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Abstract

The thicknesses of 384 rhythmic couplets were measured along a composite sequence of glacial Lake Ojibway glaciolacustrine deposits recovered in two sediment cores from Frederick House Lake, Ontario. The visual comparison of distinctive couplets in the CT-scan radiographs of the Frederick House core samples to photographs of core samples from Reid Lake show a match of ±1 varve number from v1656-v1902, and ±5 varve numbers between v1903-v2010, relative to the regional numbering of the Timiskaming varve series. There are two interpretations for the post-v2010 couplets that fall within the Connaught varve sequence of the regional series. In the first, the interpreted numbering spans from v2066-v2115, which produces a gap of 55 missing varves equivalent to v2011-v2065, and corresponds to the original interpretation of the Connaught varve numbering. The second spans *v2011a-v2060a,* and represents alternative (*a*) numbering for the same varves. Varve thickness data are listed in spreadsheet files (.xlsx and .csv formats), and CT-Scan radiograph images of core samples are laid out on a mosaic poster showing the interpreted varve numbering and between-core sample correlations of the varve couplets.

Introduction

Extensive glaciolacustrine deposits accumulated within a succession of proglacial lakes, known as Barlow, Barlow-Ojibway and Ojibway, which formed against the Laurentide Ice Sheet as it retreated northwards from western Quebec-northeastern Ontario in the late Pleistocene-early Holocene (Vincent and Hardy, 1979; Veillette, 1994; Dyke, 2004; Breckenridge et al., 2012). These sediments comprise the Greater and Lesser clay belts (Coleman 1909, 1922) and are well preserved within modern lake basins in the region (e.g., Doughty et al., 2013; Brooks, 2016a, 2018a; Brooks and Adams, 2020). The sediments are composed of rhythmic couplets that Antevs (1925, 1928) interpreted to be varves. He correlated the varve thickness patterns between locations in the region to compile the Timiskaming varve series, and numbered the varves from 1 (oldest) to about 2100 (youngest). Subsequent research verified his regional varve correlations and slightly expanded the varve series (see Hughes, 1959; 1965; Paulen, 2001; Breckenridge et al., 2012; Brooks, 2016a, 2018a, 2020, 2021; Godbout et al., 2019).

A number of varve series containing the youngest portion of the Timiskaming varve series are reported from locations just outside of the Cochrane Ice limits in the western area of the glacial Lake Ojibway basin (see Antevs, 1925, 1928; Hughes, 1959; 1965; Breckenridge et al., 2012; Godbout et al., 2019; Brooks, 2021). The most recently reported is the Frederick House Lake series by Brooks (2021), who focused particularly on the Connaught varves (post v2010), which forms the youngest sequence of the Timiskaming varve series.

This Open File complements and draws heavily from Brooks (2021). It contains thickness data for the Frederick House Lake varve series compiled from two sets of core samples recovered from Frederick House Lake (Fig. 1; Appendix A), and includes CT-Scan radiograph images of the core samples laid out in a poster-sized figure (Appendix B). Similar to Brooks (2016b, 2018b), the report also contains background information on the coring site locations, and summarizes the coring methodology and the interpretation of the varve numbering.

Study area

Summarized from Brooks (2021), Frederick House Lake is located about 35 km east-northeast of Timmins, Cochrane District, northeast Ontario (Fig. 1). The lake is 9.7 km long, 5.7 km wide and 37.6 km^2 in area. Modern lake levels are controlled by the Frederick House Lake dam, located about 12.5 km downstream of the basin outlet.

The study of varves in the Frederick House Lake area began in the 1920s by Antevs (1925, 1928), and occurred subsequently in the 1950s by Hughes (1959, 1965). More recently, Paulen (2001) measured varve thicknesses at a section immediately downstream (north) of Frederick House Lake dam, while Breckenridge et al. (2012) analyzed varves recovered in core samples from Reid Lake located about 11 km southeast of Frederick House Lake (Fig. 1).

Varve sedimentation in the Frederick House Lake area began at about varve year (vyr) 1400 (roughly 9.2 ka cal BP; see Breckenridge et al., 2012, their fig. 7), and extended until the final drainage of the glacial lake occurring between 8.47-8.21 ka cal BP (Breckenridge et al., 2012; Roy et al., 2011). Varves in the area fall stratigraphically within the upper portion of the Barlow-Ojibway sequence (about v1400-v1527), all of the Frederick House sequence (v1528-v2014), and the Connaught sequence (consisting of about 60 post-v2014 varves) that were defined by Hughes (1965). Varves in the Connaught sequence are considered to directly overlie those of the Barlow-Ojibway sequence, as

