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Fluvial Sedimentology and Paleoecology of Holocene Alluvial Deposits, Red River, Manitoba
Sédimentotogie fluviatile et paléoécologie des dépôts alluviaux holocènes de la rivière Rouge, Manitoba
Flußsedimentotogie und Paläoökologie der angeschwemmten Holozänablagerungen des Red River, Manitoba

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See table of contents

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Article abstract

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FLUVIAL SEDIMENTOLOGY AND PALEOECOLOGY OF HOLOCENE ALLUVIAL DEPOSITS, RED RIVER, MANITOBA

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ABSTRACT Stratigraphic and paleoecological analyses at five sections, together with age determinations based on 19 previously published and 21 new radiocarbon dates, provide a detailed late Holocene history of the Red River, Manitoba. Ecological information, such as age frequency analysis, relative abundance, diversity and association of species was drawn from 19 mollusc species. These data indicate that the Red and Assiniboine rivers cut the valleys they occupy today within a thousand years of the regression of Lake Agassiz. In the south, up to 14 m of alluvium has accumulated during the last 7000 years. A decrease in the sedimentation rate at 1400 BP is coincident with the shift in the position of the Assiniboine from the valley of the La Salle River to its present position. Overbank sedimentation did not start in the northern part of the area until *ca.* 5200 BP. Initial rapid sedimentation rates in this area are attributed to increased precipitation and a brief eastward excursion of the Assiniboine River into the Red. In spite of increased precipitation, flood frequencies remained low in the north until 1400 BP. Increased overbank sedimentation after 1400 BP is attributed to the northward shift in the position ot the Assiniboine.

RÉSUMÉ *Sédimentologie fluviatile et paléoécologie des dépôts alluviaux holocènes de la rivière Rouge, Manitoba.* Les analyses stratigraphiques et paléoécologiques de cinq coupes, ainsi qu'une chronologie fondée sur 19 datations déjà connues et 21 nouvelles datations au radiocarbone permettent de reconstituer l'évolution de la rivière Rouge à l'Holocène. Des renseignements d'ordre écologique, comme l'analyse de la fréquence d'âge, l'abondance relative, la diversité et l'association des espèces ont été colligés sur 19 espèces de mollusques. Ces données montrent que les rivières Assiniboine et Rouge ont entaillé les vallées qu'elles occupent maintenant en moins de mille ans après le retrait du Lac Agassiz. Dans le sud, 14 m d'alluvions se sont accumulés depuis 7000 ans. La diminution du taux de sédimentation à 1400 BP coïncide avec le déplacement de l'Assiniboine de la vallée de la rivière LaSalle à son emplacement actuel. La sédimentation alluviale d'inondation n'a pas commencé dans la partie nord de la région avant environ 5200 BP. Les taux de sédimentation rapides initiaux sont attribuables aux précipitations accrues et à une brève incursion vers l'est de l'Assiniboine vers la rivière Rouge. En dépit des précipitations accrues, la fréquence des inondations est demeurée faible dans le nord jusqu'à 1400 BP. L'accroissement de la sédimentation alluviale d'inondation après 1400 BP est attribuée au déplacement de l'Assiniboine vers le nord.

ZUSAMMENFASSUNG *Flußsedimentologie und Paläoökologie der angeschwemmten Holozänablagerungen des Red River, Manitoba.* Mit stratigraphischen und paläoökologischen Analysen von 5 Schnitten sowie einer auf 19 schon bekannte Datierungen und 21 neue Radikarbondatierungen gestützten Chronologie läßt sich die Entwicklung des Red River im Holozän rekonstruieren. Ökologische Informationen wie die Analyse der Altersfrequenz, relative Haufigkeit, Vielfalt und Verbindung der Arten, wurden auf 19 Molluskenarten gesammelt. Diese Daten zeigen, daß die Flüsse Assiniboine und Red die Täler, durch sie sie jetzt fließen, in weniger als tausend Jahren nach dem Rückzug des Agassizsees eingeschnitten haben. Im Süden wurden seit 7000 Jahren 14 m Alluvium akkumuliert. Die Abnahme der Sedimentationsrate um 1400 v.u.Z. tritt gleichzeitig mit dem Wechsel des Assiniboine vom Tal des La Salle-Flusses zu seiner jetzigen Position ein. Die alluviale Überschwemmungssedimentation hat im nördlichen Teil des Gebiets nicht vor etwa 5200 v.u.Z. begonnen. Die anfänglich sehr schnellen Sedimentationsraten führt man auf verstärkte Niederschläge und einen kurzen ostwärtigen Ausfall des Assiniboine River in Richtung Red River zurück. Trotz der verstärkten Niederschläge ist die Häufigkeit der Überschwemmungen im Norden bis 1400 v.u.Z. niedrig geblieben. Die Zunahme der alluvialen Überschwemmungssedimentation nach 1400 v.u.Z. wird auf die Verlagerung des Assiniboine nach Norden zurückgeführt.

