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Introduction

The Red River, Manitoba, occupies a shallow stream-cut valley that is slightly incised into the flat clay plain of the Red River valley (Brooks and Nielsen, 2000). There are only eight ox-bow lakes and channel scars located between the Emerson at the Canada/USA border and the river mouth at Lake Winnipeg, a distance along the river valley of 170 km. This Open File Report contains sedimentological, grain size, carbon content and chronological data from two deep boreholes drilled into ox-bow lakes, Horseshoe Lake and the former Marion Lake (fully drained in 1961/62 for agricultural purposes (R. Fillon, oral communication)) along the Red River, Manitoba. The purpose of this coring program was to date the abandonment of the channel that forms the lake basin. This paper supplements recent studies examining the paleoenvironmental record contained within several ox-bow and channel scar lakes within southern Manitoba (see Brooks and Grenier, 2000; Medioli, 2001; 2003). Complimentary data on other boreholes undertaken from the Red River floodplain are contained in Brooks et al. (2000).

Core locations

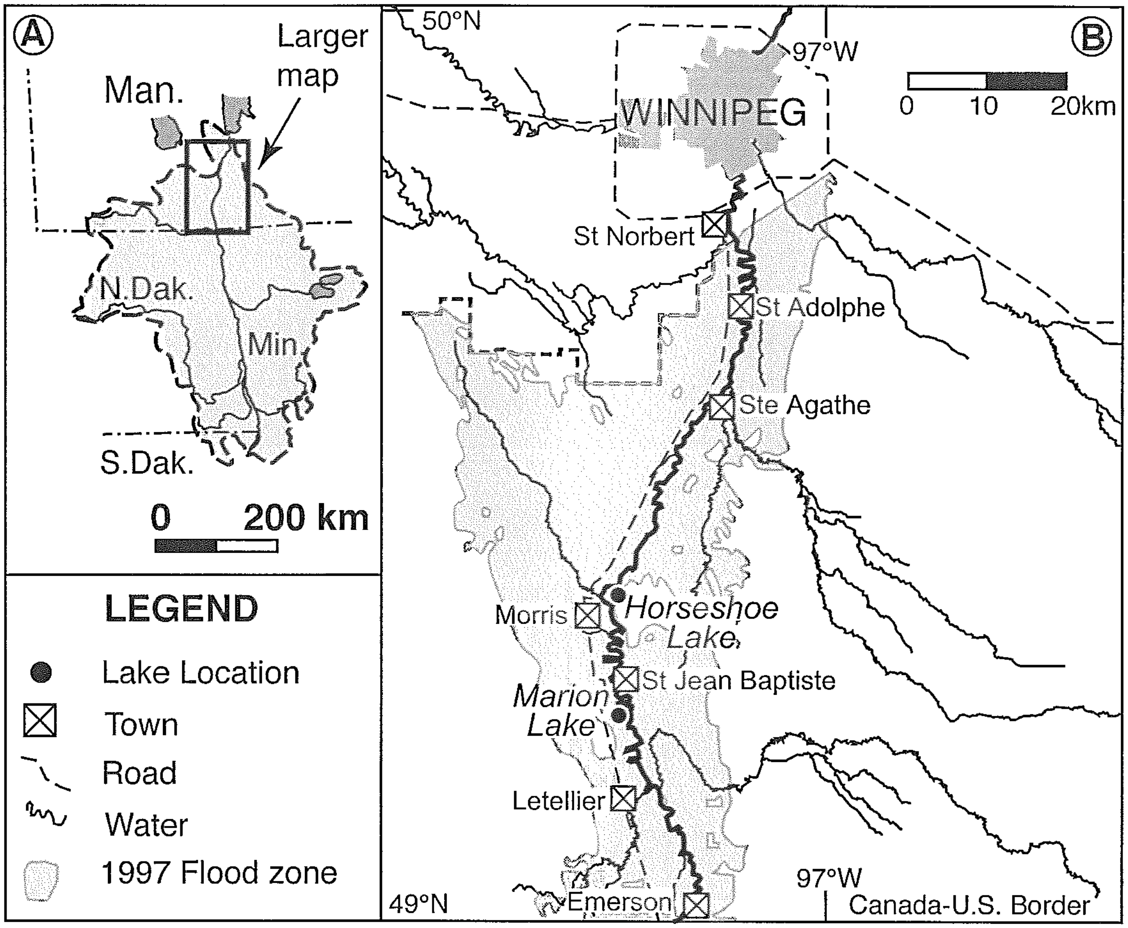
Horseshoe Lake is an oxbow lake created by the cut-off and abandonment of a meander and lies about 1 km E of the river, 2.5 km SE of the town of Morris (Fig. 1 and 2a). The coring site is located at approximately the meander apex, at the centre of the channel. The coordinates of the site are 49° 20.3′ N, 97° 19.5′ W. Marion Lake is located approximately 500 m W of the Red River, approximately 5 km SSE of the town of St. Jean Baptiste (Fig.1 and 2b). The lake was drained and is now under cultivation; the feature now represents a channel scar on the floodplain. The coring site was located at approximately the meander apex, about two-thirds of the way across the channel. The site coordinates are 49° 13.3′ N and 97° 19.3′ W.