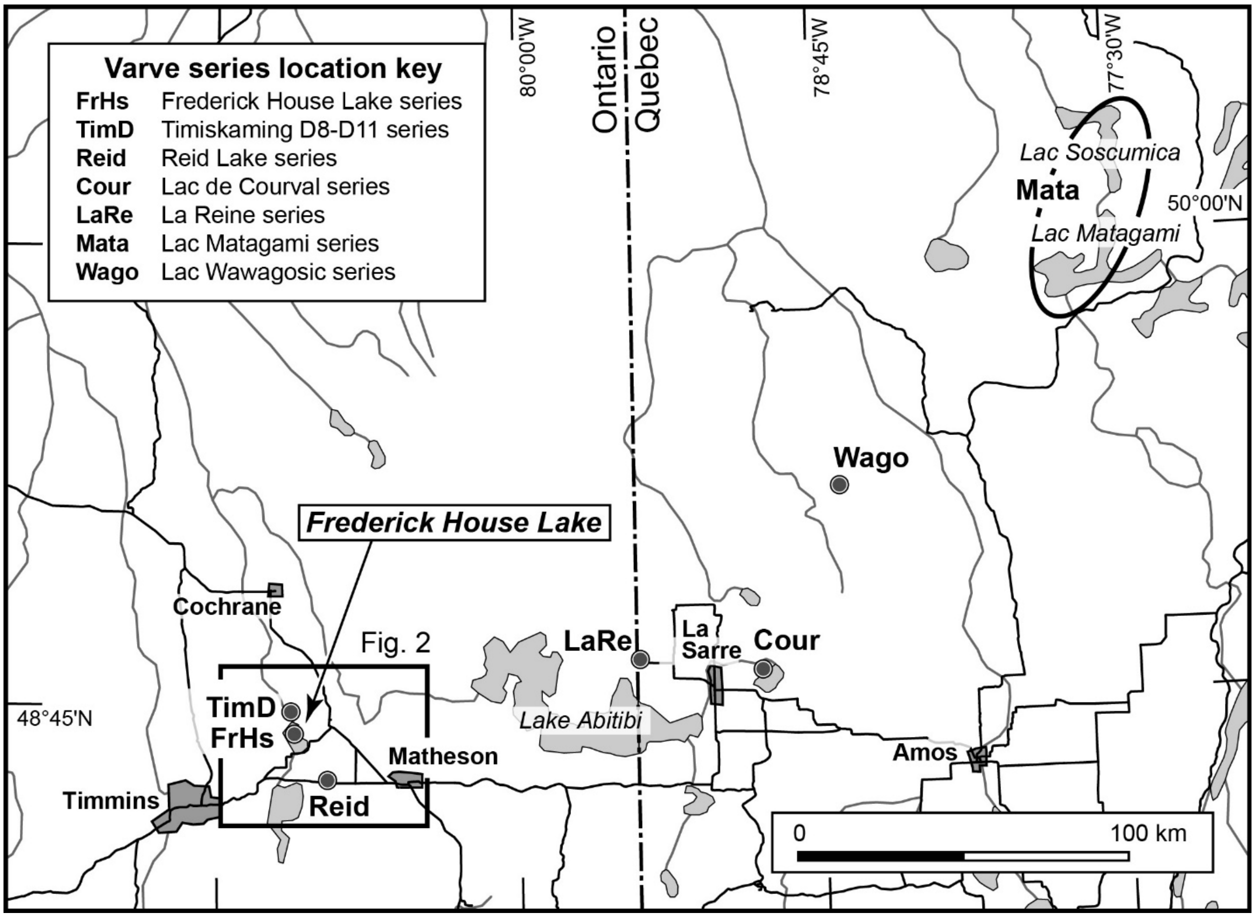

Fig. 1 Map of northeastern Ontario – western Quebec, Canada, showing the location of Frederick House Lake, and the locations of the six other varve series mentioned in the report. All of these varve series are located at single or several closely-spaced sites, except for the Lac Matagami series, which is based on 15 locations along Matagami and Soscumica lakes (see Hardy, 1976). (Figure modified from Brooks, 2021)

well as till deposited during the Cochrane advance of the Laurentide ice front (Hughes, 1965), which was the last advance to occur in the region prior to the final drainage of glacial Lake Ojibway.

Methods

Similar to reconnaissance sub-bottom acoustic profile surveys collected by the author at lakes in northeastern Ontario and western Quebec (e.g., Brooks and Grenier, 2017; Grenier and Brooks, 2017), a survey conducted at Frederick House Lake on August 12-14, 2017, used a Knudsen CHIRP Pinger SBP™ echosounder system with 15 and 200 kHz transducers mounted on a 4.9 m (16 ft) aluminum boat. Streamed differential GPS data collected with a Novotel Smart-V1 antenna-receiver were recorded along the profiling routes to fix the shot point locations. The survey route followed a rough zig-zag, or grid pattern (Fig. 2); the former in areas where there was no or limited penetration of the acoustic energy into the sub-bottom, and the latter where there were moderate to good quality reflections. The surveys collected 57.8 line-km of profiles of which the 15 kHz SEGY data were later examined using Kingdom™ software.

Coring from ice cover on March 9 and 10, 2018, recovered glacial Lake Ojibway varve deposits at two locations selected from the sub-bottom acoustic profiles (Fig. 2). Locating the coring sites in the field used differentially-corrected GPS coordinates collected with a Novotel Smart-V1 antenna-receiver. Coring utilized a Livingston piston corer (Livingston, 1955) with 50.8 mm (outside diameter) aluminum tubes that recovered segments of core 0.85 to 0.95 m long, depending on a given core tube length and the length of the piston used. At the two sampling sites, coring recovered samples from a pair of boreholes located about one metre apart. The segments of core samples from each pair of holes have overlapping sampling intervals, and form a continuous, composite sample of the penetrated sub-bottom deposits.

As described by Brooks (2016b, 2018b), analysis of the core samples used a Siemens SOMATOM Definition AS+128 CT Scanner at the Institut national de la recherche scientifique (INRS), Quebec City, Quebec, and produced tomodensitometry radiographs of the recovered deposits. Visual identification of common distinctive varves, distinctive groups of varves, or other stratigraphic features (e.g. mass transport deposits - MTDs) in the radiographs allowed the cross-correlation of marker deposits between overlapping core segments, producing a composite depositional sequence between the two coring sites. Two people independently measured varve thicknesses within each composite core, using full-scale, high-contrast, radiograph images, and the results then averaged (Zolitschka et al., 2015). Varve thicknesses are based on the visual interpretation of the top to bottom boundaries of varve couplets, and measurements made with the ruler tool in Adobe Illustrator™. Couplets that could be interpreted as one or two varves were flagged as uncertain varves. Cracks, which form from gas expansion as the cores are retrieved, cut across the core sediments in places. Where these could not be avoided, crack width was also measured and subtracted from the gross thickness of the enclosing couplet.

Sub-bottom acoustic profiles

The sub-bottom acoustic profile survey focused on the northern two-thirds of Frederick House Lake (Fig. 2), avoiding the southern area, where the lowering of the lake in 1909 exposed a large area of shallow lake bed (see Knight, 1911; Anonymous, 1938), and biogenic gas seemed likely to attenuate the acoustic energy of the profiler. (Lake level was restored subsequently by the construction of Frederick House River dam in 1938, located about 12.6 km below the lake outlet; Anonymous, 1938).

