

Deposits and Cutoff Ages of Horseshoe and Marion Oxbow Lakes, Red River, Manitoba

Sédimentologie et dates de formation des lacs en croissant Horseshoe et Marion, le long de la rivière Rouge, au Manitoba Sedimentología y datación del origen de los lagos Horseshoe y Marion a lo largo del río Red en Manitoba

Gregory R. Brooks and Barbara E. Medioli

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Article abstract

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DEPOSITS AND CUTOFF AGES OF HORSESHOE AND MARION OXBOW LAKES, RED RIVER, MANITOBA*

Gregory R. BROOKS** and Barbara E. MEDIOLI**, Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8.

ABSTRACT Horseshoe Lake and the Marion Lake scar, along the Red River, southern Manitoba, were cored to investigate the timing of the meander cutoffs and the sedimentology of the channel in-fill deposits. The Horseshoe Lake core, 10.75 m long, consists of 9.73 m of silt-rich deposits inferred to be lacustrine from 0 to 4 m deep, transitional from 4 to 5 m deep and alluvial below 5 m deep. Four wood and charcoal specimens sampled from the core yielded radiocarbon ages of 310 ± 40 , 1730 ± 50 , 2040 ± 50 and 2240 ± 50 BP. The Marion Lake core, 16.77 m long, consists of 14.73 m of silt-rich deposits inferred to be lacustrine from 0 to 5 m deep and alluvial below 8.5 m deep; the transition is indistinct and falls between 5 to 8.5 m deep. Four wood samples from the fluvial deposits yielded radiocarbon ages of 1600 ± 40 , 1700 ± 40 , 1660 ± 40 and 1620 ± 40 BP. The cutoffs that led to the formation of Horseshoe and Marion lakes are interpreted to have occurred at ~ 1990 and ~ 1520 cal BP or shortly thereafter, respectively. The silt-rich, alluvial-lacustrine deposits in the lakes lack structural and textural characteristics that can be readily recognized in core to distinguish the depositional environments. The absence of coarse sediments at the base of the fluvial units at both sites implies that minor to negligible amounts of sand were transported along the thalwegs of the channels prior to the meanders being cutoff. The dominance of silt within the oxbow deposits reflects sediment supply as the geomorphic setting of the river is within an extensive glaciolacustrine clay plain.

RÉSUMÉ *Sédimentologie et dates de formation des lacs en croissant Horseshoe et Marion, le long de la rivière Rouge, au Manitoba.* Le lac Horseshoe et l'ancien lac Marion ont fait l'objet de carottages dans le but d'établir le moment du recoupement de leur méandre et la sédimentologie des dépôts accumulés dans leur chenal. La carotte du lac Horseshoe (10,75 m) est constituée de 9,73 m de dépôts riches en limon, probablement lacustres entre 0 et 4 m de profondeur, de transition entre 4 et 5 m et alluviaux sous les 5 m. Quatre échantillons de bois et de charbon ont donné des âges au radiocarbone de 310 ± 40 , 1730 ± 50 , 2040 ± 50 et 2240 ± 50 BP. La carotte du lac Marion (16,77 m) est constituée de 14,73 m de dépôts riches en limon, apparemment lacustres entre 0 et 5 m et alluviaux sous les 8,5 m ; la transition, mal définie, se situe entre 5 et 8,5 m de profondeur. Quatre échantillons de bois provenant des dépôts fluviaux ont donné des âges au radiocarbone de 1600 ± 40 , 1700 ± 40 , 1660 ± 40 et 1620 ± 40 BP. On estime que les recoupements qui ont donné naissance aux deux lacs se sont produits il y a environ 1990 (Horseshoe) et 1520 cal. BP (Marion), ou peu après. Les dépôts alluvio-lacustres riches en limon des lacs ne comportent pas de structures et de textures assez nettes pour permettre d'identifier leur milieu de sédimentation. L'absence, dans les deux cas, de sédiments grossiers à la base de l'unité fluviale laisse supposer que des quantités minimales, voire négligeables, de sable ont été transportées le long des thalwegs avant que les recoupements ne surviennent. La prédominance du limon dans les dépôts des lacs en croissant reflète la provenance des sédiments, le cadre géomorphologique de la rivière étant celui d'une vaste plaine d'argile glaciolacustre.