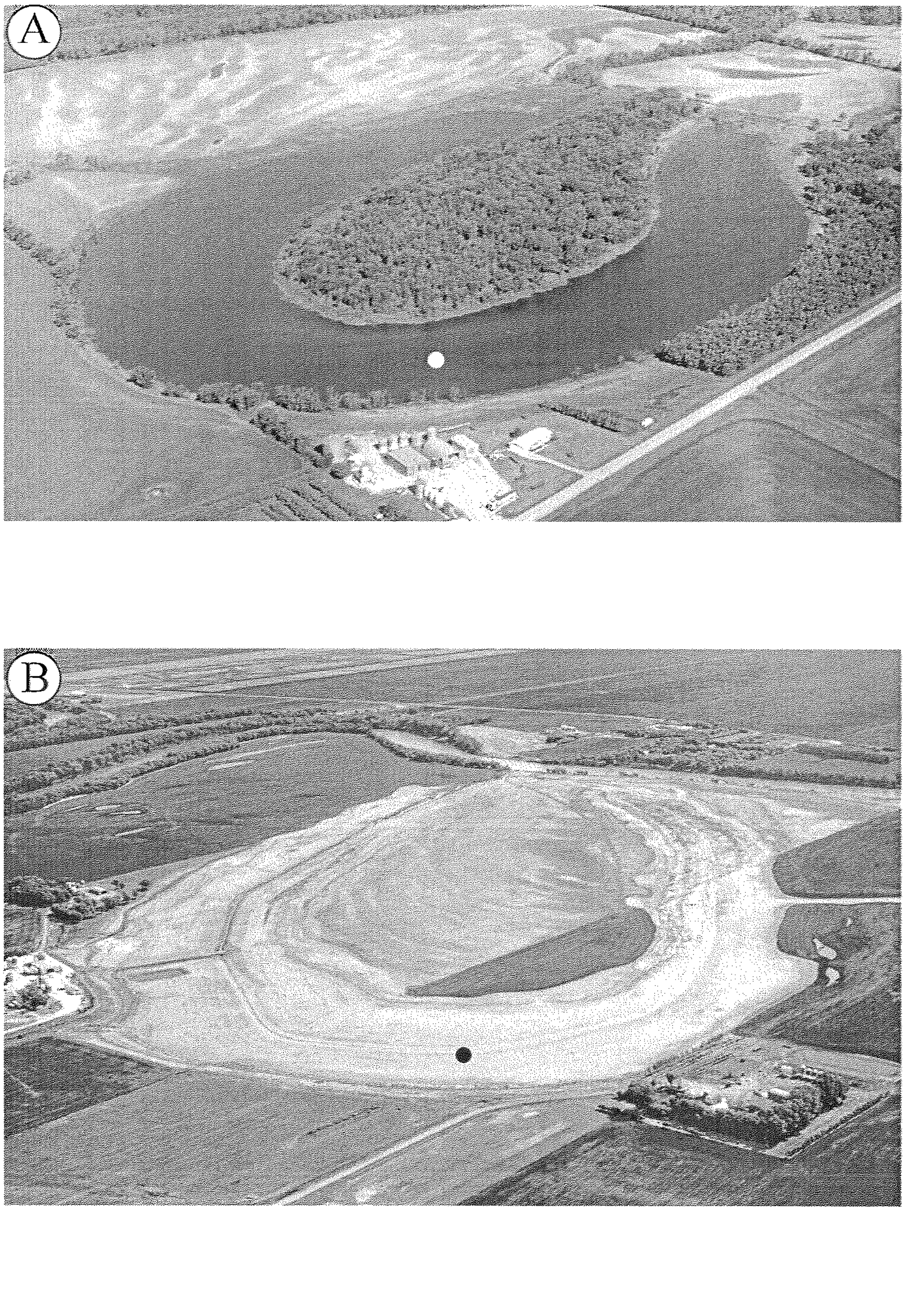
Fig. 1 A) Map showing the drainage basin of the Red River. B) Map showing the general location of Horseshoe Lake and Marion Lake within the Red River valley.

Fig. 2 A) Aerial photograph showing Horseshoe Lake and the approximate coring location on the lake. B) Aerial photograph showing Marion Lake and the approximate coring location on the lake.

Core collection and handling

The Marion Lake borehole was drilled on October 4, 1999, using a Mobile S-61 track-mounted drill rig and 7″ hollow-stem auger, while the Horseshoe Lake borehole was completed on February 28-29, 2000, using an Acker SX truck-mounted drill rig and a 7″ hollow-stem auger. Both cores were continuously sampled using a 3″ (7.6 cm) outer diameter, 2.375″ (6.0 cm) inner diameter split-spoon sampler lined with a clear acrylic tube liner. The liner received the core as the sampler and auger advanced into the sediment, and served as a core container after recovery and splitting of the sampler. Drive depths were 20″ (50.8 cm) except at the top of the cores where recovery was poor. At Marion Lake, the top 5 feet were sampled at 10″ intervals while the top 40″ of core were entirely lost at Horseshoe Lake. Core recovery below these depths was excellent, but commonly exceeded 100% because of core expansion out of the ends of the sampler. This expansion was confirmed against the drive depth of the auger, and almost certainly reflects the high proportion of clay and fine silt within the deposits and the saturated ground conditions below the water table.


