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Abstract

Cores recovered from six sites within a study area, ~3 km^2, at Lac Dasserat, northwestern Quebec, contained varved Lake Ojibway glaciolacustrine deposits. Measurements of the thicknesses of 546 couplets follow a composite sequence of varves through the recovered deposits. The couplets are interpreted to span varve numbers 1039 to 1637 with respect to the regional Timiskaming varve series. There is a gap of 48 varves in the varve record, representing an apparent erosional unconformity under the submarine landslide deposits of event horizon E. There are also two short gaps of unmeasured varves between varves 1266-1267 and 1051-1053. The 'Dasserat varve record' represents about 75% of the varve deposits preserved within the Lac Dasserat basin.

Introduction

A succession of glacial lakes, known as Barlow, Barlow-Ojibway and Ojibway, inundated large areas of northwestern Quebec-northeastern Ontario. Impounded against the retreating Laurentide Ice Sheet (LIS), the lakes evolved within the isostatically-depressed landscape of the Timiskaming and Hudson Bay basins (Vincent and Hardy 1979; Veillette 1994; Roy et al., 2015). A legacy of these glacial lakes is the regional occurrence of glaciolacustrine deposits that form the Great and Lesser clay belts areas in northwestern Quebec/northeastern Ontario, as has been described in early geological reports (e.g., Coleman 1909, 1922; Wilson 1918; James 1923).

Antevs (1925, 1928) interpreted the rhythmite couplets composing these deposits to be varves, each representing an annual sediment accumulation. He recognized that the varves form a time series that can be correlated throughout the region, based on varve thickness patterns, as subsequent research has verified (Hughes, 1959; 1965; Breckenridge et al., 2012). Known as the "Timiskamining varve series", the record is composed of about 2100 couplets, dated tentatively to have accumulated between 10,570 ± 200 and 8470 ± 200 ^{14}C cal BP (Breckenridge et al., 2012). Regionally, the varve deposits are time-transgressive with the sequences being older in the south and younger in the north, reflecting the progressive northward extension of the impounded water body in combination with the differential uplift of the landscape. No single location in the region contains the entire varve series.

Coring recovered varved Lake Ojibway glaciolacustrine deposits[1] from a study area at Lac Dasserat, northwestern Quebec (Fig. 1), as part of an investigation of the stratigraphy, distribution and triggering mechanism of submarine (or subaqueous) landslide deposits buried within the sub-bottom (Brooks, 2016; in press). The recovered deposits represent the majority of the varves preserved in the lake basin; but the oldest portion of the varve record was not cored.

This report contains data for the "Dasserat varve record" and thus augments regional varve data reported previously by Antevs (1925, 1928), Hughes (1959) and Breckenridge (2012). The report includes background information on the coring site locations and coring methodology. Data for the Dasserat varve record is listed in a digital spreadsheet file (.xlsx and .csv formats) containing couplet thicknesses measured along a composite sequence of the recovered varve deposits. An interpreted varve number (or varve year) correlated to the Timiskaming varve series accompanies each measured varve thickness in the spreadsheet file. The report also includes CT-Scanner radiograph images of the cores laid out in a poster-sized figure showing the between-coring-site correlations of the varve couplets. The Dasserat varve record data thus is available to aid future studies in the clay belt areas of northwestern Quebec/northeastern Ontario that utilize varves for chronological or stratigraphical control of the regional glaciolacustrine deposits.

[1] As there is no sedimentological or stratigraphical distinction between the glaciolacustrine deposits from the Barlow, Barlow-Ojibway, and Ojibway lake stages, for simplicity, all of the varves recovered in core from Lac Dasserat are considered to be glacial Lake Ojibway varves.