RESUMEN *Sedimentología y datación del origen de los lagos Horseshoe y Marion a lo largo del río Red en Manitoba.* Los sedimentos de los lagos Horseshoe y Marion situados a lo largo del río Red al sur de Manitoba fueron estudiados para establecer la fecha de formación de meandros y la sedimentología de los depósitos de los canales. El núcleo testigo de sondeo proveniente del lago Horseshoe, de 10,75 m de largo, está compuesto de depósitos ricos en limo de hasta 9,73 m. Dichos depósitos son considerados como de origen lacustre en una región de 0 a 4 m de profundidad, de tipo de transición entre 4 y 5 m de profundidad y de origen aluvial por debajo de 5 m de profundidad. Cuatro especímenes de madera y de carbón obtenidos de dicho núcleo testigo fueron datados con radiocarbono proporcionando una edad cercana a los 310 ± 40 , 1730 ± 50 , 2040 ± 50 y 2240 ± 50 años BP. El núcleo testigo de sondeo de 16,77 m de largo proveniente del lago Marion, esta compuesto de una zona que abarca 14.73 m de depósitos arcillosos de origen lacustre entre 0-5 m de profundidad y de origen aluvial por debajo de los 8.5 m de profundidad; la zona de transición se sitúa entre 5 y 8.5 m de profundidad pero no se encuentra bien definida. La datación con radiocarbono de cuatro muestras de depósitos fluviales proporciona una edad que las sitúa hace unos 1600 ± 40 , 1660 ± 40 y 1620 ± 40 años BP. Se cree que el corte de terreno que dio origen a la formación de los lagos Horseshoe y Marion ocurrió hace unos 19 900 a 15 200 años o poco tiempo después, respectivamente. Los depósitos ricos en limo de origen lacustre-aluvial de los lagos carecen de las características estructurales y de textura que pueden ser reconocidos fácilmente en el núcleo testigo para distinguir los ambientes de depósito. La ausencia de sedimentos de tipo grueso en la base de la unidad fluvial en ambos sitios indica que un aporte pequeño o insignificante de arena fue transportado a lo largo de la vaguada de los canales antes de que ocurriera la formación de los meandros. La predominancia de limos entre los depósitos del brazo muerto refleja el origen de los sedimentos y concuerda con el cuadro geomorfológico de un río situado dentro de una planicie arcillosa glaciolacustre muy extensa.

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* Geological Survey of Canada contribution 2003148

**E-mail addresses: gbrooks@nrcan.gc.ca, bmedioli@nrcan.gc.ca

INTRODUCTION

Oxbow lakes are common floodplain features along active meandering rivers and are the product of cutoffs. They develop most often through either a neck cutoff, when a new channel forms across the neck of an overextended bend, or a longer chute cutoff that develops along the swale of a point bar complex (e.g., Lewis and Lewin, 1983). Processes contributing to cutoffs are lateral channel migration and/or gully or chute erosion of the floodplain surface (Johnson and Paynter, 1967; Mosley, 1975; Hooke, 1995; Gay *et al.*, 1998). Along some rivers, there have been a significant number of cutoffs induced by artificial trenching of meander necks (e.g., Mississippi River; Biedenbarn *et al.*, 2000). The channel morphology and deposits preserved beneath oxbow lakes have been used in paleohydrologic and/or sedimentation studies (e.g., Reinfelds and Bishop, 1998 and references therein). Oxbow lake chronology has been established using historical records and maps (e.g., Lewis and Lewin, 1983; Gagliano and Howard, 1984), radiocarbon dating (e.g., Holland and Burk, 1982) and, in one case, the post-cutoff rate of lateral channel migration (Handy, 1972).

The Red River, Manitoba, is a low gradient, mud-dominated river (see Brooks, 2003a) where the meanders experience a low rate of lateral migration (Brooks, 2002, 2003b). Most of the river meanders have undergone a single and continuing sequence of expansion and downvalley rotation (Brooks 2002, 2003b). Only eight oxbow lakes and sloughs are located between Emerson, at the Canada-USA border, and the river mouth at Lake Winnipeg, a valley distance of about 170 km. None of the oxbow lakes/sloughs have formed historically, as inferred from 19th century maps (see Warkentin and Ruggles, 1970).

This paper reports chronological and sedimentological results from continuous, single cores sampled from the apex of Horseshoe Lake and the Marion Lake channel scar (Fig. 1), which are two of the oxbow/slough features along the Red River. The primary purpose for the coring was to establish the age of formation of the cutoff channels in support of paleoenvironmental work undertaken along the Red River (see Medioli, 2003; Medioli and Brooks, 2003a). The coring also presented the opportunity to examine the character of the channel in-fill deposits preserved within the abandoned channels. The Red River is a mud-dominated stream within a low-energy fluvial setting and represents a portion of the continuum of meandering channel planform types that is poorly documented in the geomorphic and sedimentology literature (see Brooks 2003a). The deposits within the oxbow/slough features supplement the Red River floodplain deposits accreted by lateral channel migration and overbank sedimentation that have been reported previously by Brooks (2003a, 2003b), and thereby enhance the understanding of mud-dominated, meandering streams.

