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PALYNOLOGICAL ANALYSES OF SUBTILL SEDIMENTS FROM FOUR SITES IN THE WESTERN HUDSON BAY LOWLAND REGION (PARTS OF NTS 53O; 54A, C, D)

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Palynological analyses of subtill sediments from four sites in the western Hudson Bay Lowland region (parts of NTS 53O; 54A, C, D)

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View of subtill organic-bearing sediments exposed at sites 112-21-613 (left) and 112-17-505 (right).

Abstract

The Hudson Bay Lowland contains subtill organic-bearing sediments that were deposited during previous ice-free periods in the region. This important sedimentary archive can be used to reconstruct the paleoenvironment during these previous nonglacial periods. This study analyzes the palynology of subtill sorted sediments at four previously unstudied sites in the western Hudson Bay Lowland region. The pollen assemblages at all examined intervals are dominated by boreal and peatland taxa that are largely similar to Holocene pollen assemblages in the Hudson Bay Lowland.

Résumé

Les basses-terres de la baie d'Hudson contiennent des sédiments situés sous le till qui renferment des matières organiques et qui ont été déposés dans la région pendant des périodes sans glace antérieures. Ces archives sédimentaires importantes peuvent servir à reconstruire le paléoenvironnement au cours de ces périodes sans glace antérieures. Cette étude analyse la palynologie des sédiments triés situés sous le till dans quatre sites qui n'avaient pas été examinés jusque-là, dans la région occidentale des basses-terres de la baie d'Hudson. Les assemblages polliniques sont, dans tous les intervalles examinés, dominés par des taxons boréaux et de tourbière en grande partie similaires aux assemblages polliniques de l'Holocène dans les basses-terres de la baie d'Hudson.

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Introduction

The stratigraphic record preserved in the Hudson Bay Lowland, Canada, is of keen interest to Quaternary workers because it contains an archive of past glacial and nonglacial events within North America. Owing to its location at the geographic center of North American ice sheets, if subtill nonglacial sediments in this region can be accurately dated, their ages can bracket the timing of continental glaciations. However, establishing a chronology of glacial and interglacial events in the Hudson Bay Lowland has proven very challenging. Previous attempts using radiocarbon, luminescence and uranium-series methods are subject to large errors and uncertainties (Forman et al., 1987; Allard et al., 2012; Dalton et al., 2016). Despite these challenges, there are hints that multiple nonglacial events are preserved in these stratigraphic records, with ice-free intervals dated to 211 ka (Dubé-Loubert et al., 2013), 100–125 ka (Allard et al., 2012; Gao et al., 2020) and potentially an ice-free interval occurring at ~40 ka (Dalton et al., 2019; but disputed by Miller and Andrews, 2019). Owing to the highly fragmented nature of this stratigraphic record, paired with uncertainties/difficulties in dating the nonglacial sediments, there remains a considerable debate on the precise timing of these ice-free intervals, which hinders our understanding of past glacial and nonglacial events within North America.

A promising avenue for resolving the timing of ice-free events in the Hudson Bay Lowland may lie in paleovegetation indicators that are preserved in the nonglacial sediments. In studies of well-dated Quaternary records from northern Europe, paleovegetation (and, by extension, paleoclimate) differed substantially between interstadial and interglacial times (Helmens et al., 2012; Plikk et al., 2016; Sarala et al., 2016). This relationship is so well established that shifts in vegetation are routinely used to assign interstadial/interglacial status to sites that are otherwise undated. A similar application would be invaluable toward reconciling the challenging stratigraphy records in the Hudson Bay Lowland. To that end, numerous paleoecological analyses of organic-bearing sediments underlying tills in this region have been undertaken over the past ~50 years (Terasmae and Hughes, 1960; Skinner, 1973; Mott and DiLabio, 1990; Dalton et al., 2017; Dalton et al., 2018). Most of these studies examine pollen, which is relatively well preserved in the fossil records. In the absence of reliable chronology constraints on many of these nonglacial intervals, most of the earlier palynological work was focused on qualitatively determining whether they represented interstadial (presumably colder/drier vegetation) or interglacial conditions. More recently, workers have employed quantitative techniques to assign paleoclimate variables to the fossil records (Dalton et al., 2017; Dalton et al., 2018). However, the spatial coverage of these studies is restricted to the eastern Hudson Bay Lowland, and there remains a need to extend this quantitative approach to a broader coverage of the region.

In this report, palynological analyses are documented for 32 pollen samples spanning three subtill sites in Manitoba: 112-19-613, 115-20-200 and 112-17-505 (Figure 1). We also report additional pollen data from a site in westernmost Ontario (site 11-PJB-186; Figure 1). A summary of all samples is provided in Table 1. For each site, we describe the overall trends/characteristics of the pollen assemblage and present results of quantitative paleoenvironmental reconstructions using the modern analogue technique. Our ultimate goal is to determine whether sufficient differences in paleovegetation (and thus, paleoclimate) exist between different nonglacial intervals. Optically stimulated luminescence dating of these fossil sites is in progress (Gauthier et al., 2021). However, AMS radiocarbon ages are available for all sites investigated (Table 2).

Methods

Field data collection

At each site investigated, colluvium was thoroughly cleared to reveal in situ sediments. Sediment grain size, structure and the nature of contacts between facies were described. Samples for palynological analysis were collected every 10–30 cm from subtill organic-bearing sediments where an appropriate sample medium was described. A complete description of the Quaternary stratigraphy at each site investigated is provided in Appendix 1 to provide a context for the subtill sediment palynology analysis.

Loss-on-ignition

Organic matter content was determined (as % dry mass) using standard loss-on-ignition methodology (Heiri et al., 2001). Known masses of dried samples were combusted at 550°C for four hours and the percent mass lost is then equated to the percent organic matter.

Palynological methods

The 32 sediment samples (subsampled to 1 cm^3) were processed at the Paleoecology Laboratory at the University of Toronto following standard palynological techniques (Faegri and Iversen, 1975). This involved the removal of humic acid using KOH, digestion of sediment using hydrofluoric acid, acetolysis to clean pollen grains, dehydration alcohol, and mixing the resulting pollen residue with silicone oil to facilitate mounting the samples onto slides. During processing, we also used heavy-liquid floatation (sodium polytungstate) to remove additional sediments that remained after digestion in hydrofluoric acid (Zabenskie, 2006; Campbell et al., 2016). Pollen concentrations for each sample were estimated by adding a known number of *Lycopodium* spores (Stockmarr, 1971) or ceramic palynospheres (Kitaba and Nakagawa, 2017).