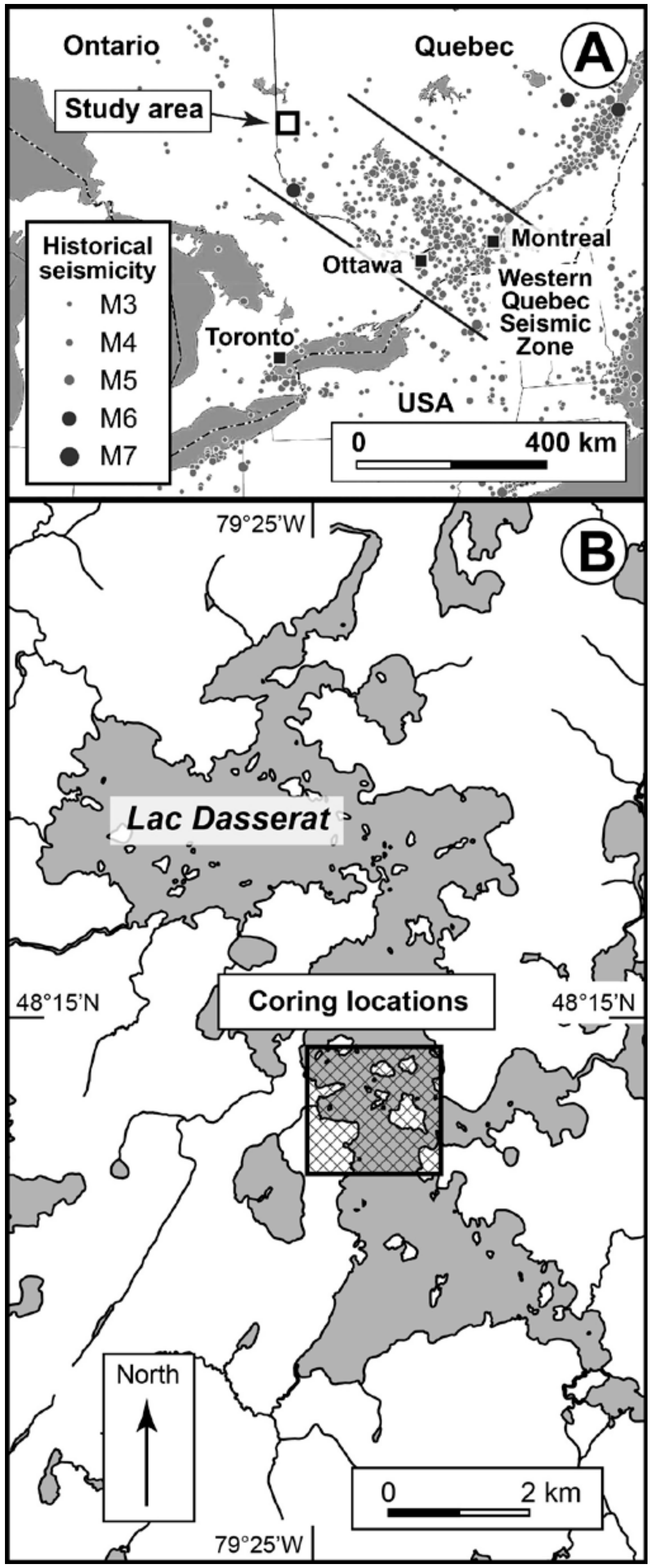

Fig. 1 Maps showing A) the location of Lac Dasserat within northwestern Quebec, and B) the study area within the Lac Dasserat basin (from Brooks, in press). The box in B) delineates the map in Fig. 2 showing the coring locations.