STUDY SITES

Horseshoe Lake is a closed-basin, perennial oxbow lake, 1 250 m long, up to 150 m wide and up to ~2.0 m deep. The lake is the product of a neck cutoff of an overextended meander. It

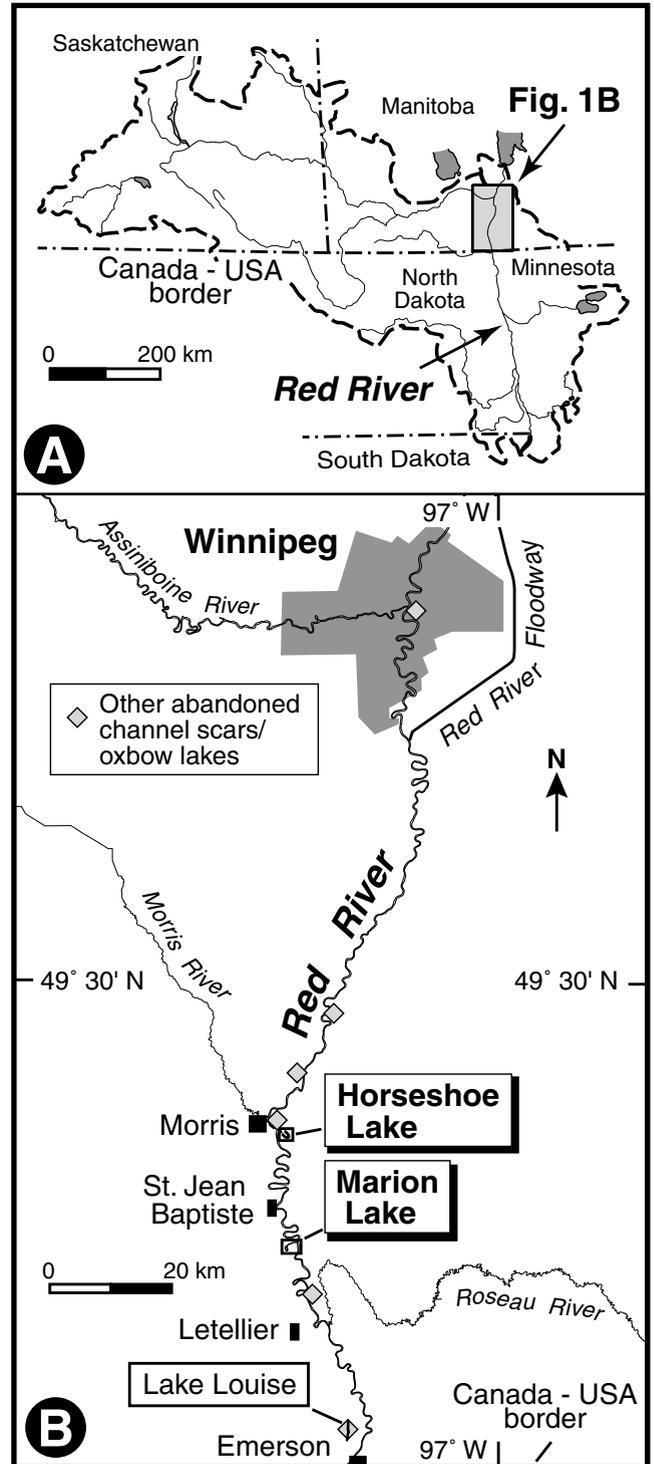


FIGURE 1 A) Map of the Red River drainage basin and B) map of the Red River valley showing the locations of Horseshoe Lake and the Marion Lake channel scar (referred to as Marion Lake in the text). Also shown in B) are the locations of other abandoned channel scars and lakes along the Red River.

A) Carte du bassin versant de la rivière Rouge et B) carte de la vallée de la rivière Rouge montrant l'emplacement du lac Horseshoe et de l'ancien lac Marion (Marion Lake dans le texte). Figurent aussi les reliques d'autres chenaux et lacs anciens.

is located 2.5 km ESE of Morris, Manitoba, and 0.75 km E of the Red River, and is surrounded by cultivated fields and a deciduous woodland (Fig. 2A). The contemporary lake water is brackish and spring-fed; the brackish waters reflect the salinity of local groundwater (Betcher *et al.*, 1995). In late spring and early summer elevated concentrations of phosphorous are indicative of hypereutrophic conditions (Medioli, 2003). Reflecting this, the lake supports extensive algal growth throughout the growing season that results in a strong oxygen gradient in the water column and an anoxic sediment-water interface.

Marion Lake was a perennial, closed-basin oxbow lake until being drained in 1961 or 1962 for agricultural purposes (R. Fillion, personal communication, February 2003). It formed due to a neck cutoff of an overextended meander and is now a channel scar on the floodplain that is under cultivation (Fig. 2B). The channel scar is crescent-shaped, surrounded by cultivated fields and situated on the west side of the river, 5 km S of St. Jean Baptiste (Fig. 2B). On a 1945 aerial photograph (Fig. 3), Marion Lake was 2 100 m long and up to 200 m wide. We are unaware of any water quality or bathymetric data reported for Marion Lake.