Pollen grains were examined using a compound microscope at 400x, with critical identifications under oil immersion at 1000x. Identification followed the pollen key of McAndrews et al. (1973), along with reference material held at the University of Toronto. Effort was made to count at least 150 grains of herb, arboreal and shrub species. Raw pollen data are available in Appendix 2. Only those samples containing >5000 pollen grains/cm^3 and

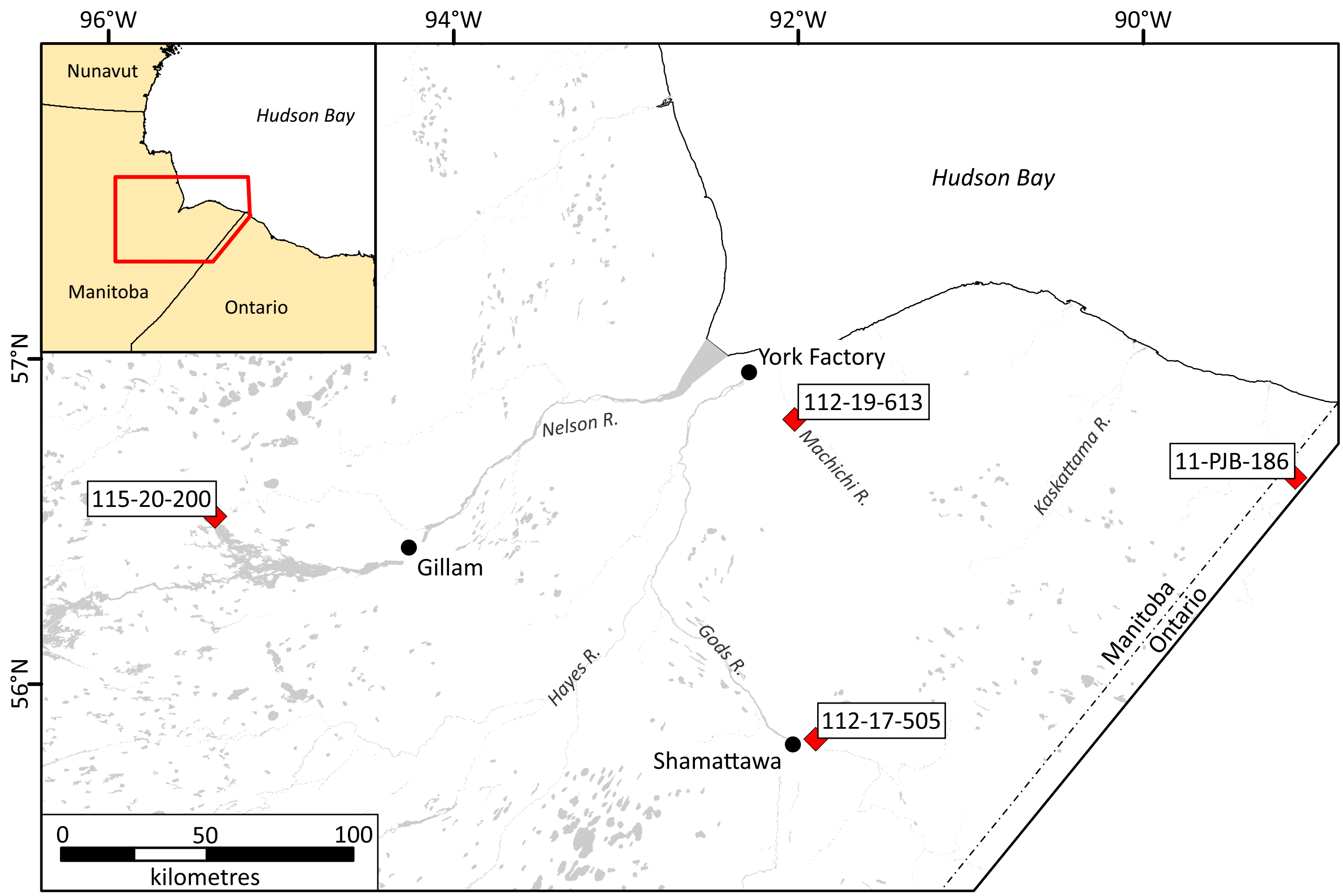

Figure 1: *Location of sites with subtill nonglacial sediments that were investigated as part of this study (indicated by the red diamonds).*

<10% broken/unidentified grains were carried forward for statistical analyses. As a result, 14 of 32 samples were not appropriate for statistical analysis (but the raw counts are included in Appendix 2). Stratigraphic plots for each site include only those pollen groups reaching 1% abundance in at least one sample, and were produced using R package 'rioja' (Juggins, 2015). Organic content was also determined for each sample using standard loss-on-ignition methods, which involve the combustion of sediment at 550°C for four hours (Heiri et al., 2001).

Pollen data were used to derive paleoclimate inferences using the modern analogue technique (Overpeck et al., 1985). This technique compares each fossil sample statistically to a modern calibration set of pollen sites (4882 sites spanning North America; Whitmore et al., 2005; Dalton et al., 2017). Only those sites from the modern-day calibration set that are sufficiently similar to the fossil sites (i.e., squared chord distance dissimilarity of <0.25) as appropriate analogues were considered. These values can range from 0.0 to 2.0, with 0.0 indicating identical proportions of species within the samples being compared. These criteria are slightly more relaxed than that recommended by Overpeck et al. (1985), who suggested only considering analogues when sites have a squared chord distance dissimilarity of <0.15. The strict criteria of Overpeck et al. (1985) are largely relevant for Holocene samples and would only have produced paleoclimate reconstructions at 13 of the 18 pollen intervals in this study. Instead, our expanded criteria allowed for reconstruction at 16 of the 18 pollen intervals. The benefit of using this expanded criteria is additional inference about paleoclimate. However, the trade-off is slightly less similarity between the pollen assemblage at the fossil site and the calibration set. This is accounted for in our relatively generous errors shown for each reconstruction. Finally, wetland and aquatic pollen/spore groups were removed from consideration in the modern analogue technique because they are highly influenced by local conditions and are less indicative of regional climate (they are retained in Appendix 2).

Once analogue sites from the modern-day calibration set were determined, the calibration set was examined to determine which climate variables could be most reliably reconstructed. Four different climate variables were examined: mean annual temperature, total annual precipitation, mean summer temperature (June, July, August) and total precipitation for the summer months. Modern-day climate data (annual precipitation, mean summer temperature) for the sites are interpolated from gridded climate data, available from Natural Resources Canada (2015). As described in Dalton et al. (2017), statistical tests of collinearity and calculation of the $\lambda1/\lambda2$ ratio (see Ter Braak and Prentice, 1988; Juggins et al., 2014) suggests that total annual precipitation and mean summer temperature (June, July, August) are the

Table 1: Summary of samples processed for pollen, spanning three subtill sites in Manitoba and one site in westernmost Ontario (site 11-PJB-186).