A
Larger map
Man.
N.Dak.
Min.
S.Dak.
0 200 km
LEGEND
Lake Location
Town
Road
Water
1997 Flood zone
B
50°N
97°W
0 10 20km
WINNIPEG
St Norbert
St Adolphe
Ste Agathe
Morris
Horseshoe Lake
St Jean Baptiste
Marion Lake
Letellier
Emerson
49°N
97°W
Canada-U.S. Border


A
B

Immediately upon removal from the split-spoon sampler, the sediment colour, texture and compaction of the core were described qualitatively from the ends of the core liner, and the depth range of the auger drive was marked on the liner. The liners ends were covered with plastic caps, taped to form an air tight seal, and stored in wooden core boxes. The Marion Lake core boxes were shipped to GSC-Atlantic, Dartmouth, Nova Scotia, for detailed lithological logging and subsampling, as described below. The Horseshoe Lake core was sent to GSC-Ottawa for lithological logging and subsampling. All cores are stored at GSC-Ottawa.

Lithological logs

The deposits at Horseshoe Lake were penetrated to 10.75 m deep, while at Marion Lake the penetration depth is 16.77 m. These cores both represent the Late Holocene history of sedimentation in the lake basins.

In the lab, the cores were split, and logged for textural and structural sedimentology to the mm scale. The cores were subsampled for grain size analysis, macrofossils (wood, charcoal, shells) and total organic carbon (TOC) content. For sediment analyses, bulk samples were collected over depths of 10 cm at about 2 m intervals as well as at some selected intervening depths. The general colour of the deposits were noted using a Munsell colour chart, and all of the cores were photographed. Organic materials were subsampled and submitted to Beta Analytical for AMS (Acceleration Mass Spectrometry) radiocarbon age dating. The dates are summarized in Table 1.

Summary lithological logs of the boreholes are depicted in Fig. 3 and 4 (Horseshoe Lake and Marion Lake respectively). The sedimentological features of these deposits are represented symbolically on these cores. The sedimentology of the deposits is subtle, reflecting the generally uniform fine-grained texture of the sediments. At some depths ranges, post-depositional $CaCO_3$ and Fe-oxide precipitates and disseminated organic matter, significantly masked the structure of the deposits. Two graphs adjacent to each of the lithological logs depict the occurrence of the authigenic $CaCO_3$ and Fe oxide precipitates. Lithofacies descriptors were assigned to the deposits following Brooks (in press). The depth positions and ages of the dated organic samples are show in Fig. 3 and 4.

Sediment grain size and carbon content analyses were undertaken at the Terrain Sciences Division Sedimentology Laboratory, using the techniques described by Klassen, et al. (2000). The total organic carbon (TOC), total inorganic carbon (TIC) and total carbon (TC) data are plotted on Fig. 3 and 4. See Appendix 1 for a complete listing of these data. A composite grain size (phi) diagram for the samples from each borehole is depicted in Fig. 5 and the data are archived in Appendix 2.

Table 1. Summary of the AMS radiocarbon ages obtained from the Horseshoe Lake and Marion Lake cores.

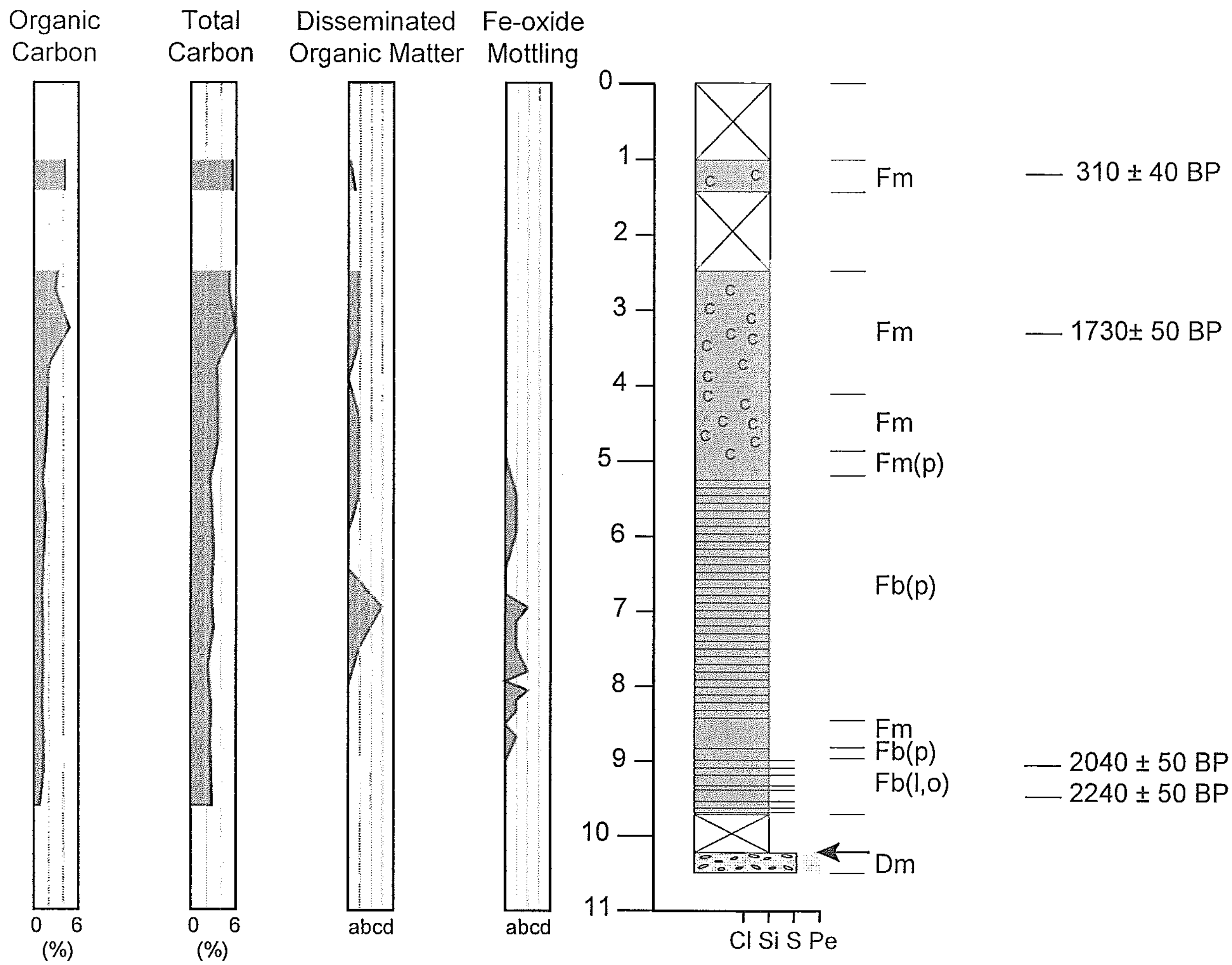
Fig. 3 Lithological log of the deposits from the Horseshoe Lake borehole. Adjacent to the borehole log are graphs depicting the relative proportions of organic carbon, total carbon, disseminated organic matter and authigenic Fe-oxide precipitate.