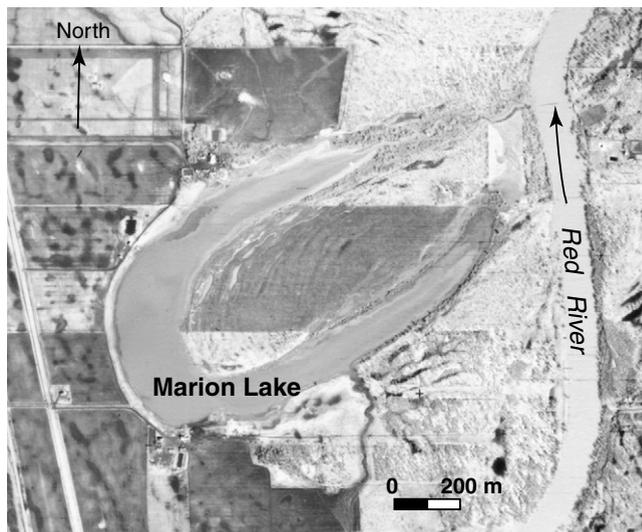


FIGURE 3. A 1945 vertical aerial photograph showing Marion Lake prior to drainage (NAPL A7561-53, taken May 14, 1945).

Photographie aérienne de 1945 montrant le lac Marion avant son assèchement (photographie NAPL A7561-53, prise le 14 mai 1945).

METHODS

Horseshoe Lake was cored on February 28 and 29, 2000, using an Acker SX wheel-mounted drill rig, while the Marion Lake scar was cored on October 4, 1999, using a Mobile S-61 track-mounted drill rig. Both coring sites were located near the apices of the original meanders (Fig. 2). The cores were continuously sampled using 7" (178 mm) hollow stem auger and a 3" (76 mm) OD (2.375" [60 mm] ID) split spoon sampler, as summarized in Medioli and Brooks (2003b).

In the laboratory, the cores were split and logged for textural and structural sedimentology to the millimetre scale. The deposits were subsampled for particle size analysis, macrofossils (wood, charcoal, shells) and total organic carbon (TOC) content. For sediment analyses, bulk samples were collected over depths of 0.1 m at ~0.5 to 1.0 m (Horseshoe Lake) and ~1.0 m (Marion Lake) intervals. Summary logs for the cores are presented in Figure 4. Plots depicting particle size distribution for the two cores are shown in Figure 5. Logs depicting total carbon, authigenic CaCO₃ precipitate, Fe-oxide mottling and disseminated organic content can be found in Medioli and Brooks (2003b).

Eight wood and charcoal samples (four from each core) were submitted to Beta Analytic Inc. (Miami, Florida) for accelerator mass spectrometry radiocarbon dating. All of the dated samples represent maximum ages for the encapsulating deposits at the respective sampling depths. None of the samples were in growth position but all were selected carefully to favour "fresh looking" specimens and thus avoid dating materials that had experienced long distance transport and possibly multiple reworking. The radiocarbon ages were calibrated to calendar years by Beta Analytic Inc., following Talma and Vogel (1993) and using the calibration dataset of Stuiver *et al.* (1998). The radiocarbon ages are listed in Table I and shown stratigraphically in Figure 4.

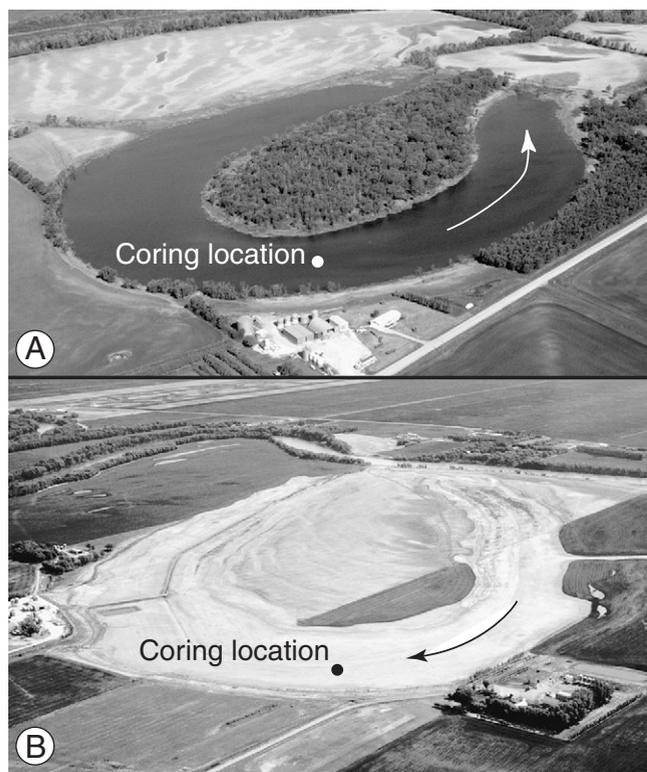


FIGURE 2. Oblique aerial photographs of A) Horseshoe Lake (looking NW) and B) the Marion Lake channel scar (looking NE) showing the locations of the coring sites and the direction of flow when the channels were active (both photographs taken on May 9, 1997).