Site	Sampling interval (m depth)	Sample medium	Are pollen data of sufficient quality for paleoclimate reconstruction?
112-19-613 (lat./long., DD: 56.8540, -92.0541)	2.35–2.40 (PM007)	Peat	No. >10% broken.
	3.10–3.12 (PM012)	Grey silt	Yes.
	3.30–3.32 (PM013)	Grey silt	Yes.
	3.50–3.52 (PM014)	Grey silt	Yes.
	3.70–3.72 (PM015)	Grey silt (organic-bearing)	Yes.
	3.90–3.92 (PM016)	Organic-rich horizon	No. >10% broken.
	4.10–4.12 (PM017)	Brown silt	No. >10% broken.
	4.30–4.32 (PM018)	Brown silt	Yes.
	4.50–4.52 (PM019)	Brown silt	Yes.
	4.70–4.72 (PM020)	Diamict	No. >10% broken.
	4.90–4.92 (PM021)	Sandy gravel	No. >10% broken.
	5.70–5.72 (PM022)	Silt	Yes.
	5.90–5.92 (PM023)	Fine sand	No. >10% broken.
	6.20–6.22 (PM024)	Poorly sorted fine sand	Yes.
	6.47–6.49 (PM025)	Organic horizon	Yes.
115-20-200 (lat./long., DD: 56.5372, -95.2946)	0.05–0.07 (PM001)	Laminated silt	No. Low conc.
	0.15–0.17 (PM002)	Laminated silt	No. Low conc.
	0.35–0.37 (PM003)	Silt above sand/gravel	No. Low conc. and >10% broken.
	0.45–0.47 (PM004)	Silt between sand beds	No. Low conc. and >10% broken.
	0.55–0.57 (PM005)	Silt between sand beds	No. Low conc. and >10% broken.
	0.65–0.67 (PM006)	Organic-rich silt	Yes.
	0.75–0.77 (PM007)	Organic-rich silt	Yes.
	0.85–0.87 (PM008)	Organic-rich silt	Yes.
	0.95–0.97 (PM009)	Organic-rich silt	Yes.
	1.05–1.07 (PM010)	Organic-rich silt	Yes.
	1.15–1.17 (PM011)	Organic-rich silt	Yes.
	1.25–1.27 (PM012)	Organic-rich silt	Yes.
	1.35–1.37 (PM013)	Organic-rich silt	No. >10% broken.
	1.45–1.47 (PM014)	Organic-rich silt	No. >10% broken.
112-17-505 (lat./long., DD: 55.8680, -91.9630)	0.88–0.9 (PM032)	Fine sand	No. >10% broken.
	1.08–1.1 (PM033)	Organic bed in sand	Yes.
	1.38–1.4 (PM034)	Silt	Yes.
11-PJB-186 (lat./long., DD: 56.61, -89.29)	0.05	Organic-rich silt	No.
	0.10	Organic-rich silt	Yes.
	0.20	Organic-rich silt	No.
	0.30	Organic-rich silt	No.
	0.40	Organic-rich silt	Yes.
	0.50	Organic-rich silt	Yes.
	0.55	Organic-rich silt	Yes.
	0.60	Organic-rich silt	No.
	0.70	Organic-rich silt	Yes.
	0.80	Organic-rich silt	No.
	0.90	Organic-rich silt	Yes.
	0.95	Organic-rich silt	Yes.
	1.10	Organic-rich silt	No.
	1.20	Organic-rich silt	No.
	1.40	Organic-rich silt	No.

Abbreviation: conc., concentration; DD, decimal degrees.

Table 2: AMS radiocarbon ages for each site investigated. Radiocarbon sample depths for sites in northeastern Manitoba are shown on stratigraphic columns in Appendix 1, and in Figure 9 for site 11-PJB-186.

Site ID	Lab code	Age (^{14}C years BP)	Material dated	Surrounding material
112-19-613	UOC-10976	>55 000	Wood	Peat
112-19-613	UOC-10978	>55 000	Wood	Organic-rich silt
115-20-200	UOC-13391	>50 000	Wood	Organic-rich silt
112-17-505	UOC-9641	>56 000	Wood	Sandy gravel
11-PJB-186	ISGS A1656	45 700 ±1300	Wood	Organic-rich silt
11-PJB-186	ISGS A1995	50 100 ±3300	Wood	Organic-rich silt
11-PJB-186	UOC-0587	49 586 ±949	Wood	Organic-rich silt and clay
11-PJB-186	UOC-0839	>48 800	Wood	Organic-rich silt and clay

Abbreviation: ID, identification.

most reliable for reconstruction. Paleoclimate reconstructions were made using the R package 'analogue' (Simpson, 2007; Simpson and Oksanen, 2014) using the three closest analogues and cross-validation (n = 500 bootstrap iterations).

In addition to the three sites from Manitoba, we also include pollen data from 11-PJB-186 in this report. Pollen processing and analysis is identical to the 32 samples described above. These samples were previously analyzed but have not been published.

Results

Site 112-19-613

A total of 15 sediment samples spanning a variety of peat, organic-bearing silt and sands were examined for pollen (Table 1). Six of the 15 intervals contained a relatively large number of broken or otherwise poorly preserved pollen grains and are therefore excluded from further analysis. The nine intervals where pollen was well preserved (Figure 2) are characterized by the highest percentage of *Sphagnum* spores as well as the highest percentage of *Salix* grains of the four sites in this report. The uppermost sample intervals also contain high percentages of Cyperaceae (>100%). Together, these data suggest similar-to-present boreal peatland conditions and local wetland conditions (e.g., Farley-Gill, 1980), with potentially a transition from bog (high *Sphagnum*) to fen (high Cyperaceae) late in the fossil record. The relatively high abundance of *Salix* and *Betula* suggest occasional vegetation disturbance in the region, potentially as the result of riparian conditions. Aquatic indicators (*Equisetum*, *Typha* and *Pediastrum*) are occasionally present in the fossil interval, which suggest an occasional transition to a local aquatic depositional environment. Finally, the organic content of the examined intervals ranges from 2–25%, which suggests dramatic transitions between organic-bearing and minerogenic depositional environments.

Regarding paleoclimate reconstructions and the modern analogue technique, squared chord distance dissimilarity analysis suggests ample analogue sites in the modern-day calibration set (Figure 3; Table 3). This is particularly true for the lowermost sample at this site (interval 6.47), which has 229 suitable analogues. The top three analogues for each interval at this fossil site (i.e., those used for the paleoclimate reconstructions) are taken from a variety of regions spanning the boreal forest, peatland and tundra vegetation regions of North America (Figure 4). The largest concentration of analogues sites are from the Canadian Prairies and Hudson Bay Lowland, which re-enforces the boreal-peatland interpretation for this fossil site.

As detailed in Table 3, quantitative paleoenvironmental reconstructions at site 112-19-613 suggest

i) mean summer temperature varied from 10.1–14.9°C, as compared to present-day 12.2°C; and
ii) total annual precipitation was similar to present-day (434 mm) or wetter (>500 mm) during the examined interval.

A notable trend in the paleoclimate data is decidedly warmer temperatures early in the fossil interval (~14.9°C) that gradually shift toward cooler-than-present conditions later in the fossil record (~10.1°C). It is possible that the early, relatively stable part of the fossil record represents ambient conditions during the ice-free interval (~14.9°C) and that the gradual transition toward cooler conditions in the uppermost examined sediments represents climate deterioration associated with ice advance.

Site 115-20-200

A total of 14 sediment samples spanning a variety of organic-bearing silts were examined for pollen (Table 1). Seven of the 14 intervals contained relatively large numbers of broken or otherwise poorly preserved pollen grains and are therefore excluded from further analysis. The seven intervals where pollen was well preserved (Figure 5) are dominated by boreal (*Picea*, *Pinus*, *Betula*, *Salix*, *Alnus*) and herbaceous taxa (notably, <10% Poaceae and Asteraceae). Very few wetland indicators are present at this site (e.g., largely <10% Cyperaceae and *Sphagnum*). A notable interval is 0.95 m, where *Betula* pollen grains comprise >80% of the assemblage. Overall, this pollen assemblage suggests similar-to-present conditions during the fossil interval (e.g., Farley-Gill, 1980). Aquatic indicator *Pediastrum* was occasionally noted in