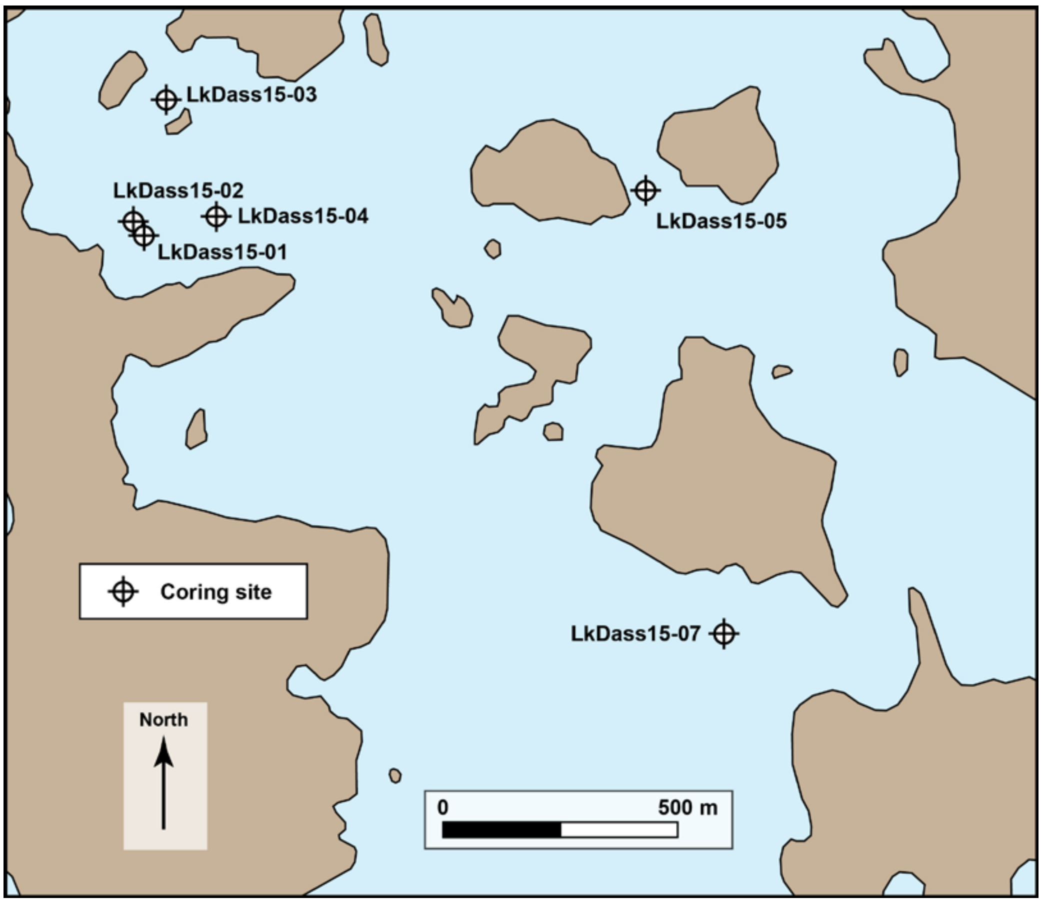

Fig. 2 Map showing the locations of the six coring sites within the Lac Dasserat study area.

Study area

Lac Dasserat is located ~425 km northwest of Ottawa, Ontario, near the Quebec–Ontario border (Fig. 1A). The lake covers ~28 km^2, is up to 12.4 km long, 6.5 km wide, and 17 m deep. The lake is irregularly shaped and its undulating bathymetry reflects the relief of the underlying bedrock. The immediately surrounding area consists of hilly terrain with relief up to 20 m high. The local surficial geology is mapped predominately as deep-water, glaciolacustrine sediments with numerous outcrops of bedrock, pockets of glacial deposits, and wetlands (Veillette at al. 2010). The coring sites are located within a study area, ~3 km^2, in the lower-middle portion of the lake, where a high-density sub-bottom acoustic profile survey was collected to map submarine landslide deposits (Fig. 1; Brooks, 2016; in press).

Coring methodology

Core was collected at six sampling sites from an ice cover platform in March 2015 (Table 1). Coring site selection targeted specific landslide deposits of interest, whilst minimizing water depth and limiting coring depth to within 4 to 6 m of the lake bed. Locating the coring sites in the field used differentially-corrected GPS coordinates collected with a Novotel Smart-V1 antenna-receiver. The coring utilized a Livingston corer (Livingston, 1955) with 50.8 mm (O.D.) aluminum tubes that recovered sections of core 0.84 to 1.0 m long.

Each sampling site consisted of a pair of recovered cores, located about one metre apart. One core started at the lake bed (0 m depth) and the other at 0.5 m depth. Together, the two cores yielded overlapping segments that form a continuous, composite sample of the targeted sub-bottom deposits for the sampling site. Immediately upon recovery, core tubes are sealed with plastic caps and taped securely, and then stored to prevent freezing.

Table 1 Summary of Lac Dasserat coring sites (see Fig. 2 for locations). All of the sites were selected based on sub-bottom acoustic profile returns and targeted submarine landslide deposits.