Photographie aérienne oblique (A) du lac Horseshoe (en direction du nord-ouest) et (B) de l'ancien lac Marion (en direction du nord-est) montrant l'emplacement des sites de carottage et la direction de l'écoulement lorsque les chenaux étaient actifs (les deux clichés ont été pris le 9 mai 1997).

FIGURE 4. Logs of the A) Horseshoe and B) Marion lake cores depicting lithofacies, particle size, TOC and the depths of the radiocarbon ages. The depositional environments are inferred as explained in the text.

Stratigraphie des carottes du lac Horseshoe A) et du lac Marion B) présentant les lithofacies, la granulométrie, le carbone organique total et les profondeurs correspondant aux âges au radiocarbone. Les milieux de sédimentation sont interprétés de la manière indiquée dans le texte.

DEPOSITS

HORSESHOE LAKE

The Horseshoe Lake core is 10.51 m long and consists of 9.73 m of silt-rich deposits overlying 0.78 m of a pebbly diamicton (Figs. 4A and 5A). Recovery was poor in the upper 2.5 m of the core where deposits between 0 to 1.02 m and 1.45 to 2.49 m are absent. The silt-rich deposits are interpreted as alluvial-lacustrine sediments relating to Red River-Horseshoe Lake aggradation, as is consistent with the late Holocene-aged wood and charcoal samples contained in the deposits (Fig. 4A; Table I). The diamicton deposits are interpreted as glaciogenic in origin, probably till (see Teller, 1976), and are unrelated to the overlying alluvial-lacustrine sequence.

The alluvial-lacustrine sequence consists of weakly-defined sedimentary structures composed of cosets of massive beds (<40 cm thick; Fb lithofacies), cosets of pseudo-bedding imparted by slight colour variations and/or Fe-oxide mottling (<40 cm thick; Fb(p) lithofacies), and massive bedding (>40 cm thick; Fm lithofacies; Fig. 4A). Very fine/fine sand laminations, ~1 cm thick, occur within the lower metre of the sequence. Deposit colour is dark grey (2.5Y2.5/1 to 2.5Y5/1). The transition from alluvial to lacustrine sedimentation is weakly defined. Texturally, the deposits above 4 m are slightly coarser (8 to 15 % sand) than below (1 to 5 % sand). Also, shells and shell fragments are present above ~5 m depth and there is a slight shift in TOC from 3-5 % to 1-2 % above and below 3.5 m, respectively (Fig. 4A). Based on these characteristics, the deposits are inferred to be lacustrine from 0 to 4 m deep, transitional from 4 to 5 m deep, and alluvial below 5 m deep (Fig. 4A).

MARION LAKE SCAR

The Marion Lake core is 16.77 m deep and consists of 14.73 m of silt-rich deposits overlying 2.04 m of clay-silt deposits (Figs. 4B and 5B). The texture and appearance of the clay-silt deposits are consistent with the Lake Agassiz deposits reported at a study site 1.5 to 2.5 km north by Brooks (2003a) and are similarly interpreted. The silt-rich deposits are interpreted as alluvial-lacustrine sediments associated with Red River-Marion Lake aggradation, as is consistent with the late Holocene-aged wood samples contained in the core (Fig. 4B; Table I).

The alluvial-lacustrine deposits consist of weakly defined, cosets of massive bedding (<40 cm thick; Fb lithofacies), massive beds (>40 cm thick; Fm lithofacies), and disturbed beds (Fz lithofacies; Fig. 4B). Deposit colour is dark grey (2.5Y2.5/1