Fig. 4 Lithological log of the deposits from the Marion Lake borehole (see legend in Fig. 3). Adjacent to the borehole log are graphs depicting the relative proportion of organic carbon, total carbon, authigenic $CaCO_3$ precipitate and disseminated organic matter.

Sample number	Core Location	Latitude	Longitude	Depth (m)	Material	^{13}C / ^{12}C ratio (‰)	Radiocarbon Age
Beta-151980	Marion Lake	49°20.3′ N	97°19.5′ W	9.89	Wood	-26.3	1600 ± 40 BP
Beta-151981	"	"	"	13.08	Wood	-26.9	1700 ± 40 BP
Beta-151982	"	"	"	13.15	Wood	-27.4	1660 ± 40 BP
Beta-151983	"	"	"	13.43	Wood	-24.9	1620 ± 40 BP
Beta-151984	Horseshoe Lake	49° 13.3′ N	97° 19.3′ W	1.18	Wood	-28.3	310 ± 40 BP
Beta-151985	"	"	"	3.30	Charcoal	-23.9	1730 ± 50 BP
Beta-151986	"	"	"	9.07	Charcoal	-20.6	2040 ± 50 BP
Beta-151987	"	"	"	9.47	Wood	-30.0	2240 ± 50 BP

Figure 3

Horseshoe Lake, Manitoba



Legend

Lithofacies

Fb	Fine-grained, massive, bedded
Fm	Fine-grained, massive
Fm (Gl.)	Fine-grained, massive (glaciolacustrine)
Fl	Fine-grained, laminated
Fz	Fine-grained, disturbed (flow) structures
Dm	Diamicton
(w)	Weak bedding
(l)	Bedding defined by laminations (isolated or in groupings)
(o)	Bedding defined by organic laminations
(p)	Pseudobedding imparted by colour variation or concentration of iron oxide mottling

Pebbly sand (Pe)
Sand (S)
Silt (Si), muddy-silt
Clay (Cl)
No recovery

Bioturbation
Disturbed (flow) structures
Bedded deposits
Beds of interlaminated silt/v.f. sand (0.01 to 0.1 m thick)
c Shell fragments, shells
Major stratigraphic unconformity
340 ± 40 BP Radiocarbon age

