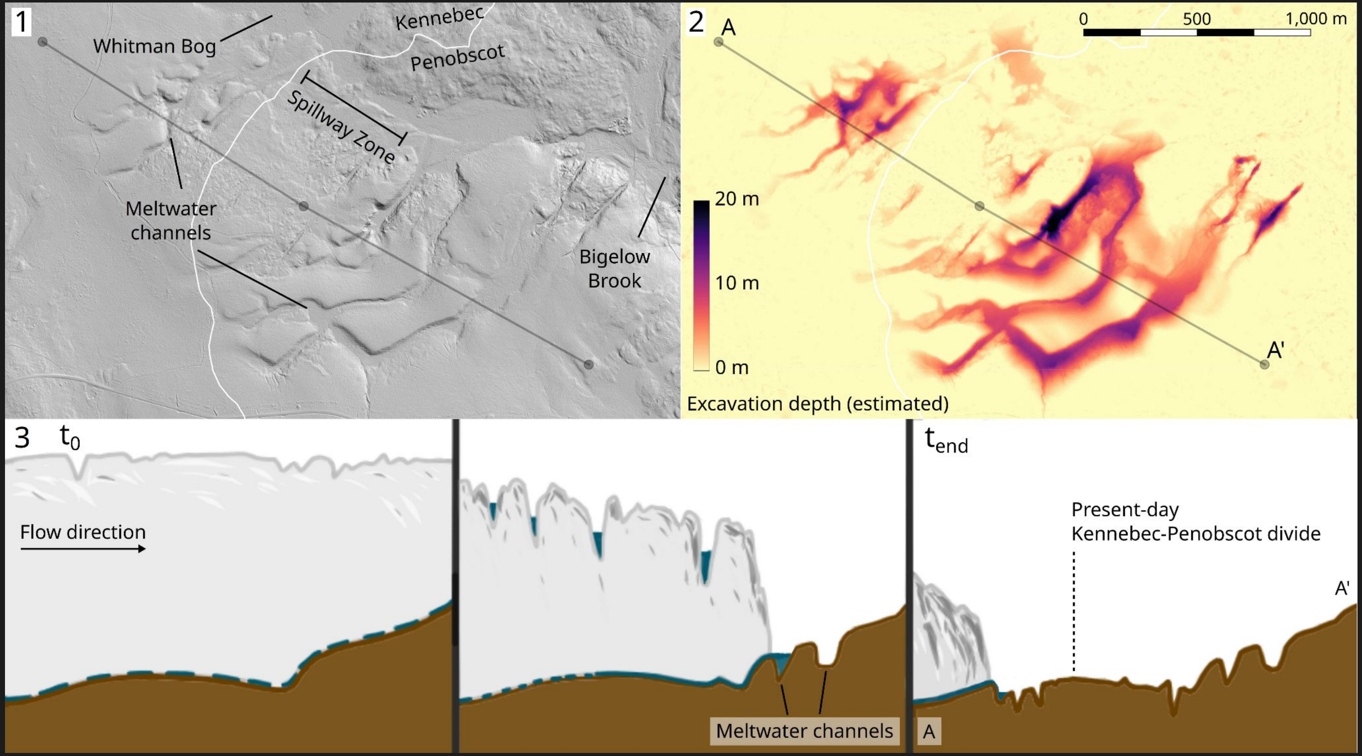
- Outwash channels (OC) exist on both sides of present-day drainage divide (white line)
- Whitman Bog (WB) appears to contain lake deposits
- Apparent spillway from Whitman Bog to Bigelow Brook (BB)

- OC as source of inorganics?



Outwash channels

Key takeaways:
- Volume of sediment eroded from channels is same order of magnitude as volume of clay in K-M subsurface
- Channel erosion caused by large volume of meltwater from retreating ice sheet (panel 3)



Summary points

- Sedimentation studies can be successful in glaciated regions, but complex!
- Sediment focusing makes accurate sediment volume calculation challenging. Radar (or other geophysics) necessary

- Continuum curve suggests switch in the K-M sediment dynamics around 8500 cal yr BP
- Glacial outwash channels probably major source of sediment in the K-M tributary system, perhaps much of the clay in the subsurface
- Modern sedimentation is higher than in past 7000 years, but nowhere near rates seen prior to 8500 cal yr BP

References / questions?

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Quantities

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Table 3: Table of quantities.

Description	Quantity	Units	Error	Source
Deglaciation age	13.0–14.2	cal ka BP	2σ	*Anderson et al.* (1992); *Dorion et al.* (2001); *Borns et al.* (2004); *Gramly* (2009); *Dalton et al.*, (2020)
Volume of sediment excavated from outwash channels	6.0–6.4	10^6 m^3	2σ	Topographic difference calculation
Volume of paraglacial clay in K-M	4.0–4.2	10^6 m^3	2σ	GPR volume
Density of clay	2024–2120	kg m^{-3}	2σ	*Schjønning et al.* (2017) based on 76% clay content and 2% organic matter
Clay-gyttja transition age	8.41–8.55	cal ka BP	2σ	^{14}C sample D-AMS 028115
Volume of gyttja in K-M	2.1–2.3	10^6 m^3	2σ	GPR volume
Density of gyttja	1140–1460	kg m^{-3}	2σ	*Holstad and Degago* (2021)
Paraglacial sediment load	1417–1913	Mg/yr	2σ	Calculated based on GPR volume, density, and estimated duration ranges
Postglacial sediment load	62–81	Mg/yr	2σ	Calculated based on GPR volume, density, and estimated duration ranges
Sediment load, AD 1990-2020	317–363	Mg/yr	2 SEM	^{210}Pb analysis (mean yearly value)
WEPP discharge estimate	1.8	10^7 m^3	n/a	*Flanagan and Nearing*, (1995)
WEPP sediment delivery estimate	67	Mg/yr	n/a	*Flanagan and Nearing*, (1995)

Ages

Table 1: ^{14}C analysis of core samples taken at Kingsbury and Mayfield basins.

Pond	Sample code	Core — thrust	Depth (m)	Sample type	^{14}C yr	1σ	Cal yr	1σ
Kingsbury	D-AMS 028113	GE262-KBP18-1A — 01L	0.970	macrofossil	1891	32	1798	80
	D-AMS 028114	— 02L	1.835	macrofossil	3687	28	4028	66
	D-AMS 028115	— 03L	2.600	macrofossil	7703	38	8479	70
	D-AMS 028116	*— 04L**	*3.255*	*bulk sediment*	*19397*	*126*	23402	350
Mayfield		GE262-MAY19-1A — 03L	2.25	pine cone	3299	29	3512	58
		— 04L	3.13	bulk sediment	5229	33	5964	51

* *sample reported but likely contaminated with dead carbon.*