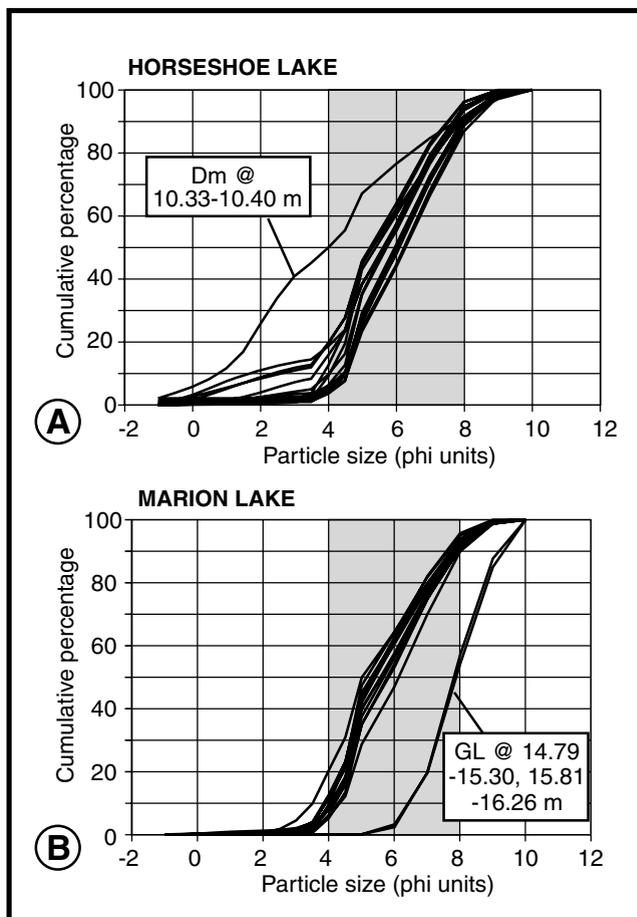


FIGURE 5. Plots of particle size distribution for the A) Horseshoe and B) Marion lake cores; shading highlights the silt size range (4-8 phi units or 0.0625-0.0039 mm). In A) Dm refers to the matrix of a glaciogenic diamicton sample and in B) GL refers to glaciolacustrine samples.

Diagrammes de la granulométrie dans les carottes du lac Horseshoe (A) et du lac Marion (B) ; les parties tramées mettent en évidence la granulométrie des particules correspondant au limon (de 4 à 8 unités phi ou de 0,0625 à 0,0039 mm). En A), Dm désigne la matrice d'un échantillon de diamicton glaciogénique et en B), GL désigne des échantillons glaciolacustres.

to 2.5Y5/1). There is no obvious vertical textural grading, except for a slight coarsening locally at ~5 m depth (Fig. 4B). TOC ranges between 0.4 to 1.2 % between 2 and 14.8 m deep and is slightly higher, 1.4 to 2.4 %, above 2 m deep (Fig. 4B). Shells or shell fragments occur only sporadically below 2 m depth. The presence of the Fz lithofacies below 8.5 m depth, however, is consistent with Red River alluvial deposits (see Brooks, 2003a), while the general presence of bioturbation between 2 and 5 m depth likely represents a lacustrine environment (Fig. 4B), as bioturbation was not observed in flood-plain deposits over these depth ranges (see Brooks, 2003a). Based on these characteristics, the deposits are inferred to be lacustrine from 0 to 5 m deep, alluvial below 8.5 m deep with the transition being indistinct and falling between 5 to 8.5 m deep (Fig. 4B).

TABLE I
Radiocarbon ages from the Horseshoe Lake and Marion Lake cores

Core location	Sampling coordinates	Dated material	Laboratory number	Depth (m)	$^{13}\text{C}/^{12}\text{C}$ (‰)	Radiocarbon age (BP)	Calibrated ages and 1σ error range (cal BP)
Horseshoe Lake	49° 13.3' N 97° 19.3' W	wood	Beta-151984	1.18	-28.3	310 ± 40	380 ^a (300-440)
"	"	charcoal	Beta-151985	3.30	-23.9	1730 ± 50	1620 (1560-1710)
"	"	charcoal	Beta-151986	9.07	-20.6	2040 ± 50	1990 (1930-2050)
"	"	wood	Beta-151987	9.47	-30.0	2240 ± 50	2320 (2160-2330)
Marion Lake	49° 20.3' N 97° 19.5' W	wood	Beta-151980	9.89	-26.3	1600 ± 40	1520 (1420-1540)
"	"	wood	Beta-151981	13.08	-26.9	1700 ± 40	1580 (1550-1690)
"	"	wood	Beta-151982	13.15	-27.4	1660 ± 40	1550 (1530-1580)
"	"	wood	Beta-151983	13.43	-24.9	1620 ± 40	1530 (1500-1550)

a. Age represents the mean of three intercepts with the calibration curve.

RADIOCARBON AGES

From the Horseshoe Lake core, the four wood and charcoal samples were collected at 1.18, 3.3, 9.07, and 9.47 m depth and yielded radiocarbon ages of 310 ± 40, 1730 ± 50, 2040 ± 50, and 2240 ± 50 BP, respectively (Table I). All of the ages are concordant with the sampling depth; the stratigraphically shallowest age (310 ± 40 BP at 1.18 m depth) is substantially younger than the other samples. The 2040 ± 50 and 2240 ± 50 BP ages are situated within alluvium and the 310 ± 40 and 1730 ± 50 BP ages within lacustrine deposits (Fig. 4A).