Relative proportion of core deposits

a	1-4%
b	5-8%
c	9-15%
d	16-25%

Figure 4

Marion Lake

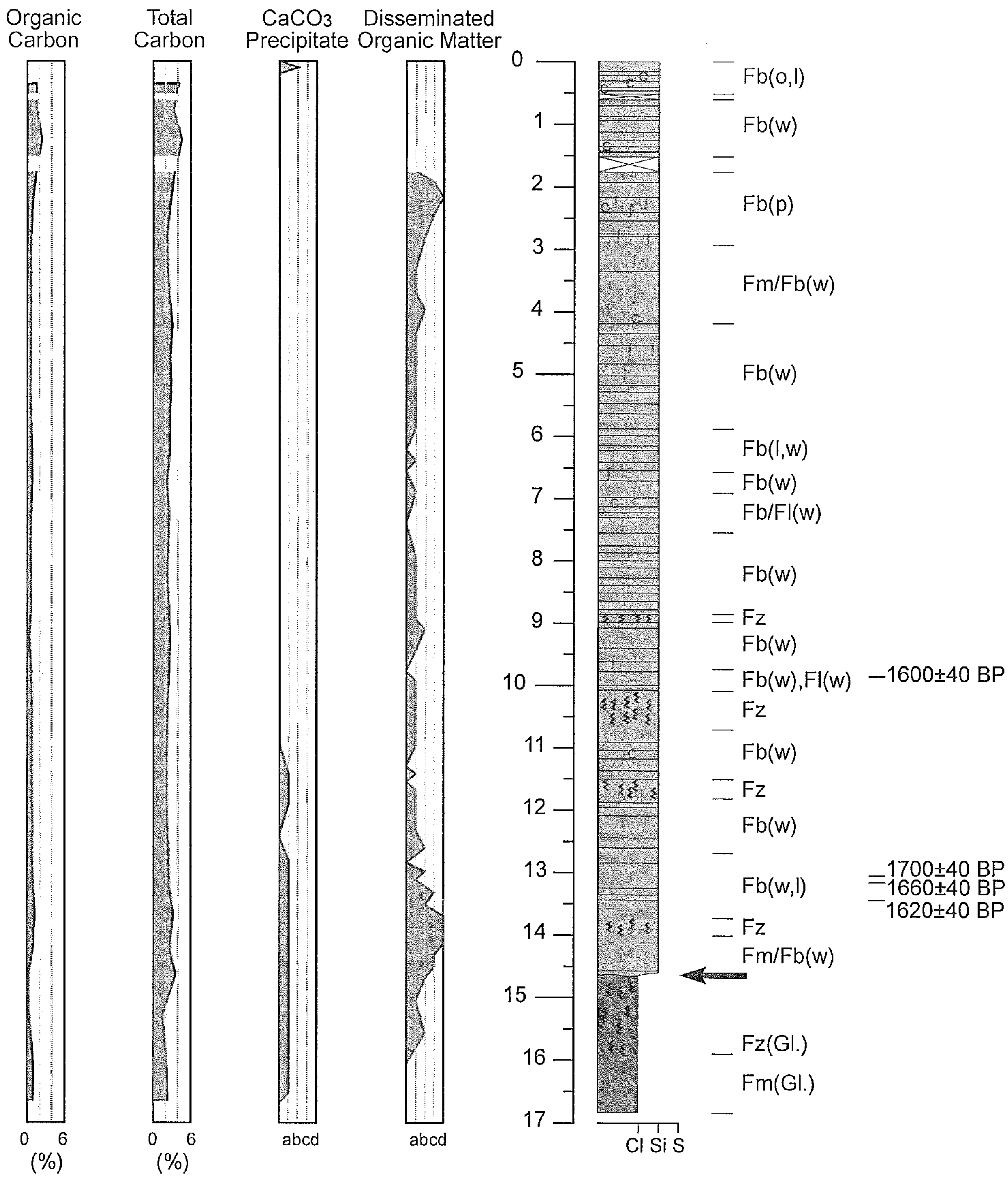
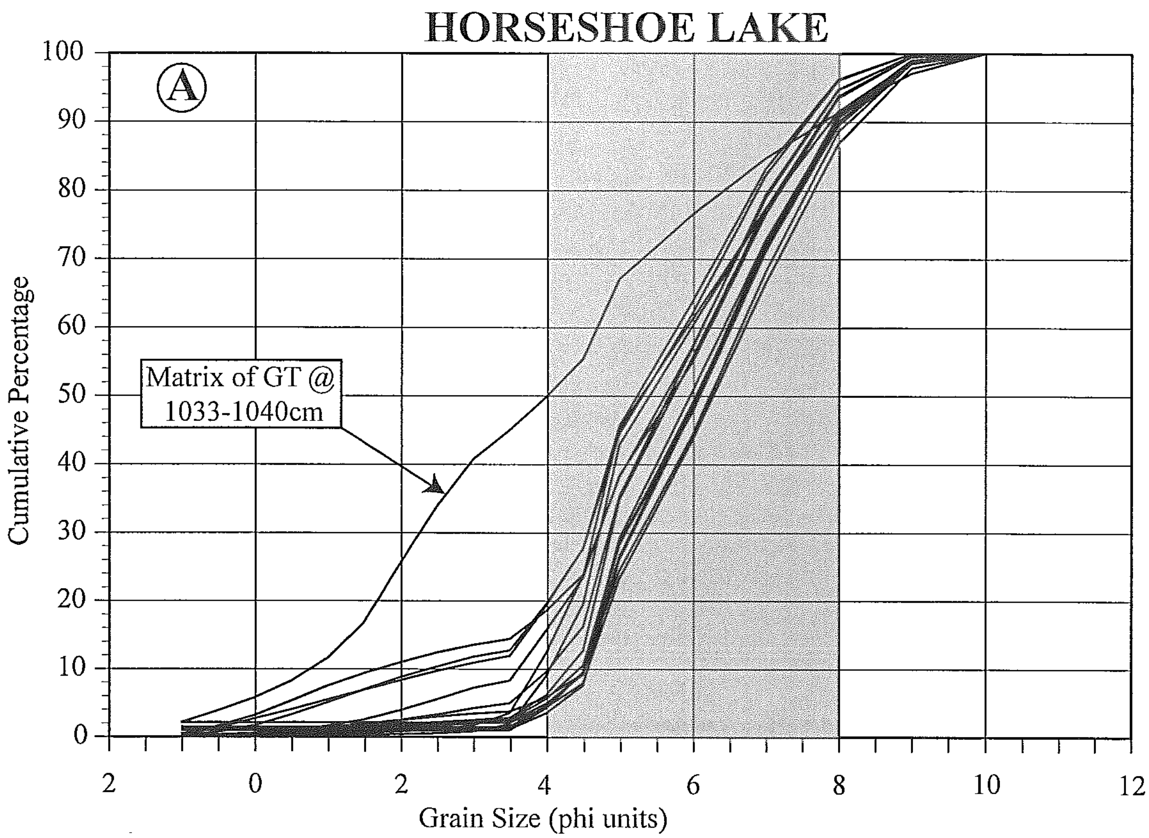
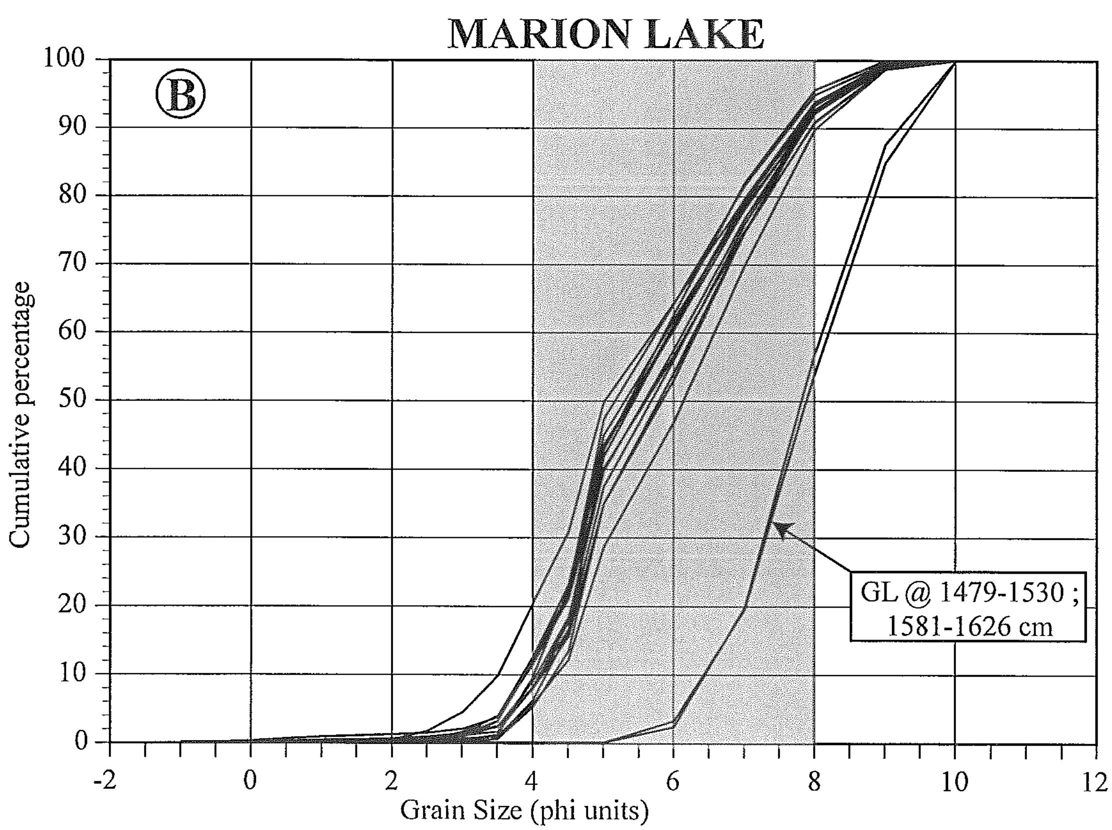