Coring Site	Date of coring	Latitude	Longitude	Depth of core penetration (m)	Water depth (m)
LkDass15-01	March 17 and 19, 2015.	48.24171	-79.4153	4.84	2.83
LkDass15-02	March 19, 2015	48.24197	-79.4156	6.0	3.05
LkDass15-03	March 13, 2015	48.2443	-79.4146	4.0	3.25
LkDass15-04	March 15 and 18, 2015	48.24203	-79.4132	3.48	5.08
LkDass15-05	March 14, 2015	48.24234	-79.4008	4.0	2.85
LkDass15-07	March 20, 2015	48.23383	-79.3989	4.84	4.20

Analysis using a Siemens™ SOMATOM Definition AS+128 CT-Scanner at the Institut national de la recherche scientifique facility, Quebec City, Quebec, produced radiographs of the whole (unsplit) cores. This yielded tomodensitometry radiographs of the deposits in the X and Y longitudinal planes at a 1:1 resolution of 2.048 pixels/mm (52 ppi), which is sufficient for measuring varve thicknesses.

In the laboratory, split core were logged and subsampled. At the time of writing, the split cores are stored at 4°C in a refrigerator at 601 Booth Street, Ottawa, Ontario.

As shown in Fig. 3 and in detail in Appendix A, the respective radiographs are arranged vertically in relative stratigraphic position under each of the respective six core headings. Each core segment is depicted by a pair of X and Y longitudinal radiographs that extend through the centre axis of the deposits. The varves are correlated between the overlapping core segments at each coring site by identifying common distinctive varves in the radiographs. Applying this process to the radiographs between the different coring sites, produced a composite sequence through the recovered deposits. The correlation also identified stratigraphically common portions of the recovered deposits between the coring sites, providing some redundancy in the sampled deposits.

As can be seen in Appendix A, there generally is minimal to no deformation of the varve couplets, except in the upper ~10 cm of many cores. Here, it is common and interpreted to arise from pushing the corer to the start of the sampling depth. Microfaulting may also be present at the top of a core segment, possible for the same reason, but it is commonly present elsewhere within the recovered core segments. In such cases, the microfaulting presumably is *in situ* within the glaciolacustrine deposits since it is not obviously the product of coring.

Submarine landslide deposits

Although not the subject of this report, there are five stratigraphic occurrences of submarine (or subaqueous) landslide deposits in the cores that are highlighted by colour shading in Fig. 3 and Appendix A. Although composed of resedimented varves, the landslide deposits are readily recognized in core by the presence of tilted, deformed, contorted, convoluted, brecciated, and/or otherwise disturbed couplets that contrast markedly with the undisturbed, quasi-horizontal, over- and underlying beds/laminations. Brooks (2016, in press) identified these stratigraphic occurrences as event horizons, each consisting of one or more separate landslide deposits. The deposits in the cores are part of horizons B, E, F, G or H out of the eight event horizons mapped in the Lac Dasserat study area.

Varve thickness record

The measurements of varve thicknesses followed a composite sequence of varves through the recovered deposits. Although there is overlap between some portions of the cores, there is only one measurement of each stratigraphic occurrence of a varve through the varve sequence. As much as possible, the choice of measurement sites focused on intervals of varves that lacked (or had less occurrences of) cracking, microfaulting and/or the perpendicularity of the couplets to the core tube sidewalls. The measured intervals of core segments are listed in Table 2. The measured varves are all situated within undisturbed glaciolacustrine deposits. The landslide deposits are also comprised of varves, but these are resedimented deposits and hence are stratigraphically out of sequence.