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INTRODUCTION

River terraces preserved in drainage basins throughout southern Manitoba (Klassen, 1972, 1975; Welch, 1973; Nielsen,1988) have been the focus of relatively few studies in spite of the potential of terraces to provide "one of the best geomorphic indicators of Holocene environmental changes" (Rains and Welch, 1988, p. 454). The complex sequence of Holocene alluvial sediments exposed along the Red River of southern Manitoba (Fig. 1) provides an abundance of archaeological remains that have been the focus of recent studies (Buchner, 1989; Kroker, 1989). Neither study was concerned with the evolution of the river valley.

This study focuses on the geomorphology, sedimentology, molluscan fauna and chronology of sediments exposed along the Red River between the south end of Winnipeg and Lockport (Fig. 2). Characteristic morphologies and sediments, as exemplified in 5 measured sections, are described and a chronology based both on previously reported and on 21 new radiocarbon dates is presented. Climatic and hydrological inferences are based on the molluscan fauna preserved in the alluvium.

REGIONAL SETTING

The Red River of Manitoba is a suspended sediment load stream originating in Minnesota and North Dakota and draining north into Lake Winnipeg (Fig. 1). The river drains an area of about 287, 000 km^2. Along much of its length it crosses the flat Lake Agassiz clay plain with a gradient of about 0.1 m/km (Clark, 1950).

The Lake Agassiz Plain near Winnipeg consists of up to 24 m of fine grained silt and clay deposited prior to approximately 8500 BP (Fenton *et al.*, 1983). In places north of Winnipeg, till and Paleozoic carbonate bedrock outcrop in the riverbed.

The Red River exhibits a high degree of meandering between the Canada – U.S. border and Kildonan Park at the north end of Winnipeg (Fig. 2) and has a sinuosity of 1.91 in the city of Winnipeg. Along this section of the river the flood plain is typically less than 2 km wide, but during periods of extremely high spring flow, floodwaters may extend tens of kilometres east and west of the channel. From Kildonan Park to St. Andrews, the channel is relatively straight with a sinuosity of 1.16 and the floodplain is only a few hundred metres wide (Fig. 2). North of St. Andrews the channel narrows and at Lockport the river is entrenched. During spring floods this constriction creates a backwater upstream (to the south) which causes the channel to overflow. Between Lockport and Lake Winnipeg the river remains relatively straight.

Comparison by Clark (1950) of cross sections measured in 1912 and 1950 near St. Agathe indicates no significant change in the channel morphology of the river. He also compared measurements from photographs of the river taken in 1857 with the 1950 channel data and concluded that the carrying capacity of the river had diminished due to more abundant vegetation along the river.

Welch (1973) noted that active erosion is removing terrace deposits occupying the convex bank of meanders between Winnipeg and Lockport, suggesting the Red River is becom-