Fig. 5 Composite grain size diagrams for each of the boreholes. A) Red River alluvial sediments are distinguished from the coarser curve (flagged by depth) of matrix of glacial till (GT) in the Horseshoe Lake borehole; B) In the Marion Lake Borehole, Red River alluvial sediments are distinguished from finer glaciolacustrine (GL) Lake Agassiz sediments. The shaded areas of the plots delineate the silt size range.

Acknowledgements

This work is part of a larger project undertaken by the Geological Survey of Canada and the Manitoba Geological Survey to investigate the paleoflood history of the Red River and geomorphic controls on the Red River flood problem. Funding for this work was provided by the Red River Valley Flood Protection Program. We sincerely thank G. Clement and R. Fillion for providing us with access the core sites, D. Berk (Manitoba Geological Survey) for logistical support, M. Nixon, C. Prévost and E. Nielsen for help coring, and I. Hardy for use of the core logging facilities at GSC-Atlantic. J. Guertin, T. Hunbert and C. Van Hoof assisted with the lithological core logging and subsampling.


HORSESHOE LAKE
A
Matrix of GT @
1033-1040cm
Cumulative Percentage
Grain Size (phi units)
100
90
80
70
60
50
40
30
20
10
0
2
0
2
4
6
8
10
12


MARION LAKE
B
GL @ 1479-1530 ;
1581-1626 cm
Cumulative percentage
Grain Size (phi units)
100
90
80
70
60
50
40
30
20
10
0
-2
0
2
4
6
8
10
12

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Medioli, B. E.

2003: The search for a paleoflood record using the physical and geochemical properties of cores from shallow lakes, Red River Valley, Manitoba and North Dakota; Geological Survey of Canada, Current Research 2003-B1, 11p.