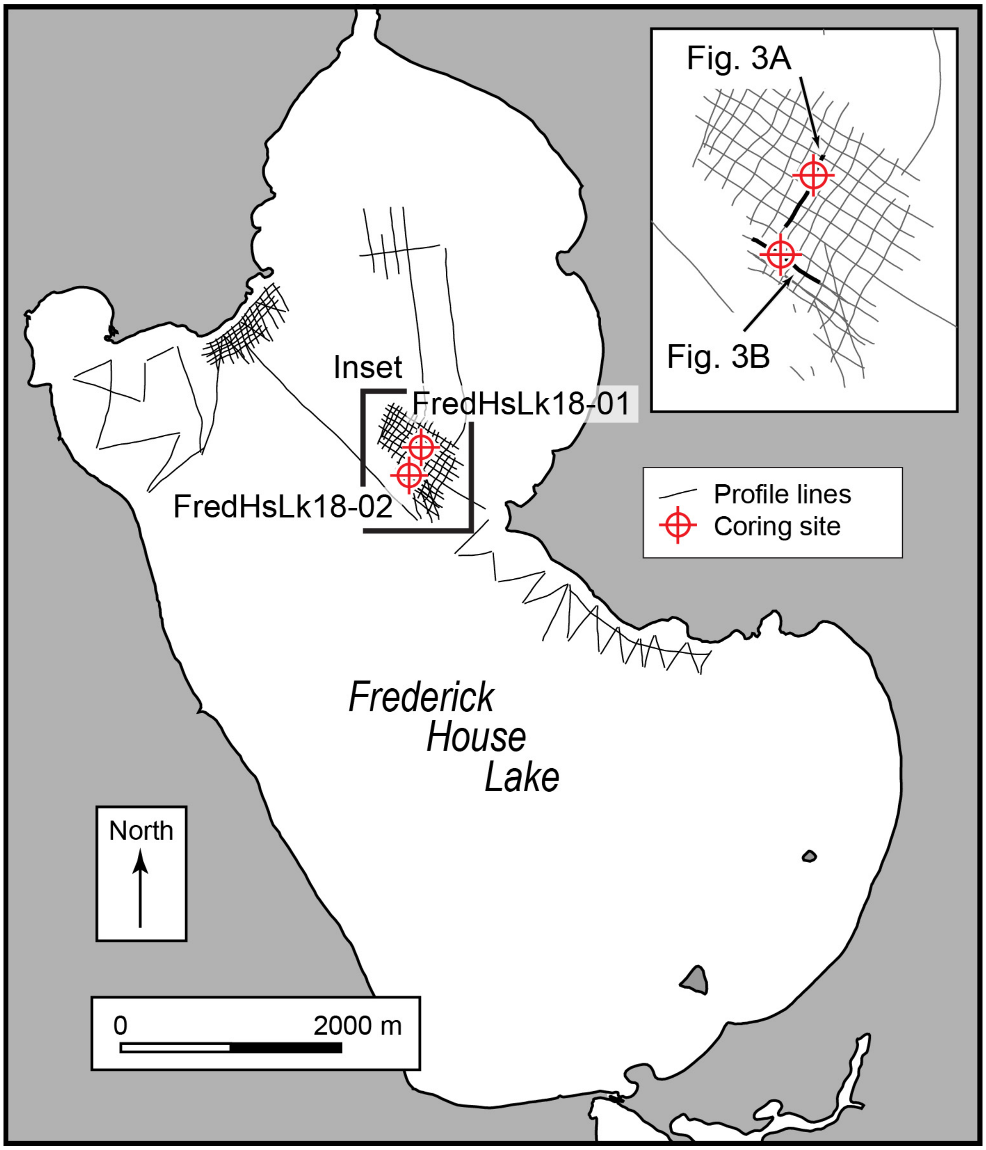

Fig. 2 Map of Frederick House Lake showing the sub-bottom acoustic profile lines collected in August 2018, and the locations of the two sediment coring sites. Inset map shows the locations of the profiles depicted on Fig. 3A and 3B.

The profiles contain three depositional facies (Fig. 3), as is consistent with other lakes in the glacial Lake Barlow-Ojibway basin (see Doughty et al., 2013; Brooks, 2016a, 2018a). Brooks (2021) interpreted: i) the thickest facies, which consists of multiple, decimeter-scale, parallel reflections, as glaciolacustrine deposits; ii) beds or lenses, which exhibit internally massive or chaotic reflections, as mass transport deposits (MTDs); and iii) a massive facies, which is the stratigraphically youngest in the lake, as post-glacial lacustrine sediments (Fig. 3).

As reported by Brooks (2021), notable in the acoustic profiles is a massive to chaotic MTD bed, 7-10 m thick, encountered in the dense pattern of profiles in the east-central part of the lake and in the central area of the north basin. This deposit extends across a distance of at least 2 km (Fig. 3). Although occurring discontinuously, the thick MTD bed represents a major depositional event within the Frederick House Lake sub-bottom stratigraphy. The lack of internal stratification within this facies is consistent with a deposit that accumulated rapidly as a single depositional event within a short interval of time (hours? days? few weeks?).

Core samples

Sediment coring at two sites specifically targeted the sequence of glaciolacustrine facies over- and underlying the thick MTD bed, as shown on Fig. 3, at the locations summarized in Table 1. Composite logs of the sampled deposits are shown in Fig. 4. See Brooks (2021) for a summary of the sampled deposits in the cores.

Table 1 Summary of March 2018 coring sites at Frederick House Lake, Ontario.

Coring site	Geographical coordinates	Water depth (m)	Depth of core penetration (m)	Comments
FredHsLk18-01	48.6712 -80.9328	4.5	7.45	Core samples recovered sequence of varve deposits underlying thick disturbed clay bed.
FredHsLk18-02	48.6694 -80.9339	5.0	5.45	Core samples recovered sequence of varve deposits overlying thick disturbed clay bed.

Frederick House varve series

The Frederick House varve series is a composite set of varves compiled using the core segments from cores FredHsLk18-01 and FredHsLk18-02 that are listed in Table 2. A mosaic of CT-Scan radiograph images from both cores is shown in reduced size in Fig. 5, and in poster size in Appendix B. The measured varve thicknesses along the composite core are listed in Appendix A in .xlsx and .csv formats. The thickness data are plotted in Fig 6 in combination with thickness data from the nearby Reid and Timiskaming D8-D11 series, and the more distant La Reine, Courval, Wawagosic, and

Table 2 Core segments used to compile the Frederick House Lake varve series.

Varve number range (original/*alternative* numbering; see text for explanation)	Core, core segment
2084/*2029a*-2115/*2060a*	FredHsLk18-02, 400-495 cm
1967-2079/*2024a*	FredHsLk18-01, 300-395 cm
1865-1966	FredHsLk18-01, 350-445cm
1835-1864	FredHsLk18-01, 400-495 cm
1811-1834	FredHsLk18-01, 450-545 cm
1735-1810	FredHsLk18-01, 500-595 cm
1712-1718	FredHsLk18-01, 550-645 cm
1695-1711	FredHsLk18-01, 600-695 cm
1657-1694	FredHsLk18-01, 650-745 cm

Matagami series (see Fig. 1). Brooks (2021) assigned numbering that follows the regional Timiskaming series to the Frederick House couplets in two parts, as summarized by varve numbering range in the following sub-sections.