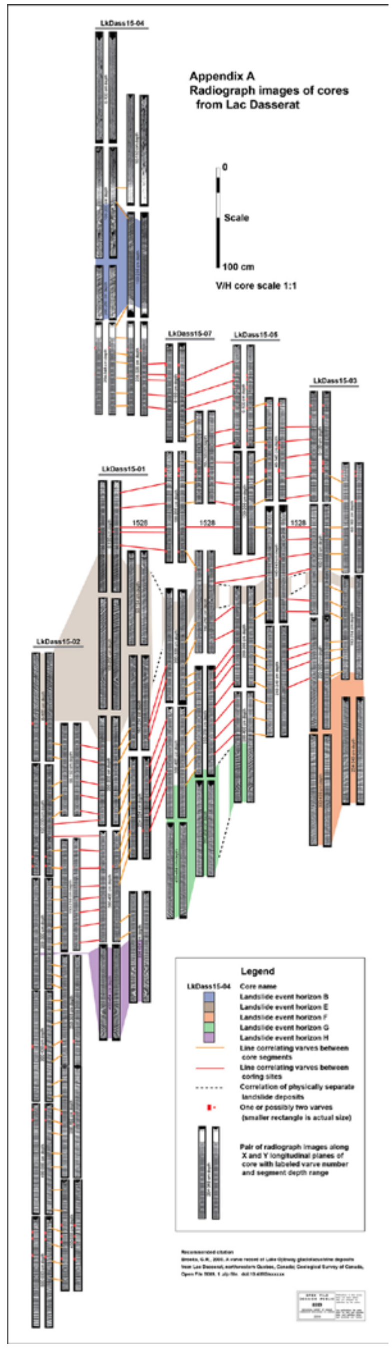

Fig. 3 Small-scale version of the core diagram showing the general lay-out of the radiographs; the version in Appendix A needs to be consulted to see specific details. In the figure, the radiographs are arranged vertically in relative stratigraphic position under the six core headings. Each core segment is represented by a pair of radiographs showing the deposits along the central longitudinal X and Y planes. Correlation lines link selected varves between core segments (orange lines) and between the coring sites (red lines). The correlation line labeled ‘1528’ marks a distinctive thickening of the varves that occurs regionally within the Lake Ojibway glaciolacustrine deposits. Five stratigraphic occurrences of landslide deposits are present within the cores and are represented by the coloured areas.

Two people measured the thickness of each varve using 1:1 (or larger) scale radiograph images and the measurement tool in Illustrator™, and the results averaged (Zolitschka et al., 2015). The measurements were made adjacent to a reference line placed over each varve in the Illustrator file to ensure consistency of measurement locations between the two sets of varve measurements. The average varve thicknesses are listed in a spreadsheet in both .xlsx and .csv formats in Appendix B.

Table 2 Listing of the range of varve numbers and, the respective cores and core segments along which the varve thicknesses were measured.

Varve number range	Core, core segment
1596-1637	LkDass15-04, 254-348 cm
1576-1595	LkDass15-07, 0-100 cm
1556-1575	LkDass15-07, 66-150 cm
1528-1555	LkDass15-07, 100-200 cm
1484-1527	LkDass15-05, 140-240 cm
1418-1435	LkDass15-03, 100-200 cm
1408-1417	LkDass15-05, 140-240 cm
1366-1407	LkDass15-05, 200-300 cm
1354-1365	LkDass15-07, 250-350 cm
1278-1353	LkDass15-07, 300-400 cm
1253-1277	LkDass15-02, 200-300 cm
1238-1252	LkDass15-02, 250-350 cm
1175-1237	LkDass15-02, 300-400 cm
1153-1174	LkDass15-02 350-450 cm
1098-1152	LkDass15-02, 400-500 cm
1085-1097	LkDass15-02 450-550 cm
1039-1084	LkDass15-02, 500-600 cm

Varve correlation to the Timiskaming varve series

The thicknesses of 546 measured varves forming the Dasserat varve record are plotted in Fig. 4. Stratigraphically, the sequence is continuous through the composite core, except where interrupted by the landslide deposit of event horizons E and H and by a zone of strong microfaulting, ~50 mm thick, in the lowest segment of core LkDass15-02 (see Appendices A and B).