Measured Depth	Corrected Depth	Total Carbon	Organic Carbon	Inorganic Carbon	Comments
(cm)	(cm)	(%)	(%)	(%)	
118-120	119	5.5	4.1	1.4	
118-120	119	5.5	4.2	1.3	duplicate
268-270	275.5	5.1	3.0	2.1	
318-320	323.5	5.9	4.8	1.1	
368-370	371.5	3.5	2.0	1.5	
418-420	418	3.6	1.9	1.7	
468-470	469	3.6	1.7	1.9	
518-520	518	2.6	1.3	1.3	
568-570	669	2.9	1.6	1.3	
618-620	618	3.0	1.4	1.6	
668-670	660.5	2.8	1.2	1.6	
718-720	719	3.0	1.3	1.7	
768-770	769	2.3	1.3	1.0	
830-832	830	2.7	1.2	1.5	
830-832	830	2.7	1.2	1.5	
880-882	879	2.6	1.4	1.2	duplicate
915-917	915	2.7	1.3	1.4	
924-926	925	2.8	0.8	2.0	

Measured Depth (cm)	Corrected Depth (cm)	Total Carbon (%)	Organic Carbon (%)	Inorganic Carbon (%)	CaCO3 (%)	Comments
25	36	4.1	1.5	2.6	21.7	
75	77	3.4	1.6	1.8	15.0	
125	125	4.6	2.4	2.2	18.3	
175	180	3.4	1.4	2.0	16.7	
225	229	2.8	0.9	1.9	15.8	
275	278	2.3	0.7	1.6	13.3	
325	323	2.4	0.7	1.7	14.2	
375	375	2.7	0.7	2.0	16.7	
375	375	2.7	0.6	2.1	17.5	duplicate
425	422	3.1	0.7	2.4	20.0	
475	471	2.8	0.7	2.1	17.5	
525	523	2.9	0.6	2.3	19.2	
575	575	2.7	0.7	2.0	16.7	
625	625	2.7	0.8	1.9	15.8	
675	672	2.3	0.8	1.5	12.5	
725	723	2.6	0.7	1.9	15.8	
775	774	2.5	0.6	1.9	15.8	
775	774	2.5	0.6	1.9	15.8	duplicate
825	824	2.3	0.7	1.6	13.3	
875	875	2.6	0.7	1.9	15.8	
925	924	2.7	0.4	2.3	19.2	
975	975	2.6	0.7	1.9	15.8	
1025	1022	2.4	0.8	1.6	13.3	
1075	1075	2.3	0.8	1.5	12.5	
1125	1124	2.2	0.8	1.4	11.7	
1175	1175	2.2	0.8	1.4	11.7	
1225	1223	2.3	0.9	1.4	11.7	
1275	1275	2.5	0.8	1.7	14.2	
1325	1324	2.6	1.0	1.6	13.3	
1375	1366	3.2	1.2	2.0	16.7	
1425	1424	2.7	0.9	1.8	15.0	
1475	1464	3.6	0.2	3.4	28.3	
1525	1529	1.5	0.3	1.2	10.0	
1575	1564	1.9	0.7	1.2	10.0	
1625	1616	2.2	1.0	1.2	10.0	
1675	1664	2.3	0.9	1.4	11.7	

Grain size data Horseshoe Lake Appendix 2

		Size Fraction (Reported as a percentage <2mm)																		
	Phi Values	(-1.0)-(-0.5)	(-0.5)-0.0	0.0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-6.0	6.0-7.0	7.0-8.0	8.0-9.0	9.0-10.0	<10.0
Sample No.	Average depth	2-1.4mm	1.4-1mm	1000-710μm	710-500μm	500-350μm	350-250μm	250-120μm	180-120μm	120-80μm	88-63μm	63-44μm	44-31μm	31-16μm	16-8μm	8-4μm	4-2μm	2-1μm	<1μm
00-RR-1A120-130	125	0.28	1.04	1.38	1.32	1.47	1.45	1.40	1.38	1.20	1.03	7.42	8.36	18.02	18.09	19.36	13.07	3.73	0.00
00-RR-1A270-280	275	0.17	0.56	0.96	1.59	1.82	1.91	1.83	1.54	1.45	0.94	6.88	8.06	16.90	17.52	20.12	13.89	3.88	0.00
00-RR-1A320-330	325	0.18	0.16	0.23	0.42	0.65	0.93	1.39	1.60	1.69	1.09	7.43	7.69	15.03	16.50	21.57	16.98	6.01	0.45
00-RR-1A370-380	375	0.44	1.16	1.58	2.12	2.23	1.86	1.60	1.45	1.12	0.89	4.15	5.30	14.37	19.00	21.65	15.79	4.98	0.31
00-RR-1A520-530	425	0.03	0.18	0.31	0.37	0.39	0.31	0.31	0.31	0.31	0.35	3.34	6.51	22.26	20.67	21.73	16.42	5.78	0.42
00-RR-1A420-430	475	0.06	0.16	0.24	0.35	0.45	0.57	0.71	0.79	0.95	0.75	4.61	6.63	19.21	21.60	22.36	15.38	4.88	0.33
00-RR-1A470-480	525	0.11	0.14	0.11	0.12	0.14	0.17	0.18	0.19	0.20	0.21	2.81	5.18	19.75	21.46	22.08	17.78	8.19	1.19
00-RR-1A570-580	575	0.02	0.23	0.28	0.35	0.52	0.54	0.58	0.49	0.46	0.31	2.07	3.53	15.17	19.80	23.79	20.46	9.95	1.45
00-RR-1A620-630	625	0.01	0.05	0.11	0.22	0.40	0.37	0.32	0.28	0.26	0.26	2.68	4.26	17.38	22.00	23.82	18.48	8.02	1.08
00-RR-1A670-680	675	1.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.13	4.85	18.87	20.68	22.20	18.26	9.12	1.41
00-RR-1A720-730	725	2.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.24	3.58	15.38	20.27	22.91	20.32	11.03	2.13
00-RR-1A770-780	775	0.02	0.09	0.19	0.35	0.43	0.34	0.35	0.29	0.27	0.21	3.08	4.94	17.88	19.25	23.39	19.72	8.19	1.00
00-RR-1A820-830	825	1.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.26	5.31	19.02	19.94	22.61	18.88	8.74	1.23
00-RR-1A871-880	875	1.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.34	4.05	18.59	21.91	23.80	19.28	7.91	0.94
00-RR-1A917-927	922	0.02	0.06	0.05	0.04	0.07	0.11	0.11	0.12	0.27	1.08	7.11	10.47	23.49	17.28	17.11	14.24	7.20	1.18
00-RR-1A956-966	961	0.15	0.17	0.06	0.08	0.11	0.12	0.17	0.23	0.62	1.82	8.90	11.20	21.71	15.89	16.20	14.11	7.26	1.19
00-RR-1A1033-1040	1036	2.14	1.73	1.90	2.45	3.38	5.29	8.71	8.31	6.86	4.29	4.83	5.57	11.68	9.36	8.22	6.74	5.64	2.89