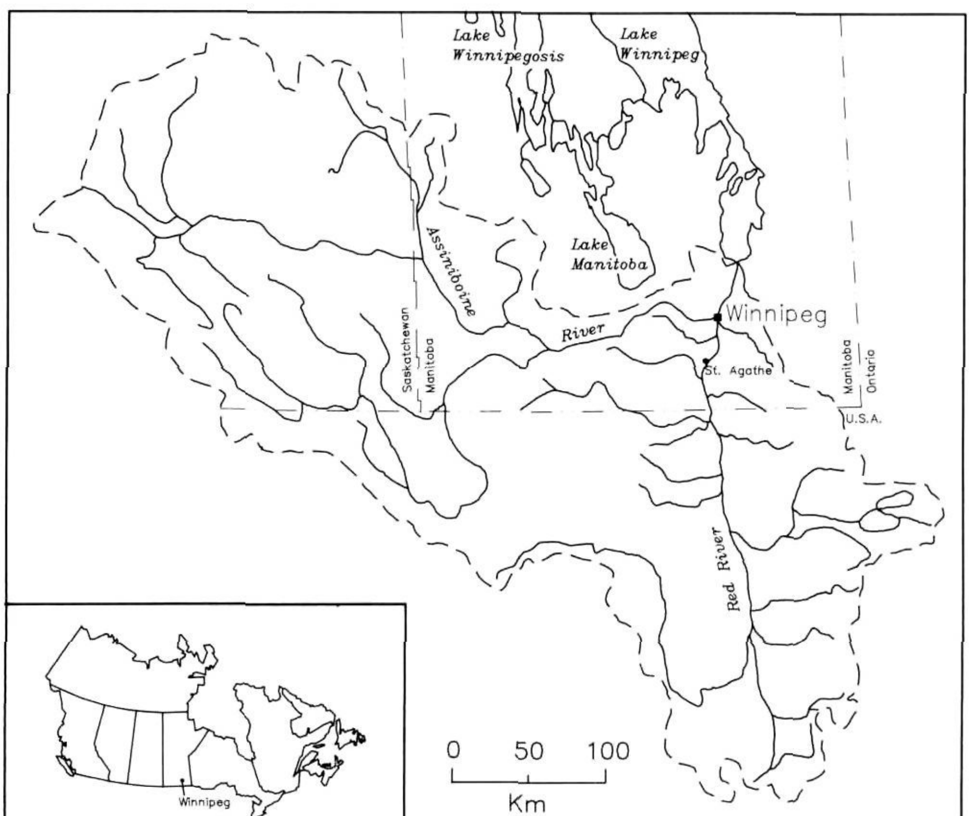


FIGURE 1. Location of the Red River drainage basin. The study area is located in, and north, of the city of Winnipeg.

Localisation du bassin versant de la rivière Rouge. La région à l'étude est située dans Winnipeg et au nord de la ville.

ing straighter in this stretch. He attributed this to decreasing current activity, due either to isostatic uplift or the dam at Lockport, both of which would decrease the south-north gradient. However, the narrow flood plain and the absence of relict features associated with meandering suggests the river has never meandered but has always been relatively straight in this stretch. The abandoned channels south of St. Andrews and at Parkes Creek are too small to have been occupied by the Red River and are thought to have formed as chutes during flooding. Neither of these abandoned channels can be considered as evidence of meandering.

FLOODPLAIN MORPHOLOGY

The present day floodplain of the Red River slopes from an elevation of 230 m at the south end of Winnipeg to an elevation of 222 m at the north end of the study area (Fig. 3). The present day floodplain forms a prominent level inside the valley, which is exceded only by the highest floods (Fig. 4). The floodplain varies considerably in width, being widest in the south and narrowest in the north where the river has cut through the Lake Agassiz clay plain and is floored by till and bedrock. The river is graded to the rapids at Lockport which forms base-level for the upstream portion of the river. Below