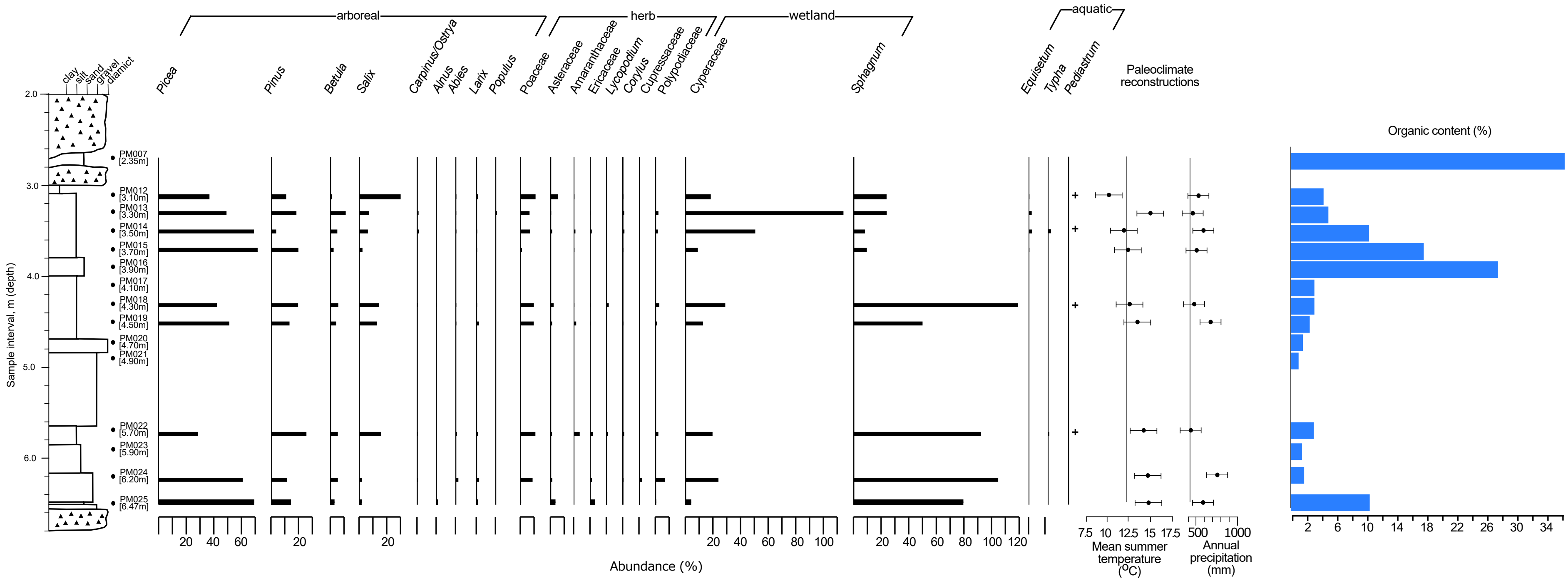

Figure 2: *Stratigraphic plot for site 112-19-613, showing pollen data, paleoclimate reconstructions and organic content for each interval. Vertical lines in the paleoclimate reconstruction plots represent modern-day conditions, which are 12.2°C and 434 mm, respectively (Natural Resources Canada, 2015). Only those pollen groups reaching 1% abundance in at least one sample are shown here. Black dots on the pollen diagram represent sampled intervals. See Appendix 1, Figures 11 and 12 for a description of the entire Quaternary stratigraphy exposed at site 112-19-613.*

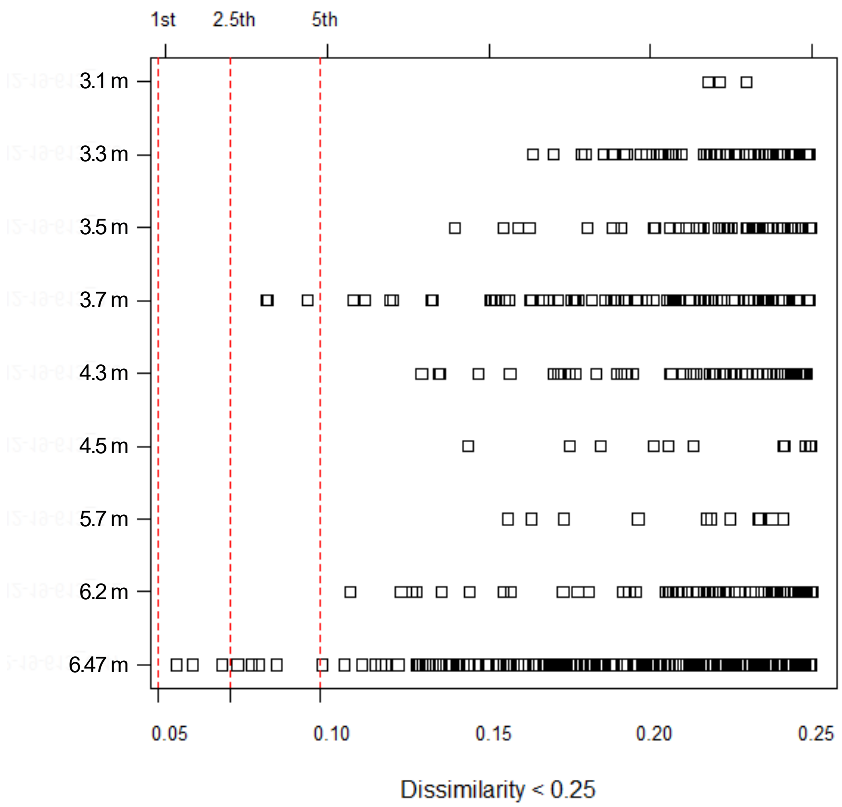

Figure 3: *Results of squared chord distance dissimilarity analysis between fossil pollen from site 112-19-613 and the modern-day calibration dataset (4882 sites spanning North America; Whitmore et al., 2005; Dalton et al., 2017). These values can range from 0.0 to 2.0, with 0.0 indicating identical proportions of species within the samples being compared. The top analogues are mapped in Figure 4.*

the fossil interval, which suggests an occasional transition to a local aquatic depositional environment. Finally, the organic content of the examined intervals ranges from 2–8%, which suggests a high minerogenic component during the fossil interval.

Regarding paleoclimate reconstructions and the modern analogue technique, squared chord distance dissimilarity analysis suggests ample analogue sites in the modern-day calibration set (Figure 6; Table 3). The top three analogues for each interval at this fossil site (i.e., those used for the paleoclimate reconstructions) are taken from a variety of regions spanning the boreal forest, peatland and tundra vegetation regions of North America (Figure 4). The largest concentration of analogue sites are from the Canadian Prairies and northern Quebec regions, which reinforces the boreal-peatland interpretation for this fossil site.

As detailed in Table 3, quantitative paleoenvironmental reconstructions at site 115-20-200 suggest

i) mean summer temperature varied from 9.4–15.2°C, as compared to present-day 12.7°C; and
ii) total annual precipitation was similar to present-day (482 mm) or wetter (up to 920 mm) during the examined interval.

Overall, paleotemperature data show no appreciable trend throughout the examined interval. However, total annual precipitation remained similar or higher than present throughout the examined fossil interval, which suggests a wetter precipitation regime than is currently in place over the region.

Site 112-17-505

A total of three sediment samples spanning organic-bearing silts and sands were examined for pollen (Table 1). One of the three intervals contained relatively large numbers of broken or otherwise poorly preserved pollen grains and are therefore excluded from further analysis. The two remaining intervals where pollen was well preserved (Figure 7) suggest typical boreal peatland conditions, with dominant arboreal (*Picea*, *Pinus*, *Salix*) and wetland (Cyperaceae, *Spahgnum*) components, and smaller components of herbaceous groups (notably, Poaceae and Polypodiaceae). These data suggest similar-to-present conditions during the fossil interval (e.g., Farley-Gill, 1980). Moreover, Polypodiaceae spores suggest a local presence of ferns, which implies a relatively shaded local environment with likely wetland conditions. Aquatic indicator *Pediastrum* was throughout the fossil interval, which suggests a local aquatic depositional environment. Finally, the organic content of the examined intervals ranges from 4–6%, which suggests a high minerogenic component during the fossil interval.