	Phi Values	Size Fraction (Reported as a percentage <2mm)																	
		(-1.0)-(-0.5)	(-0.5)-0.0	0.0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	4.5-5.0	5.0-6.0	6.0-7.0	7.0-8.0	8.0-9.0	9.0-10.0	<10.0
Sample No.	Average depth	2-1.4mm	1.4-1mm	1000-710µm	710-500µm	500-350µm	350-250µm	250-120µm	180-120µm	120-80µm	88-63µm	63-44µm	44-31µm	31-16µm	16-8µm	8-4µm	4-2µm	2-1µm	<1µm
99RR2-61-122	106	0.04	0.03	0.03	0.03	0.05	0.08	0.17	0.15	0.14	0.26	4.81	6.41	16.52	18.33	22.89	19.96	8.81	1.29
99RR2-153-204	194	0.04	0.04	0.07	0.08	0.12	0.14	0.20	0.27	0.54	0.87	5.65	7.56	19.41	19.30	20.47	16.28	7.74	1.22
99RR2-255-306	295	0.00	0.00	0.01	0.01	0.01	0.02	0.04	0.21	0.76	1.38	6.67	9.34	21.35	17.87	19.13	15.71	6.60	0.87
99RR2-357-407	401	0.01	0.03	0.06	0.06	0.05	0.03	0.05	0.24	0.88	2.66	8.71	10.25	20.57	16.96	17.63	14.44	6.42	0.95
99RR2-459-510	490	0.00	0.01	0.02	0.02	0.03	0.06	0.37	1.29	2.74	5.35	10.64	10.37	19.01	14.53	15.25	13.05	6.24	1.02
99RR2-561-612	594	0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.15	0.69	2.26	9.06	10.96	21.82	16.96	16.58	13.67	6.65	1.09
99RR2-663-714	682	0.00	0.01	0.02	0.02	0.03	0.03	0.07	0.30	1.19	2.31	7.80	9.32	19.08	16.57	18.23	15.92	7.85	1.25
99RR2-765-816	795	0.00	0.01	0.02	0.05	0.07	0.07	0.10	0.19	0.72	1.33	5.71	8.34	20.88	18.66	19.84	16.22	6.86	0.91
99RR2-867-912	900	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.09	0.37	4.71	8.19	21.49	18.19	21.56	18.05	6.71	0.49
99RR2-969-1020	999	0.03	0.09	0.09	0.08	0.06	0.04	0.05	0.13	0.76	1.98	8.59	10.09	21.07	18.08	18.22	14.28	5.84	0.51
99RR2-1071-1122	1100	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.04	0.23	0.75	8.61	12.64	24.92	16.96	17.32	13.28	4.68	0.36
99RR2-1173-1224	1200	0.10	0.05	0.06	0.05	0.04	0.03	0.03	0.05	0.16	0.42	5.34	9.91	26.70	19.84	19.26	13.64	4.29	0.00
99RR2-1275-1320	1299	0.02	0.06	0.09	0.13	0.13	0.10	0.12	0.17	0.30	0.58	6.47	9.61	24.10	19.24	18.63	14.15	5.61	0.48
99RR2-1377-1422	1401	0.03	0.09	0.21	0.33	0.27	0.18	0.17	0.23	0.60	1.71	7.77	9.84	21.59	18.22	17.97	14.21	6.04	0.54
99RR2-1479-1530	1503	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.15	16.24	34.61	30.85	15.02
99RR2-1581-1626	1596	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.29	17.43	37.19	30.64	12.33