v1656-v2010

As shown in Fig. 6 and listed in Table 3, the majority of the varves in the stratigraphically lower core FredHsLk18-01 (v1656-v2010) are readily correlated to the Timiskaming varve series using the Reid and Timiskaming D8-D11 plots, based on: i) the distinct thickening, then thinning, of varves between v1820-v1880; and ii) the general thickness pattern between v1656-v1718. A visual comparison of distinctive couplets in the CT-scan radiographs to Reid Lake core photographic imagery show a match of ±1 varve number from v1656-v1718, and v1735-v1902 (Fig. 7A and B), but a difference of up to five numbers between v1903-v2010/v2014 (the Reid numbering is slightly higher; Fig. 7C). Brooks (2021) attributed the latter shift to differing interpretations of clusters of indistinct, thin couplets within parts of this range. Also within this range, there is a poor visual match of couplets between the two series because of the commonly greater thickness to the Reid summer layers. Breckenridge et al. (2012) report that some of the thicker (cm-scale) summer layers contain sand, and they describe these couplets as rhythmites because of uncertainty about whether they represent varves *per se*. By comparison, very fine sand-coarse silt is present in thicker summer layers periodically through the Frederick House series between v1657-v1980, within both relatively thin and thick couplets. No obvious evidence was observed to suggest that the coarser layers represent anything other than the summer layer of varve sedimentation. Nevertheless, the Breckenridge et al. (2012) count of the rhythmite couplets is close to that of the Frederick House series (within the five couplet shift), possibly suggesting that the Reid couplets are varves. For example, couplets with similar thickness patterns are numbered v1964-v1975 and v1969-v1980 in the Frederick House and Reid series, respectively (Fig. 7C). Encouragingly, the v1900-~v2010/v2014 thickness patterns of both the Frederick House and Reid series reasonably resemble the nearby Timiskaming D8-D11 series (Figs. 1 and 6), which Antevs (1928) considered to be composed of varves. Brooks (2021) assumed the occurrence of continuous varve sedimentation between v1903-v2010 in the Frederick House series.

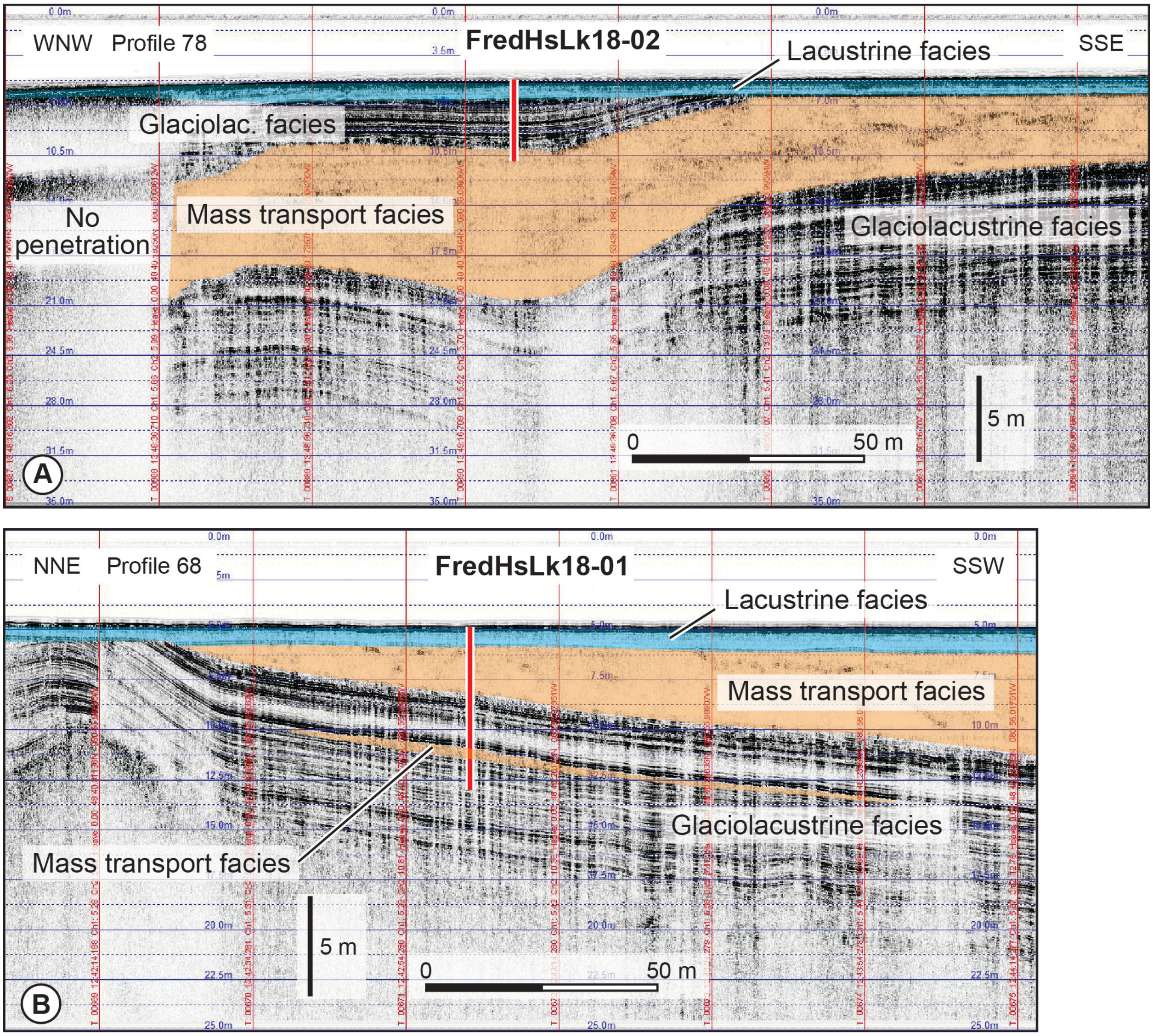

Fig. 3 Sub-bottom acoustic profiles at the locations of the FredHsLk19-02 (A) and FredHsLk19-01 (B) sediment coring sites showing glaciolacustrine , mass transport (orange shading), and lacustrine (blue shading) facies. The red vertical line in each profile represents the position and approximate depth of penetration of the recovered core samples. Note, the thick unit of mass transport facies interbedded between the upper (in A) and lower (in A and B) units of glaciolacustrine facies in the two profiles. See Fig. 2 for core locations.