Regarding paleoclimate reconstructions and the modern analogue technique, squared chord distance dissimilarity analysis suggests ample analogue sites in the modern-day calibration set (Figure 8; Table 3). The top three analogues for each interval at this fossil site (i.e., those used for the paleoclimate reconstructions) are taken from a variety of regions spanning the boreal forest, peatland and tundra vegetation regions of North America

Table 3: Results of modern analogue technique paleoclimate reconstructions for the three intertill sites in Manitoba and a site in westernmost Ontario (site 11-PJB-186, previously analyzed but unpublished).

Site ID	Sampling interval (m depth)	Number of modern-day sites with a squared chord distance dissimilarity of <0.25	Mean summer temperature, June–August (°C; pollen-inferred)	Mean annual precipitation (mm; pollen-inferred)
112-19-613	3.10–3.12	3	10.1	539
	3.30–3.32	59	14.9	462
	3.50–3.52	44	11.9	593
	3.70–3.72	82	12.3	513
	4.30–4.32	61	12.5	481
	4.50–4.52	11	13.5	680
	5.70–5.72	11	14.2	440
	6.20–6.22	60	14.6	758
	6.47–6.49	229	14.7	589
115-20-200	0.65–0.67	106	13.2	484
	0.75–0.77	166	12.4	564
	0.85–0.87	382	15.2	644
	0.95–0.97	29	14.9	736
	1.05–1.07	297	9.4	920
	1.15–1.17	197	11.7	612
	1.25–1.27	137	12.9	673
112-17-505	1.08–1.1	249	13.9	689
	1.38–1.4	282	13.4	537
11-PJB-186	0.10	257	9.4	514
	0.40	46	14	439
	0.50	34	14.2	440
	0.55	24	14.1	439
	0.70	26	14.4	442
	0.90	24	14.3	441
	0.95	100	14.5	443

Abbreviation: ID, identification.

(Figure 4). The largest concentration of analogues sites are from the Canadian Prairies and northern Quebec regions, which re-enforces the boreal-peatland interpretation for this fossil site.

As detailed in Table 3, quantitative paleoenvironmental reconstructions at site 112-17-505 suggest

i) mean summer temperature varied from 13.4–13.9°C, as compared to present-day 13.4°C; and
ii) total annual precipitation was similar to present-day (474 mm) or wetter (up to 689 mm) during the examined interval.

It is difficult to ascertain any paleoclimate trends given that only two fossil intervals were used for the reconstruction.

Site 11-PJB-186

A total of 15 sediment samples spanning organic-bearing silts were examined for pollen (Table 1). Eight of the 15 intervals contained a relatively large number of broken or otherwise poorly preserved pollen grains and are therefore excluded from further analysis. The seven remaining intervals where pollen was well preserved (Figure 9) are dominated by boreal (*Picea*, *Pinus*, *Betula*, *Salix*, *Alnus*) and peatland taxa (dominantly Cyperaceae) suggesting vegetation was similar to present-day in the region. However, a notable difference is the relatively large percentage of Poaceae grains (15–30%) and moderate Asteraceae (~5%) which suggests regional grassland conditions during the fossil interval (e.g., Farley-Gill, 1980). Moreover, abundant *Alnus* (~60%) in the lowermost pollen sample suggests landscape disturbance or vegetation instability was captured early in the record. This could be related to the onset of forest growth after deglaciation, or riparian processes.

Regarding paleoclimate reconstructions and the modern analogue technique, squared chord distance dissimilarity analysis suggests ample analogue sites in the modern-day calibration set (Figure 10; Table 3). The top three analogues for each interval at this fossil site (i.e., those used for the paleoclimate reconstructions) are taken almost exclusively from the Prairies and Hudson

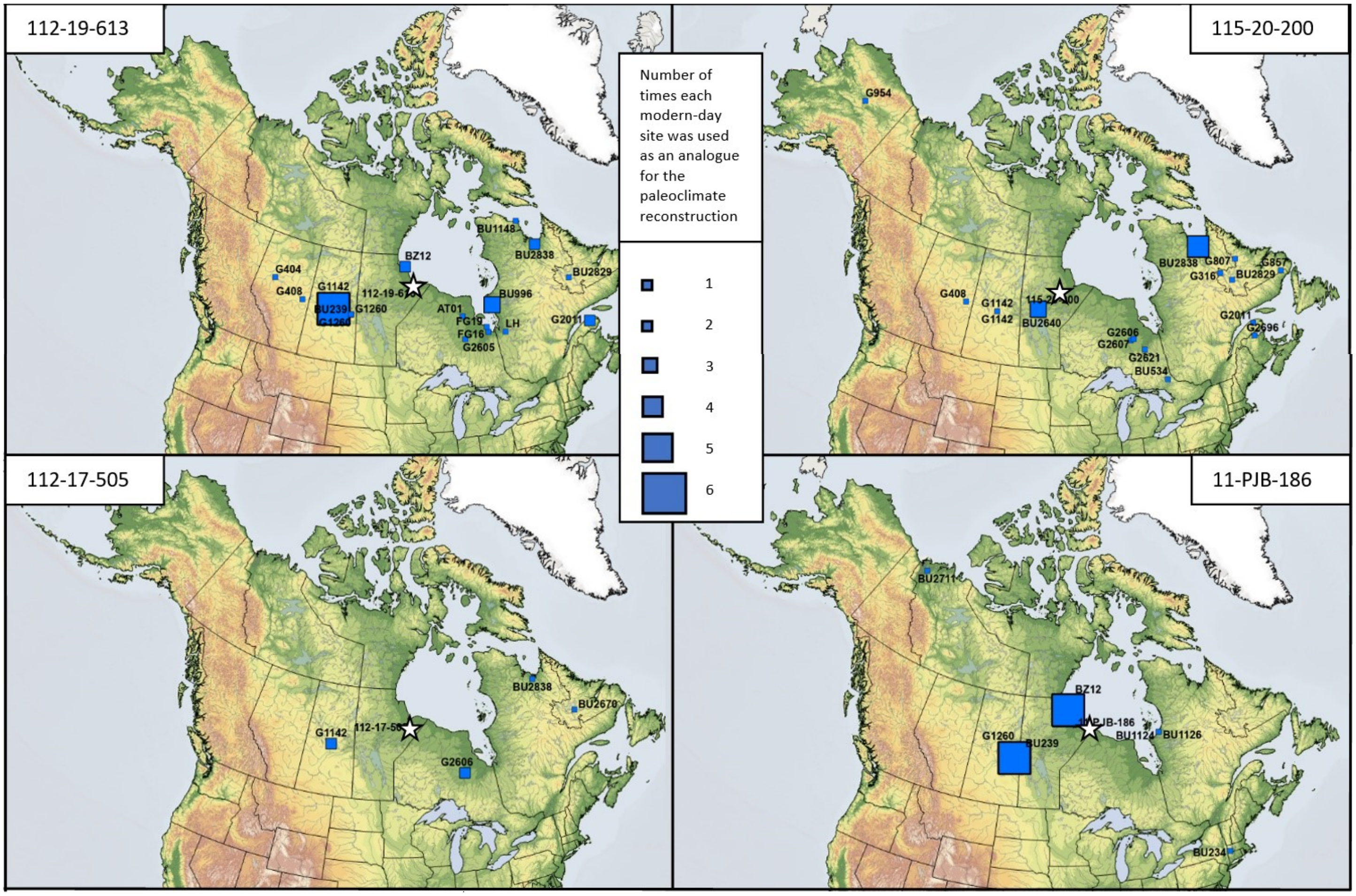

Figure 4*: Map showing the top three analogues for each pollen interval, grouped by fossil site (indicated by the star).*

Bay Lowland of North America (Figure 4), which reinforces the boreal-peatland interpretation for this fossil site.