An additional radiocarbon age from the bed of Horseshoe Lake is reported by Medioli (2003) from a coring site located ~10 m N of the coring site of this study. This age, 790 ± 50 BP (Beta-151988), is derived from plant material (*Scirpus fluviatilis*) sampled from lacustrine deposits between 0.78 to 0.84 m deep. The deposits were contained within a shallow core (0.84 m long) sampled using a Livingstone corer (Livingstone, 1955).

The four wood samples from Marion Lake were collected at 9.89, 13.08, 13.15, and 13.43 m deep and yielded radiocarbon ages of 1600 ± 40, 1700 ± 40, 1660 ± 40, and 1620 ± 40 BP, respectively (Table I). All are located within the alluvial portion of the core (Fig. 4B). There is minor transposition between the radiocarbon ages and the sampling depths (Table I), but all of the ages are similar at the 2σ error range.

INTERPRETATIONS OF RADIOCARBON AGES

The two radiocarbon ages from the alluvium in the Horseshoe Lake core reveal that alluvial sedimentation was occurring within the lake between 2240 ± 50 and

2040 ± 50 BP (or ~2320 and 1990 cal BP, respectively; Table I). The shallower of the two ages indicates that this sedimentation ceased after 2040 ± 50 BP (~1990 cal BP). The two radiocarbon ages from the lacustrine deposits signify that lacustrine sedimentation was underway by 1730 ± 50 BP (~1620 cal BP), extended through 310 ± 40 BP (~380 cal BP), and into the early 21st century within the contemporary lake.

The development of the cutoff channel that led to the formation of the lake likely occurred between 2040 ± 50 and 1730 ± 50 BP (~1990 and 1620 cal BP), as these radiocarbon ages bracket the transition from alluvial to lacustrine sedimentation. The formation of the cutoff, however, probably did not cause the immediate cessation of alluvial sedimentation within the meander loop as there would have been a lag between the cutoff breach and the infilling of the entrance and exit channels into the meander. The 2040 ± 50 BP age is interpreted to better represent the timing of the cutoff considering that the 1730 ± 50 BP age is situated at a substantially shallower depth (3.3 versus 9.07 m depth; Fig. 4A). The cutoff therefore probably occurred at ~1990 cal BP or shortly thereafter (within 100 yr?). A closed-basin oxbow lake likely was present by ~1620 cal BP.

The four radiocarbon ages from the Marion Lake core reveal that alluvial sedimentation was occurring between 1700 ± 40 and 1600 ± 40 BP (~1580 and 1520 cal BP). The shallowest and youngest of the four ages indicates that the development of the cutoff channel occurred after 1600 ± 40 BP (~1520 cal BP). Based on the similar depth of this age with that of the 2040 ± 50 BP age from Horseshoe Lake (Fig. 4A and B), the development of the Marion Lake cutoff is interpreted to have occurred at ~1520 cal BP or shortly thereafter (within 200 yr?).

DISCUSSION

The cutoff channels that formed the Horseshoe and Marion oxbow lakes are interpreted to have occurred at ~1990 and 1520 cal BP (or shortly thereafter), respectively. Although neither feature has formed recently, the age of both lakes is comparatively young relative to the 8900-year period that Red River has been established on the bed of Lake Agassiz (Brooks, 2003b). As mentioned above, Horseshoe and Marion lakes are two of only eight oxbow lakes/sloughs along the Red River in southern Manitoba; most of the meanders have undergone a single and continuing sequence of expansion and downvalley translation. That so few meanders have been cut-off probably reflects the rate of channel migration of the river. For two meanders located near St. Jean Baptiste, Manitoba, Brooks (2003b) calculated that the rate of migration has averaged up to 0.04 m a^{-1} over the past 1000 years, based on the radiocarbon ages of wood samples contained within cores of the floodplain. At a third meander, located ~15.5 km north of Morris (Fig. 1), the average rate of migration is estimated to be up to 0.08 m a^{-1} , since ~3850 cal BP, based on radiocarbon-dated charcoal sampled from a bank exposure (Brooks, 2002). These rates of migration are low relative to sand- and gravel-bed rivers on the Canadian Prairies (e.g., Hickin and Nanson, 1984). Reflecting the low rates of migration, two prominent "goose-neck" meanders along the Red River, one located ~6 km downstream of Letellier and the other at Elm Park, Winnipeg (Fig. 1), are present on 1870s maps of southern Manitoba (see Warkentin and Ruggles, 1970), but have not yet been cutoff.