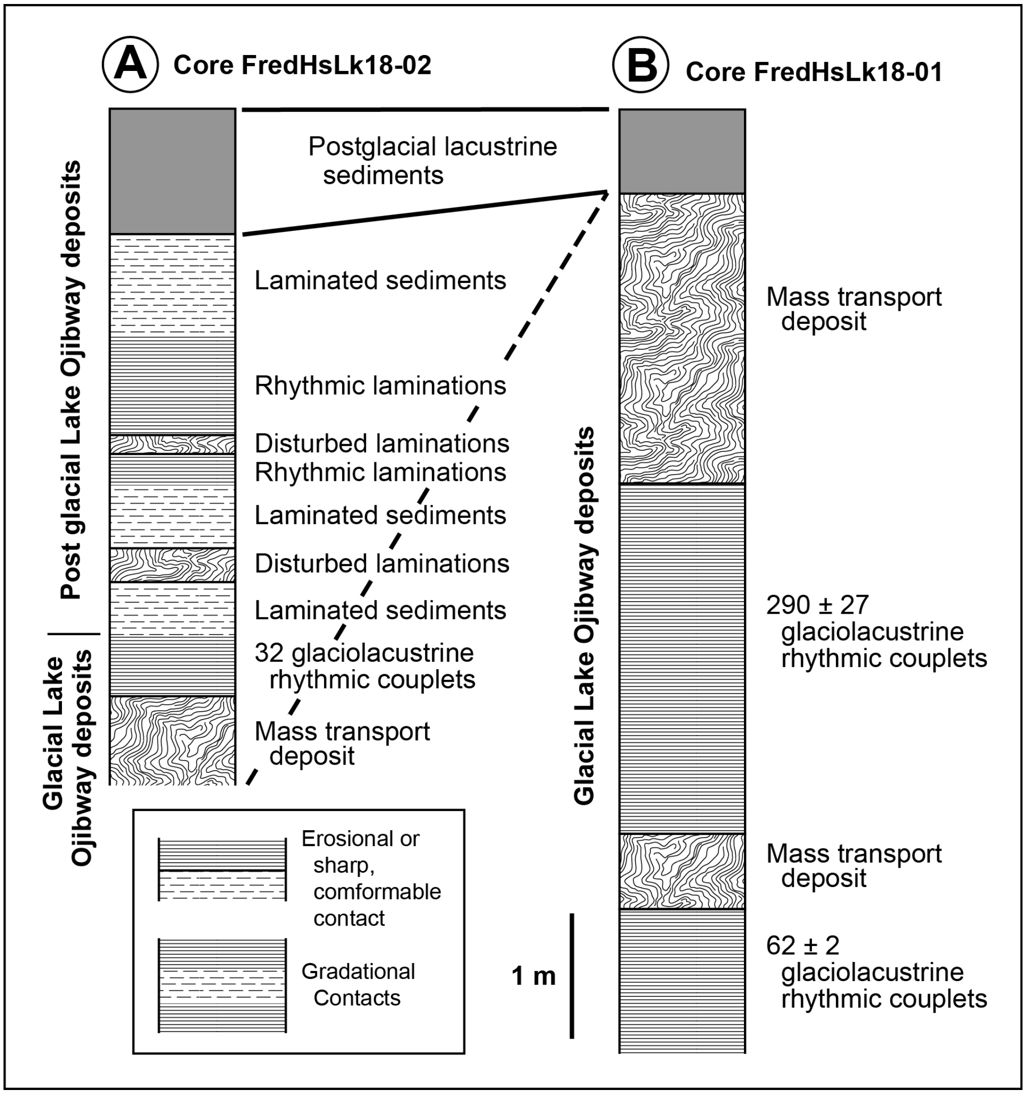

Fig. 4 Composite logs of cores FredHsLk19-02 (A) and FredHsLk19-01 (B); see Fig. 2 for core locations (from Brooks, 2021). The mass transport deposit at the bottom of core -02 is the lateral extension of that near the top of core -01, as confirmed by the sub-bottom acoustic profiles (see Fig. 3). The error range in the number of varves in a given bed reflects the presence of uncertain couplets that might be counted as one or two varves, as shown in Appendix B.

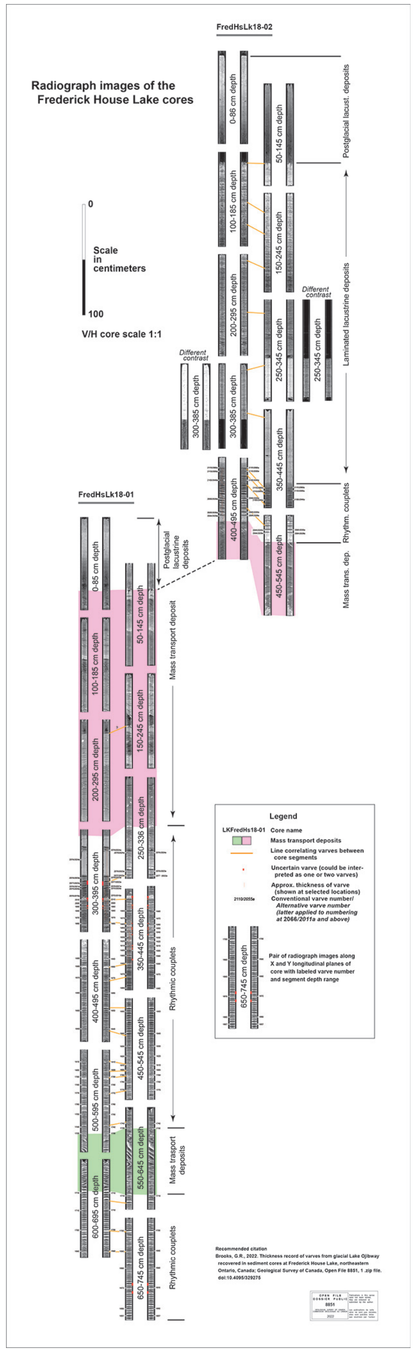

Fig. 5 Small-scale version of the core mosaic diagram, which shows the general lay-out of the images; refer to the poster-sized version in Appendix B to see specific details. In the mosaic, the radiographs are arranged in relative stratigraphic position under the core headings. Each core segment is represented by a pair of radiographs showing the deposits along central longitudinal X and Y planes. Orange lines correlate selected, distinctive varves between core segments. Selected varves are labeled by Timiskaming series varve number. Stratigraphic occurrences of mass transport deposits within the cores are represented by the colour shading.