As detailed in Table 3, quantitative paleoenvironmental reconstructions at site 11-PJB-186 suggest

i) mean summer temperature varied from 9.4–14.5°C, as compared to present-day 11°C; and

ii) total annual precipitation was similar to present-day (467 mm) during the examined interval.

A notable trend in the paleoclimate data is decidedly warmer temperatures throughout the majority of the fossil interval (14.5°C) as compared to present-day in the region.

Summary and conclusions

We report pollen data from three fossil sites from the Hudson Bay Lowland: three in Manitoba (112-19-613, 115-20-200 and 112-17-505), and one in western Ontario (11-PJB-186). All examined pollen intervals are dominated by boreal and peatland taxa that are largely similar to Holocene pollen assemblages in the Hudson Bay Lowland (Farley-Gill, 1980; O'Reilly et al., 2014; Hargan et al., 2020). All sites contain indicators of wetland deposition, with a transition from bog (high *Sphagnum*) to fen (high Cyperaceae) documented late in the fossil record at site 112-19-613. The relatively low abundances of *Abies* and *Larix* across all examined intervals is likely the result of poor preservation of these grains in the fossil record (Farley-Gill, 1980) and not a reflection of their absence during the fossil interval. Abundances of thermophilus pollen taxa (e.g., *Acer, Carya, Fraxinus, Juglans, Quercus, Tilia)* are rare across the fossil sites. Thus, any variations in quantitative paleotemperature are largely the result of varying abundances of boreal and peatland taxa (e.g., increased Poaceae and herbaceous components). Together, these data suggest that ice-free intervals in the Hudson Bay Lowland are largely similar to the Holocene, regardless of whether they are contemporaneous or represent different nonglacial intervals.

Our use of quantitative paleoenvironmental reconstructions reveals subtle differences in paleoclimate at some sites as compared to present-day. For example, at site 112-19-613, there were decidedly warmer temperatures early in the fossil interval (~14.9°C) that gradually shift toward cooler-than-present conditions later in the fossil record (~10.1°C). Decidedly warmer temperatures were also inferred from pollen data at 11-PJB-186 (warmer than 11°C).

At this time, the age of these fossil intervals is not well understood. However, once the age of these fossil sites can be established (in progress; Gauthier et al., 2021), it may be possible to link these subtle changes in paleoenvironment to changes in ice sheet configuration (e.g., interstadial vs. interglacial conditions). If sufficient differences in paleoclimate exist between different

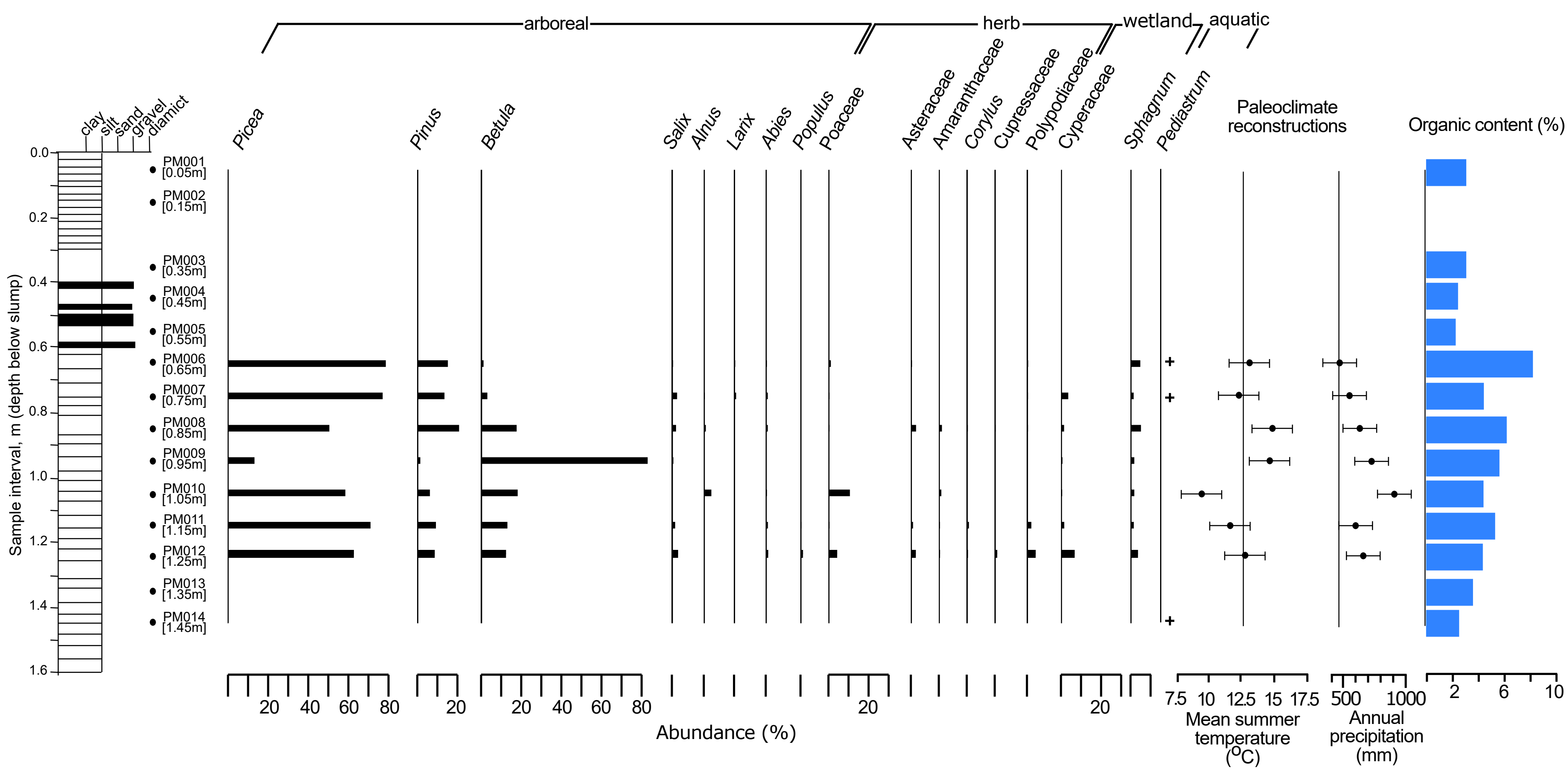

Figure 5: *Stratigraphic plot for site 115-20-200, showing pollen data, paleoclimate reconstructions and organic content for each interval. Vertical lines in the paleoclimate reconstruction plots represent modern-day conditions, which are 12.7°C and 482 mm, respectively (Natural Resources Canada, 2015). Only those pollen groups reaching 1% abundance in at least one sample are shown here. Black dots on the pollen diagram represent sampled intervals. See Appendix 1, Figures 13 and 14 for a description of the Quaternary stratigraphy exposed at site 115-20-200.*