In Fig. 4, the Dasserat varve record is shown with those from lakes Duparquet and Montbeillard (Breckenridge et al., 2012) and, A7, B7-B8a and F5-F6-F7-F8 from the Timiskaming varve series (Antevs, 1925; 1928). Correlating the portion of the Dasserat record above event horizon E is based on the recognition of varve 1528, which is a regionally distinctive varve that marks a significant increase in varve thickness within the Timiskaming varve series (Fig. 4, Appendix A; Antevs, 1925, 1928; Hughes, 1965; Breckenridge et al., 2012). Antevs varve numbers 1484 to 1637 follow in sequence the measured varves above and below varve 1528 (Fig. 4, Appendix A). An additional 13 varve numbers (to varve 1650) are assigned to varves that were too thin and/or

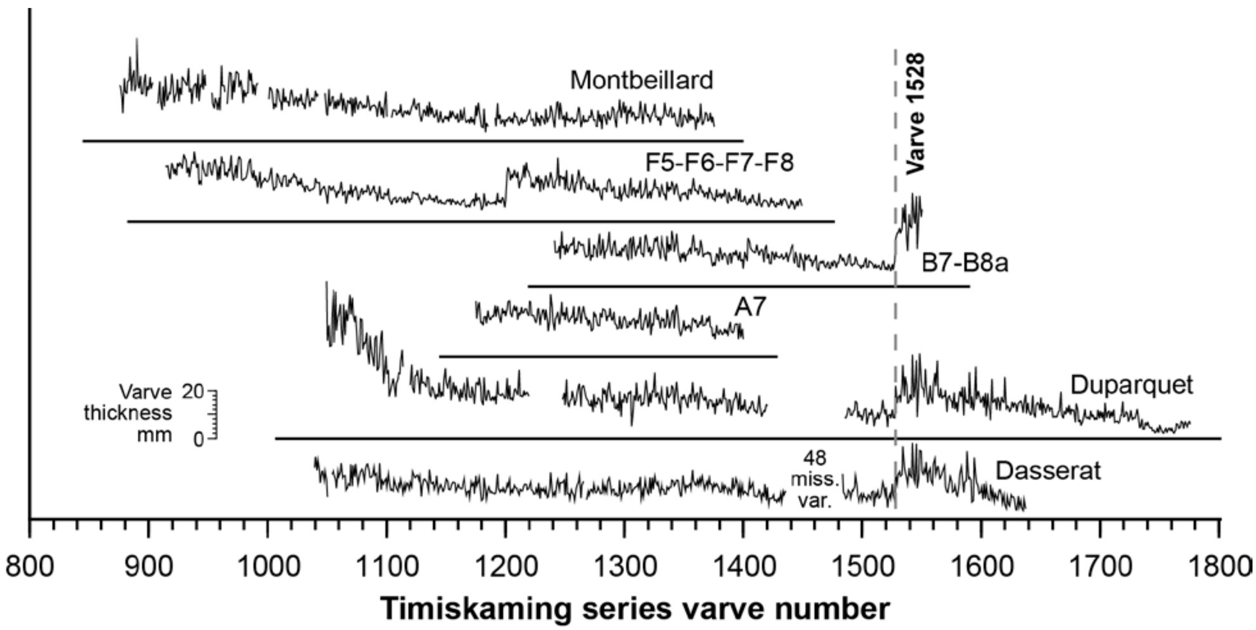

Fig. 4 Plots of the varve thickness versus Timiskaming series varve number (or varve year) for the Dasserat varve record as well as records from lakes Duparquet and Montbeillard (from Breckenridge et al, 2012), and the Timiskaming A7, B7-B8a and F5-F6-F7-F8 records (from Antevs, 1925; 1928). This figure originates from Brooks (in press) and was plotted using digital data courtesy of A. Breckenridge. Note, the marked increase in varve thickness beginning at varve 1528 within the Dasserat, Duparquet and B7-B8a plots. This thickening occurs regionally and is a useful marker bed for correlating varve records (Antevs, 1925; 1928; Hughes, 1959; 1965; Breckenridge et al., 2012). An apparently similar step in varve thickness occurs along the F5-F6-F7-F8 plot at varve number 1200, but instead this seems to be an artefact within a composite varve sequence caused by a marked northward change in varve measurement location.

deformed to be measured; these are shown in Appendix A, but are not included in Fig. 4 or in the spreadsheet data of Appendix B. Varve numbers 1039 to 1435 are assigned to varves below horizon E, based on similar thickness patterns to the Duparquet and Montbeillard records. Cross-correlation statistics from ANTEVS (V1.1) varve correlation software (Vollmer, 2014) between the Dasserat and the Timiskaming A7, B7-B8a, and F5-F6-F7-F8 varve records are listed in Table 3. Pearson's r values of 0.499 to 0.609 at offsets of zero years are interpreted to support the Timiskaming varve series numbering assigned to the Dasserat record that is shown in Fig. 4 and listed in the spreadsheet data of Appendix B (Rayburn and Vollmer, 2013).