One of the lakes/sloughs on the Red River floodplain that differs morphologically from the others, however, is Lake Louise, near Emerson, located ~2 km west of the modern Red River channel (Fig. 1; see Brooks and Grenier, 2001; Medioli, 2003). This lake, ~2 km long, is situated within a portion of a ~9 km long paleochannel that was formed by a large-scale avulsion cutoff. The channel course can be traced discontinuously upstream into Minnesota and North Dakota for at least 16 km, but there is no comparable paleochannel downstream (to the north) in Manitoba. While there are no dates relevant to the formation of this lake, it is speculated that Lake Louise is early Holocene in age because it is the product of a major avulsion rather than localized neck cutoff like the seven oxbow lakes and sloughs in Manitoba. The avulsion may relate to the initial establishment of the Red River in southern Manitoba during the final recession of Lake Agassiz (Morris phase), which perhaps experienced a minor transgression that caused the relocation of the channel.

The similarity of the silt-rich, alluvial-lacustrine deposits in the cores and the weak to indistinct transition zone is consistent with the sedimentological character of the Red River floodplain. As summarized by Brooks (2003a), floodplain alluvium contained in cores is composed primarily of silt, lithofacies are weakly defined and an upward fining texture is absent. Brooks deemed these characteristics to reflect the silt-dominated character of the Red River sediment load, which lacks textural contrast to impart well-defined sedimentary structures that will be preserved and recognized in core. Although sand-size sediments in the form of aggregate pellets of silt are transported

and deposited by the river, this texture is lost through compaction and/or disintegration following burial (Brooks, 2003a). Like the floodplain deposits and reflecting the silt-dominated character of the sediment load, the deposits in the Horseshoe and Marion lake basins lack structural and textural characteristics that can be readily recognized in core despite the shift from a fluvial to lacustrine depositional environment.

Although the deposits are dominated by silt, a slight upward coarsening (1-5 to 8-15 % sand) occurs in the Horseshoe Lake core between the alluvial-transitional and lacustrine units (Fig. 4), which is opposite to what would be expected from a shift of a fluvial to lacustrine depositional environment (see e.g., Miall, 1996). The cause of this textural change is unclear, but may relate to a change in local sediment supply into the oxbow basin from immediately upstream, perhaps associated with the realignment of the channel in the valley bottom due to the development of the cutoff.

The lack of a coarse basal unit in the cores is also generally consistent with the floodplain deposits reported by Brooks (2003a), where silt dominated the entire vertical sequence of 7 of 10 floodplain cores (in the three other cores, interbedded silt and medium/coarse sand with a single occurrence of pea gravel was present in the lower ~1 m). This absence or slight occurrence of coarse basal sediment within the oxbow lake and floodplain deposits implies that minor to negligible amounts of sand are transported along the thalweg of the river channel. Consistent with this, only silt bed materials have been observed by the first author at low flows along the margin of the modern Red River channel between Emerson and Morris (Fig. 1), although a detailed survey of the channel bed materials has not been undertaken. The absence or minimal occurrence of a coarse basal unit contrasts markedly with the deposits of other mud-dominated rivers reported in the literature where a well-defined basal sand unit is present (e.g., Jackson, 1978, 1981; Taylor and Woodyer, 1978; Woodyer *et al.*, 1979; Page *et al.*, 2003). The paucity of sand within the Red River deposits relates to sediment supply as the geomorphic setting of the river is within an extensive glaciolacustrine clay plain (the former bed of Lake Agassiz) in the Red River valley (Brooks, 2003a).

SUMMARY AND CONCLUSIONS

Radiocarbon ages from the Horseshoe Lake core reveal that alluvial sedimentation ceased after ~1990 cal BP and that lacustrine sedimentation was underway by ~1620 cal BP. The cutoff is interpreted to have occurred at ~1990 cal BP or shortly thereafter (within 100 yr?) as the formation of the cutoff channel probably did not cause the immediate cessation of alluvial sedimentation within the cutoff meander.

The shallowest radiocarbon age from the Marion Lake core reveals that alluvial sedimentation was occurring at ~1520 cal BP. Based on the similar depth of this age with that of the 2040 ± 50 BP age from Horseshoe Lake, the cutoff at Marion Lake is interpreted to have occurred at ~1520 cal BP or shortly thereafter (within 200 yr?).

The weak to indistinct definition of the alluvial-lacustrine deposits in the cores reflects the silt-dominated character of

the Red River sediment load, which lacks textural contrast to impart well-defined sedimentary structures that can be preserved and recognized in core. The absence of a coarse basal unit in the fluvial deposits infers that minor to negligible amounts of sand was being transported along the channel thalweg at the time the channels were cut off.

The lack of definition of the alluvial and lacustrine oxbow deposits, and the absence of a coarse basal unit is consistent with the Red River floodplain deposits previously reported in the literature. The dominance of silt in these deposits reflects sediment supply as the geomorphic setting of the river is within an extensive glaciolacustrine clay plain.

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