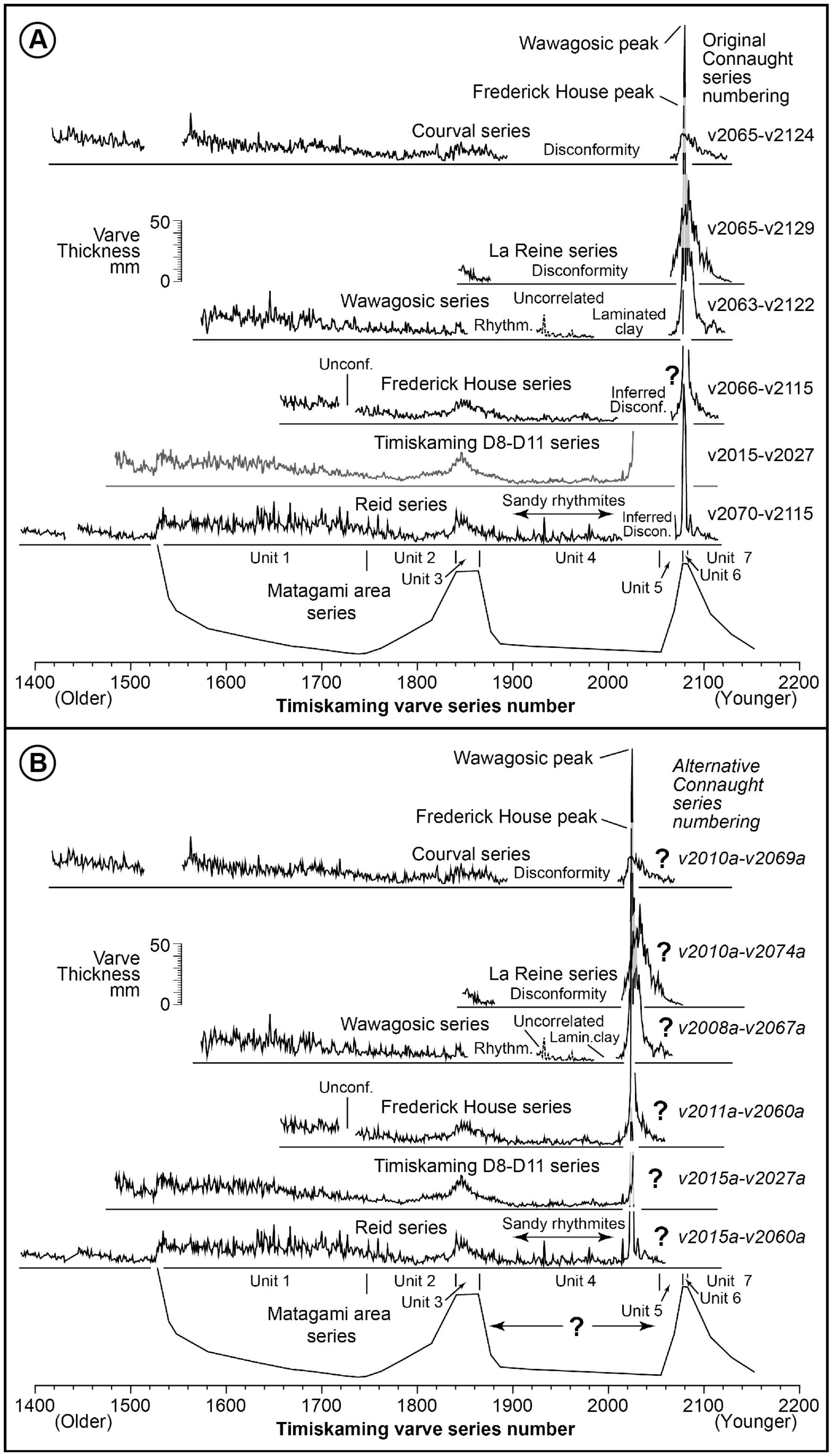

Fig. 6 Plots of varve thicknesses for the Frederick House varve series and the Timiskaming D8-D11, Reid, Courval, La Reine, Wawagosic, and Matagami series (diagrams modified from Brooks, 2021). The pre-v2010 portion of the Frederick House plot is identifical in A) and B), and the thickness patterns are correlated to Reid and Timiskaming D8-D11 plots. In A), the post-v2010 (Connaught sequence) of the Frederick House series is correlated to those of the Reid, Courval, La Reine, Wawagosic, and Matagami series, which infers a 55 vyr disconformity immediately below v2066 in the Frederick House plot. In B), the Frederick House series plot

(*caption continued*) depicts alternative numbering for the Connaught sequence, which extends continuously from v2010 i.e., without a 55 vyr discontinuity. Alternative numbering is also applied to the Reid, Courval, La Reine, Wawagosic, and Matagami series, by shifting the Connaught portion of the plots by 55 vyr to the left relative to the plots in A). In both A) and B), the Timiskaming D8-D11 plot is shown with the original numbering of Antevs (1928). In A), the pre-~v2060 numbering of the Courval, La Reine, Reid and Wawagosic plots follows the Timiskaming varve series of Antevs (1925, 1928), as interpreted by Breckenridge et al. (2012) or Godbout et al. (2019; La Reine). The post-~v2060 numbering follows Breckenridge et al. (2012) or Godbout et al. (2019; La Reine). The unit sub-divisions across the generalized Matagami plot follow Hardy (1976), and annotations on the other plots (except Frederick House and La Reine) follow Breckenridge et al. (2012). (Data courtesy A. Breckenridge – Reid, Timiskaming D8-D11, Wawagosic, Courval and Matagami series; P.-M. Godbout – La Reine series.) The post ~v2010 numbering in B) follows Brooks (2021).

Table 3 Summary of the interpreted varve numbering of the Frederick House Lake series with the two possible numberings of the post-v2010 couplets that form the Connaught sequence.

Varve sequence	Varve range	Comment
Frederick House sequence [1]	v1656-v2010	Good correlation to nearby Reid series, as confirmed by matching common distinctive varves (see Fig. 7A, B and C).
Connaught sequence [1] scenario one	v2066-v2115	Based on correlation to the Reid, La Reine, Courval and Wawagosic series, but numbering ultimately derived from Matagami series, as explained in the text and Brooks (2021). Numbering corresponds to original numbering of Connaught sequence.
Connaught sequence [1] scenario two	*v2011a-v2060*a	Alternative numbering based on the inference of continuous varve numbering from v2010, following Timiskaming D8-D11 series (after Brooks, 2021).

[1] The Frederick House and Connaught sequences are part of the regional Timiskaming varve series, and were defined by Hughes (1965).

Within the v1656-v2010 range, the Frederick House data contains an unconformity of 16 couplets equivalent to v1719-v1734 (Fig. 6A). This gap coincides with the stratigraphic position of the lower MTD in core FredHsLk18-01 (Figs. 3B, 4B and 7A; see Appendix B). The missing varves are interpreted by Brooks (2021) to comprise at least part of the disoriented, deformed, and disturbed couplets of the lower MTD, either as part of the initial failure, erosion at the base of the flowing mass, or a combination thereof.