Table 3 Cross-correlation statistics of the Dasserat varve record (1039-1637) compared to selected records of the Timiskaming varve series.

Varve series	r [a]	z [b]	n [c]	t [d]	Offset
Timiskaming A7	0.574	4.544	226	8.612	0
Timiskaming B7-B8a [e]	0.499	4.841	310	8.764	0
Timiskaming F5-F6-F7-F8	0.609	5.504	398	12.135	0

[a] Pearsons' r values
[b] z –score
[c] Number of overlapping varves
[d] Significance measurement
[e] Record includes varve 1528

In the Dasserat record, varve 1435 is the youngest varve underlying the landslide deposits of event horizon E in the composite varve record and differs significantly from the youngest overlying varve (varve 1484). This difference reveals an erosional unconformity of 48 'missing' varves below horizon E in the composite sequence (Fig. 4). Within the five cores containing the base of this horizon, the number of missing varves is variable, ranging from 48 to 77 varves. Evidentially, the landslide deposits at these five coring sites eroded the lake bed during emplacement, although this is not obvious at every site in the profiling returns. There are two short gaps of unmeasured varves in the sequence between varves 1266-1267 and 1051-1053. The former gap occurs because of the deposition of the landslide deposits of horizon H and the latter due to heavy, localized microfaulting (see Appendix B).

There are 29 stratigraphic occurrences of uncertain varves identified in the recovered core deposits, representing ~5% of the 546 long varve sequence. The uncertain varves are flagged by small red rectangles on the core radiographs in Appendix A. An uncertain varve usually is significantly thinner than the immediately over- and underlying varves and appears more or less as a couplet within a couplet. Within sequences of overlapping varves between the coring sites, an uncertain varve commonly is present in one core, but completely absent in the equivalent location in another (or others). This, together with the much thinner couplet size, suggests that these are ‘false varves’. Such false varves are not counted within the Dasserat sequence of varves.

Possible error in the numbering of the Dasserat varve record relative to the three Timiskaming varve records is estimated to be ±2 varves, based on the occurrence of shifts of one to two varves in the positions of distinctive peaks and troughs. These shifts are localized between the records and may reflect the occurrence of missing and false varves that self-cancel up and down the records (Lamoureux, 2001).

Dasserat varve record

Because the coring is part of an investigation of landslide deposits in the sub-bottom, it did not recover the full sequence of varves preserved in Lac Dasserat. From Breckenridge et al. (2012, their Fig. 7), it is estimated that the varve sequence in Lac Dasserat begins at approximately varve number 800. Thus the Dasserat varve record, spanning varves 1039 to 1637, represents about 75% of the preserved varve record. After varve 1637, the varve couplets thin and become difficult to distinguish. This thinning is thought to reflect falling of Lake Ojibway water levels over the Dasserat basin that caused the waning and eventual cessation of local varve sedimentation. The stratigraphically younger portion of the Timiskaming varve series (varves 1700(?) to ~2100) likely never formed within the Dasserat basin.

Conclusions

The Dasserat varve record contains 546 couplet thickness measurements along a composite sequence of varves. The couplets span varve numbers 1039 to 1637 within the Timiskaming varve series. The record represents about 75% of the varve sequence preserved within the Lac Dasserat basin.

There is a gap of 48 varves in the Dasserat varve record, representing an apparent erosional unconformity under the landslide deposits of horizon E. There are two short gaps of unmeasured varves at varves 1266-1267 and 1051-1053.

Error in the numbering of the Dasserat varve record relative to three Timiskaming varve series records is estimated to be ±2 varves.

Varve 1528 is present within the Dasserat varve record. This varve corresponds to a marked increase in varve thickness that occurs regionally within the Lake Ojibway glaciolacustrine deposits.