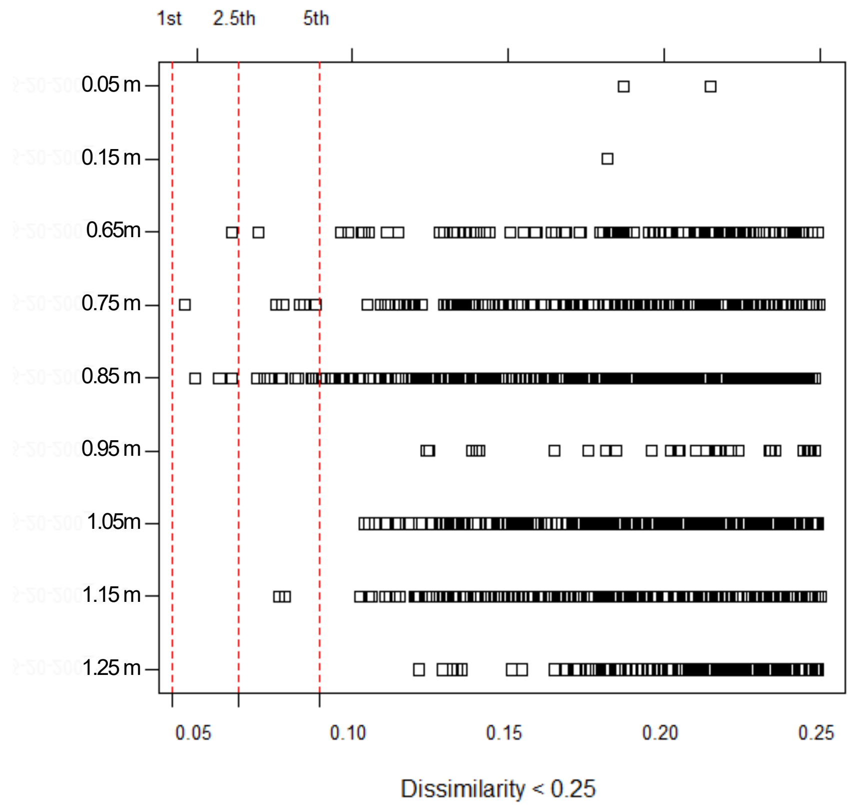

Figure 6: *Results of squared chord distance dissimilarity analysis between fossil pollen from site 115-20-200 and the modern-day calibration dataset (4882 sites spanning North America; Whitmore et al., 2005; Dalton et al., 2017). These values can range from 0.0 to 2.0, with 0.0 indicating identical proportions of species within the samples being compared. The top analogues are mapped in Figure 4. Note that insufficient modern-day analogues (less than three) were available for the uppermost two samples at this site.*

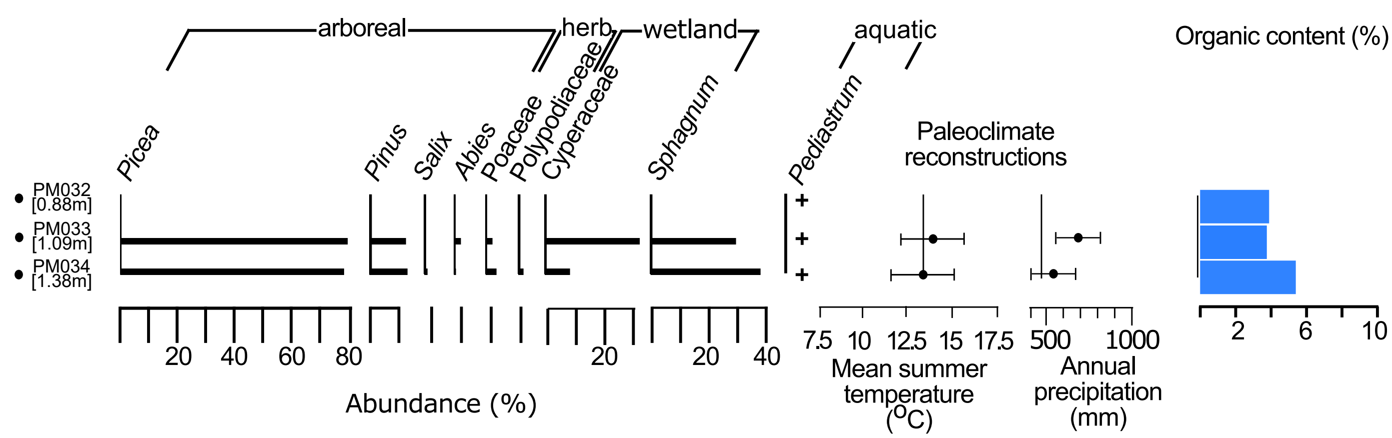

Figure 7: *Stratigraphic plot for site 112-17-505, showing pollen data, paleoclimate reconstructions and organic content for each interval. Vertical lines in the paleoclimate reconstruction plots represent modern-day conditions, which are 13.4°C and 474 mm, respectively (Natural Resources Canada, 2015). Only those pollen groups reaching 1% abundance in at least one sample are shown here. Black dots on the pollen diagram represent sampled intervals. See Appendix 1, Figures 15 and 16 for a description of the Quaternary stratigraphy exposed at site 112-17-505.*

nonglacial intervals, it may be possible to extend these paleoclimate inferences to other sites in the Hudson Bay Lowland that are poorly dated but have pollen records.

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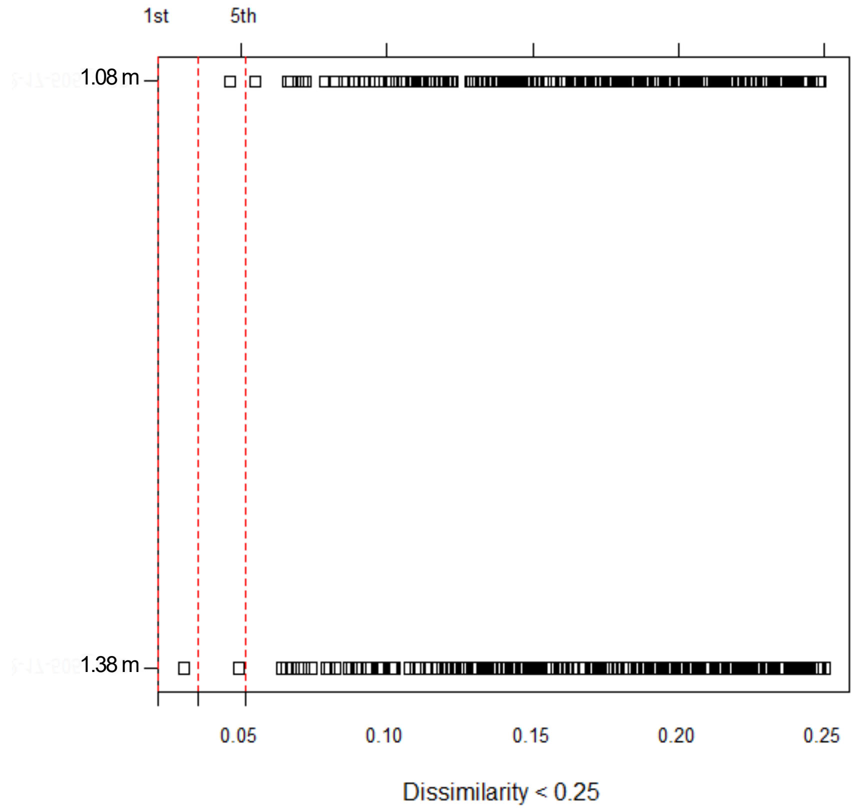