Post v2010

Brooks (2021) presents two correlation scenarios for the post-v2010 couplets. The first consists of two interpretative steps. Firstly, he recognized that the marked decrease from very thick to thin couplets within the short set of the youngest varves from core FredHsLk18-02 match well with similar

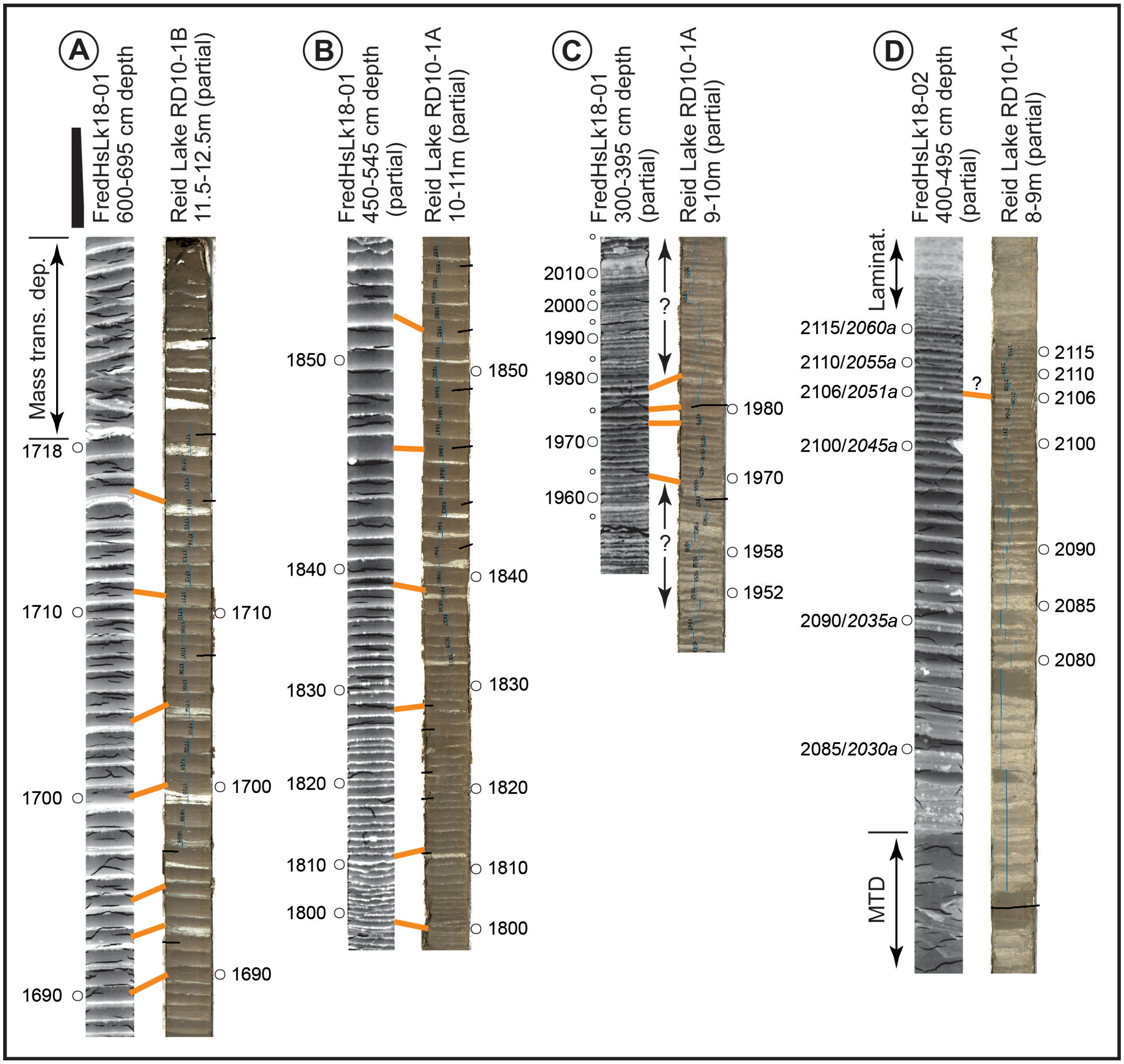

Fig. 7 Selected core samples from Frederick House Lake (CT-Scan radiographs) and Reid Lakes (scanned photographs) showing common distinctive varves between the two locations, as correlated by orange lines (see Fig. 1). The pair of core samples in A) and B) exemplify a correlation of ±1 varve number between the Frederick House and Reid couplets in the range from v1656-v1718, and v1735-v1902. In C), the core samples illustrate a short set of correlated couplets within the harder to correlate v1903-v2010 range, where couplet numbering differs by five numbers (the Reid numbering being slightly higher). The core samples in D) show a plausible correlation between distinctive varves in the post v2084/v*2029a* range. (2085/*2030a* – original/alternative varve numbering; Reid Lake couplet numbering interpreted by A. Breckenridge; Reid Lake images courtesy of A. Breckenridge).

patterns in the Reid, La Reine, Courval and Wawagosic series, as shown on Fig. 6A. The assigned numbering is defined based on an inference of a common distinctive varve (i.e., v2106) that is apparent on a Frederick House CT-Scan radiograph and photographic imagery of the Reid Lake core (see Fig. 7D). Sequential numbering is applied above and below this varve and spans v2084-v2115. This numbering range falls within the youngest part of the Connaught sequence.

In the second step, Brooks (2021) recognized that the pre-v2084 couplets, consisting of 14 varves and one partial varve, closely resemble the thickening portion of the continuous and marked thickening-thinning cycle that occurs between v2063-v2129 within plots of the Reid, La Reine, Courval and Wawagosic series, albeit with differing maximum varve thicknesses, as shown on Fig. 6A. The inferred numbering for the 14 Frederick House couplets is v2066-v2081, which creates a gap of three varves (v2081-v2083) and one unmeasured partial varve (v2080) between the peak couplet of the thickening set (v2079) and the first varve of the thinning set (v2084). This minor disconformity corresponds to the stratigraphic location of the thick MTD, and is readily accounted for by erosion at the base of the MTD. The correlation also produces an inferred disconformity of 55 missing varves where the plot spans the equivalent of v2011-v2065 (Fig. 6A). Overall, the interpreted numbering in scenario one spans v2066-v2115 (Table 3).

For the second scenario, comparison to the thickening, youngest varves of the Timiskaming D8-D11 plot suggests that the sequence of 14 varves and one partial varve is a direct continuation of the v1656-v2010 numbering. An alternative numbering for the Connaught sequence in the Frederick House series thus is shown on Fig. 6B where the varves in the thickening-thinning cycle are renumbered 2011-2025, and 2029-2060, respectively. This numbering extends continuously from v2010 and maintains the three-varve and one unmeasured partial varve gap of Fig. 6A that represents the stratigraphic location of the thick MTD between the two halves of the cycle. The reduction of the scenario two numbering, however, shifts the thickening-thinning cycle away from its good correlation with the post-v2060 portions of the Reid, La Reine, Courval and Wawagosic plots, thus creating different numbering between sequences of varves with otherwise similar thickness patterns (compare the Frederick House plot in Fig. 6B to the Reid, La Reine, Courval and Wawagosic plots in Fig. 6A). Hereafter, direct reference to the alternative varve numbering in the text or Fig. 7 appears in italic and suffixed by an '*a*' to differentiate it clearly from the original (or conventional) numbering plotted in Fig. 6A (e.g., *v2024a*). The alternative numbering interpreted in scenario two spans *v2011a*-*v2060a*, as listed in Table 3.