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References

Antevs, E., 1925, Retreat of the last ice-sheet in eastern Canada, Geological Survey of Canada Memoir 146, 138 p.

Antevs, E., 1928, The last glaciation with reference to the retreat in northeastern North America, American Geographical Society Research Series No. 17: New York, 262 p.

Breckenridge, A., Lowell, T.V., Stroup, J.S. and Evans, G., 2012, A review and analysis of varve thickness records from glacial Lake Ojibway (Ontario and Quebec, Canada): Quaternary International, v. 260, p. 43-54.

Brooks, G.R., 2016, Paleoseismic assessment of multi-mass transport deposit signatures preserved within the deposits of glacial Lake Ojibway, northwestern Quebec, Canada. 7th International INQUA Workshop on Active Tectonics Paleoseismology and Archaeoseismology, May 30-June 3, 2016, Crestone, Colorado, USA.

Brooks, G.R., in press, Evidence of late glacial paleoseismicity from mass transport deposits within Lac Dasserat, northwestern Quebec, Canada. Quaternary Research (2016), http://dx.doi.org/10.1016/j.yqres.2016.06.005.

Coleman, A.P., 1909, Lake Ojibway: last of the great glacial lakes. Ontario Bureau of Mines. v. 18, pt. 1, p. 284-293.

Coleman, A.P., 1922, Glacial and post- glacial lakes in Ontario. University of Toronto Studies, Publications of the Ontario Fisheries Research Laboratory. v. 10, 76 p.

Hughes, O.L., 1959, Surfical geology of Smooth Rock and Iroquois Falls map areas, Cochrane District, Ontario: Department of Geology, University of Kansas, unpublished Ph.D. thesis, 190 p.

Hughes, O.L., 1965, Surficial geology of part of the Cochrane District, Ontario, Canada. *in* International Studies on the Quaternary INQUA U.S.A. Wright Jr., H.E. and Frey, D.G. (ed.), Geological Society of America, Special Paper 84, 535-565.

James, W.F., 1923, Duparquet Map-Area, Quebec. Geological Survey, Canada Department of Mines. Summary Report, 1922, Part D, p. 75-96.

Lamoureux, S., 2001, Varve chronology techniques, In: Last, W.M., Smol, J.P., (Eds.), Tracking environmental change using lake sediments. Volume 1. Basin analysis, coring, and chronological techniques. Kluwer Academic Publishers, Dordrecht, pp. 247-259.

Livingstone, D.A. 1955, A lightweight piston sampler for lake deposits. Ecology 36, 137-139.

Rayburn, J.A. and Vollmer, F.W., 2013, ANTEVS: A quantitative varve sequence cross-correlation technique with examples from the northeastern United States. GFF: Journal of the Geological Society of Sweden 135, 282-292.

Roy, M., Veillette, J.J., Daubois, V., Ménard, M., 2015. Late-stage phases of glacial Lake Ojibway in the central Abitibi region, eastern Canada. Geomorphology 248, 14-23.

Veillette, J.J., 1994, Evolution and paleohydrology of glacial Lakes Barlow and Ojibway. Quaternary Science Reviews, v. 13, p. 945-971.

Veillette, J.J., Paradis, S.J. andThibaudeau, P., 2010, Surficial geology, Rouyn-Noranda–Senneterre, Quebec/Géologie des formations superficielles, Rouyn-Noranda–Senneterre, Québec. Geological Survey of Canada, Open File 6061.

Vincent, J.-S. and Hardy, L., 1979, The evolution of glacial lakes Barlow and Ojibway, Quebec and Ontario. Geological Survey of Canada Bulletin 316, 18 p

Vollmer, F.W., 2014, ANTEVS: Automatic numerical time-series evaluation of varying sequences software. Retrieved on June 23, 2015 from: www.frederickvollmer.com/antevs.

Wilson, M.E., 1918, Timiskaming County, Quebec. Geological Survey, Canada Department of Mines, Memoir 103, 197 p.

Zolitschka, B., Francus, P., Ojala, A.E.K., and Schimmelmann, A., 2015, Varves in lake sediments – a review. Quaternary Science Reviews 117, 1-41.