Figure 8: *Results of squared chord distance dissimilarity analysis between fossil pollen from site 112-17-505 and the modern-day calibration dataset (4882 sites spanning North America; Whitmore et al., 2005; Dalton et al., 2017). These values can range from 0.0 to 2.0, with 0.0 indicating identical proportions of species within the samples being compared. The top analogues are mapped in Figure 4.*

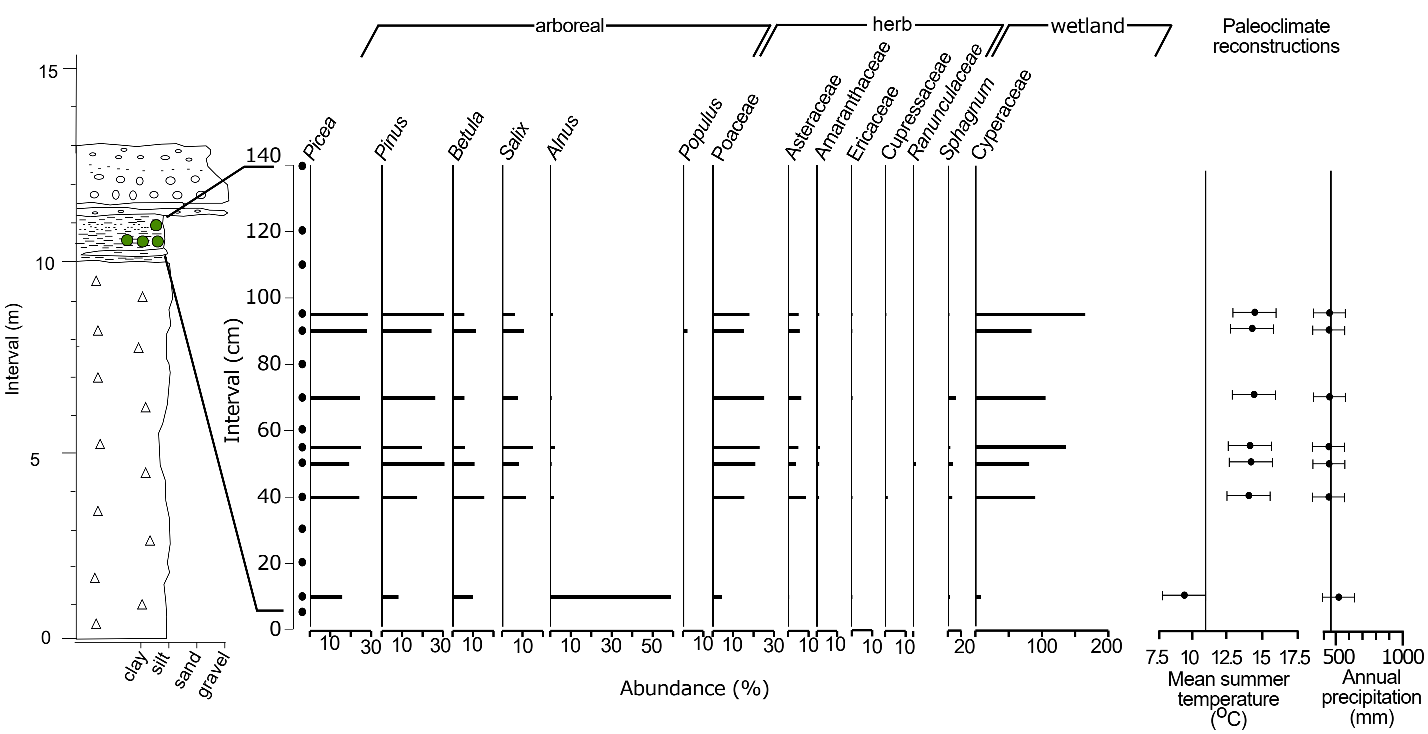

Figure 9: *Stratigraphic plot for site 11-PJB-186, showing pollen data, paleoclimate reconstructions and organic content for each interval. Stratigraphic record and radiocarbon ages (green circles) were published in Dalton et al. (2016). Vertical lines in the paleoclimate reconstruction plots represent modern-day conditions, which are 11°C and 467 mm, respectively (Natural Resources Canada, 2015). Only those pollen groups reaching 1% abundance in at least one sample are shown here. Black dots on the pollen diagram represent sampled intervals.*

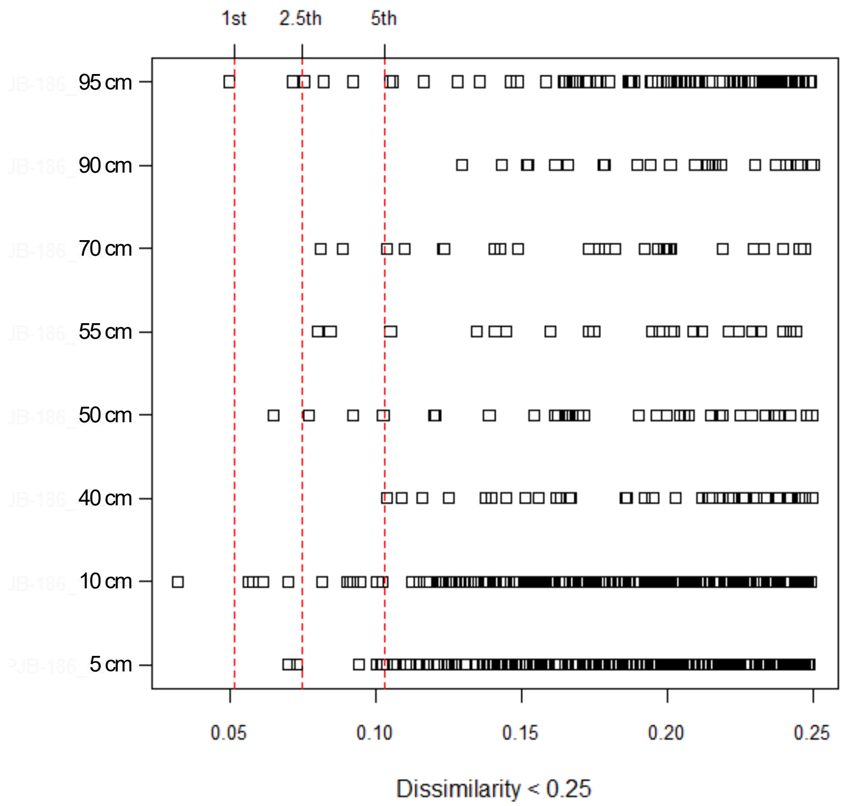

Figure 10: *Results of squared chord distance dissimilarity analysis between fossil pollen from site 11-PJB-186 and the modern-day calibration dataset (4882 sites spanning North America; Whitmore et al., 2005; Dalton et al., 2017). These values can range from 0.0 to 2.0, with 0.0 indicating identical proportions of species within the samples being compared. Total number of analogues for each fossil interval are detailed in Table 2, and top three analogues are mapped in Figure 4.*

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