Discussion

Brooks (2021) discusses in detail the origin of post ~v2060 numbering applied to the Connaught sequence in the plots on Fig. 6A. Briefly, the numbering originates from the direct or indirect correlation of the Reid, Wawagosic, Courval, and La Reine series to the Matagami series, located about 300 km to the northeast of Frederick House Lake (Fig. 1; Breckenridge et al., 2012; Godbout et al., 2019). The Matagami series was presented originally by Hardy (1976) as a generalized, floating series consisting of 650 couplets. Breckenridge et al. (2012) correlated the intermediate portion of thick Matagami varves (unit 3; Fig. 6A) to the Timiskaming series thickness data, and applied the numbering v1840-v1860 to the Matagami varves. This numbering was extended across the full range of the Matagami series, allowing, in turn, Timiskaming numbers to be extrapolated back to the thick set of floating varves of the Connaught sequence by inferring that they are equivalent to the thick group of varves at the upper end of the Matagami series (units 5-6-7, now numbered v2060-v2153; Fig. 6A).

It is reasonable to consider that the thick groups of varves of the Connaught sequence and those spanning v1840-v1860 in the Frederick House, Reid, and Timiskaming D8-D11 series directly correlate to the units 5-6-7 and 3 of the Matagami series, respectively (Fig. 6A). Brooks (2021), however, questioned whether the Matagami varves represent a suitable master series for defining the numbering of the Connaught sequences for several reasons. Firstly, the post-v1900 portions of the Frederick House, Timiskaming D8-D11, and Reid plots, less the 55 varve year disconformity (i.e., shown as a continuous varve sequence through v2000-v2020; Fig. 6B), closely resemble one another and represent the most detailed post-v1850 rhythmite records yet reported in the glacial Lake Ojibway basin. Only by inferring a uniform disconformity between these locations can the consistency between the plots be maintained (see Fig. 6A), however, it seems too coincidental that there is a uniform erosive disconformity at three different locations 7 to 23 km apart (Fig. 2). The occurrence of a 55-vyr-long termination in sedimentation at the Frederick House and Reid sites also seems doubtful. Both sites are located within sub-basins of glacial Lake Ojibway that supported residual lakes (i.e., the modern lakes), hence, neither would have completely drained during lower lake stands and sedimentation in some form should have continued over such a period.

Secondly, there is no evidence of an irregular erosive unconformity in the depth range equivalent to that spanning v1900 and the thick MTD range within the reflections of the sub-bottom acoustic profiles from Frederick House Lake. This is despite the profiles being collected at variable orientations and within a dense grid, as well as the deposits have an undulating topography within the sub-bottom.

Finally, the thin rhythmites between v1900-~v2010 within the Frederick House and Reid core samples become difficult to identify in places, as mentioned above. Also, notably, rhythmite formation wanes temporarily and there is no apparent disconformity within the Wawagosic series, where a bed of faintly laminated clay is overlain by the Connaught varves (Fig. 6A). The absence of varve sedimentation within this part of the series, and at this location, the closest varve site geographically to Matagami and Soscumica lakes (Fig. 1), casts uncertainty on the apparent clarity of the post-v1874, unit 4 portion of the Matagami series in Fig. 6A. While an over-count error of 55 couplets to unit 4 of Hardy (1976) seems excessive, more plausible is a correlation error between locations, if the count is in fact a composite from two or more locations (the translated wording of Hardy (1976) implies that this is the case). Regardless, the possibility of a varve miscorrelation or miscount in the Matagami series cannot be discounted.

Alternative numbering for the Connaught sequence in the Frederick House, Reid, Courval, La Reine, and Wawagosic, without the 55 vyr unconformity, is depicted on Fig. 6B. Similar to Breckenridge et al. (2012, their fig. 5), the alternative numbering assumes that there is no time transgressive shift in the Connaught sequence between the locations (Fig 1). As is apparent, the Connaught sequences are well aligned, and now match the post-v2014 couplets of the Timiskaming D8-D11 series, using Antevs (1928) original numbers (compare Fig. 6A and B). However, the thick varves of units 5-6-7 in the Matagami plot, the numbering of which is unchanged between Fig. 6A and B, are now isolated temporally relative to the Connaught sequences on the other plots.

Applying the alternative numbering, v2129 is the youngest couplet in theTimiskaming varve series that is identified to have formed before the terminal drainage of glacial Lake Ojibway (see Godbout et al., 2019). In the alternative numbering, v2029 is the equivalent to *v2074a*, which indicates that the overall duration of the glacial lake may be marginally shorter than previous thought, although it remains about 2100 vyr long, but is rounded up rather than rounded down.

Godbout et al. (2019) reported an anomalous set of nine coarse rhythmites situated beneath v2065 (equivalent to *v2010a*) that overlies a major erosional unconformity (Fig. 6A and B). They interpreted these rhythmites to represent a late stage drawdown event. The equivalent couplet marking the drawdown event in the Frederick House series may be an anomalous couplet containing a thick summer layer composed of silt pellets and very fine sandy silt that is numbered v2066 or *v2011a* (see Appendix B). The alternative number implies that there is no disconformity underlying the drawdown event in the Frederick House Lake series, while the original (or conventional) number indicates a disconformity of 55 vyr.

Conclusions

The Frederick House Lake series consists of a composite set of 384 measured couplet thicknesses that correlate to the regional Timiskaming varve series. The visual comparison of distinctive couplets in the CT-scan radiographs of the Frederick House core samples to photographic images of the nearby Reid varve series show a match of ±1 varve number from v1656- v1718, and v1735-v1902, and ±5 varve numbers between v1903-v2010.

There are two interpretations for the post-v2010 couplets that fall within the Connaught varve sequence. In the first scenario, the interpreted numbering spans v2066-v2081 and v2084-v2115 with a minor disconformity representing the stratigraphic location of a MTD, 7-10 m thick, that interrupted the varve sedimentation. The interpretation also produces a gap of 55 missing varves equivalent to v2011-v2065. Spanning v2066-v2115 this numbering is derived from the correlation of the varve thickness pattern to the Reid, La Reine, Courval and Wawagosic series, but ultimately originates from the Matagami series. It represents the original interpretation of the Connaught varve numbering.

For the second scenario, alternative numbering for the Connaught varves is interpreted to span *v2011a-2025a*, and *2029a-2060a*, which maintains the same minor disconformity that represents the stratigraphic location of the thick MTD. This numbering extends continuously from v2010 and is derived from the correlation of the thickness pattern to the nearby Timiskaming D8-D11 located just north of Frederick House Lake. Overall, the alternative numbering spans *v2011a-v2060a*.

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