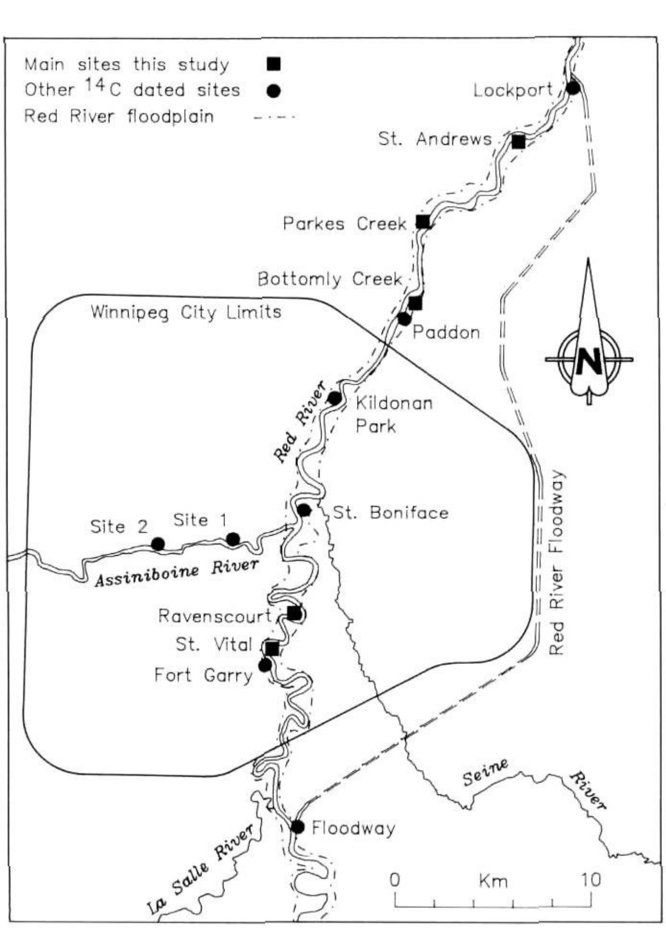


FIGURE 2. Sample sites and radiocarbon dated localities in the Winnipeg-Lockport area.

Sites d'échantillonage et de datation au radiocarbone dans la région de Winnipeg-Lockport.

the rapids at Lockport the river slopes gently to the level of Lake Winnipeg at 217.8 m (Fig. 3).

Only two abandoned meanders occur in the area, one on the east side of the Red River across from the confluence of the Red and Assiniboine rivers and the other on the west side, 4 km south of St. Andrews (Fig. 2). Elsewhere there are levees, chute cut-offs and ridge and swale morphology formed by flooding. These features result in local relief of one to two metres on the terrace. Individual meander lobes are generally highest on the upstream side and slope gently down to the north. High sections are therefore more likely to occur on the south side of meander lobes. These sections are generally vegetated indicating little active erosion. This is supported by comparison of recent maps with maps of the city from the last century which reveals little or no change in meanders. Examination of soil maps suggest the meanders of the Red River are entrenched into Lake Agassiz clay (Ehrlich *et al.*,1953).

HYDRODYNAMIC CHARACTERISTICS AND FLOODING HISTORY

The Red River has a length of 877 km and a catchment area of approximately 124,000 km^2. The Assiniboine River which joins the Red River in downtown Winnipeg, is 1,070 km long and has a catchment area of 163,000 km^2 (Penner *et al.*, 1987; Glavic *et al.*, 1988). Long-term annual mean discharge (1958-1985) for the Red at St. Agathe, above the confluence with the Assiniboine, is 4,899,722 dam^3 whereas at Lockport, the annual mean discharge (1962-1985) is 6,943,750 dam^3 (Fig. 5). The annual mean discharge for the Assiniboine River (1956-1985) is 1,496,069 dam^3 (Penner *et al.*, 1987). The Assiniboine contributes about 25% of the flow of the Red River downstream from Winnipeg. The smaller annual mean discharge of the Assiniboine River is because the Assiniboine drains the drier parts of southwestern Manitoba and southern Saskatchewan. The Red River obtains most of its flow from the more humid, forested regions to the south and east. For the Red and Assiniboine rivers, almost all peak flows and most of the total annual streamflow occur in the period April to June (Fig. 5). This is largely due to winter snows that contribute to most of the spring run-off. Summer precipitation generally does not keep pace with evapotranspiration (Glavic *et al.*, 1988).

Flooding of the Red River typically occurs in April-May. Major flooding is due to a combination of factors including a wet autumn in the previous year, an early frost before the snow fall, heavy snowfall during the latter part of the winter, a sudden and late spring, above normal rainfall throughout the drainage basin during breakup of the ice and simultaneous cresting of both the Red and Assiniboine rivers.

Clark (1950) reported that between 1875, when accurate recording was initiated, and 1950, the Red River flooded 13 times. The largest of these was the 1950 flood when the water level in Winnipeg reached 9.14 m above city datum (221.77 m) (Fig. 3) and approximately 1,650 km^2 of the Red River basin in southwestern Manitoba was under water. The largest documented flood was that of 1826 when the water level reached an estimated 11.3 m above city datum. This was closely followed by floods in 1852 and 1861 when the

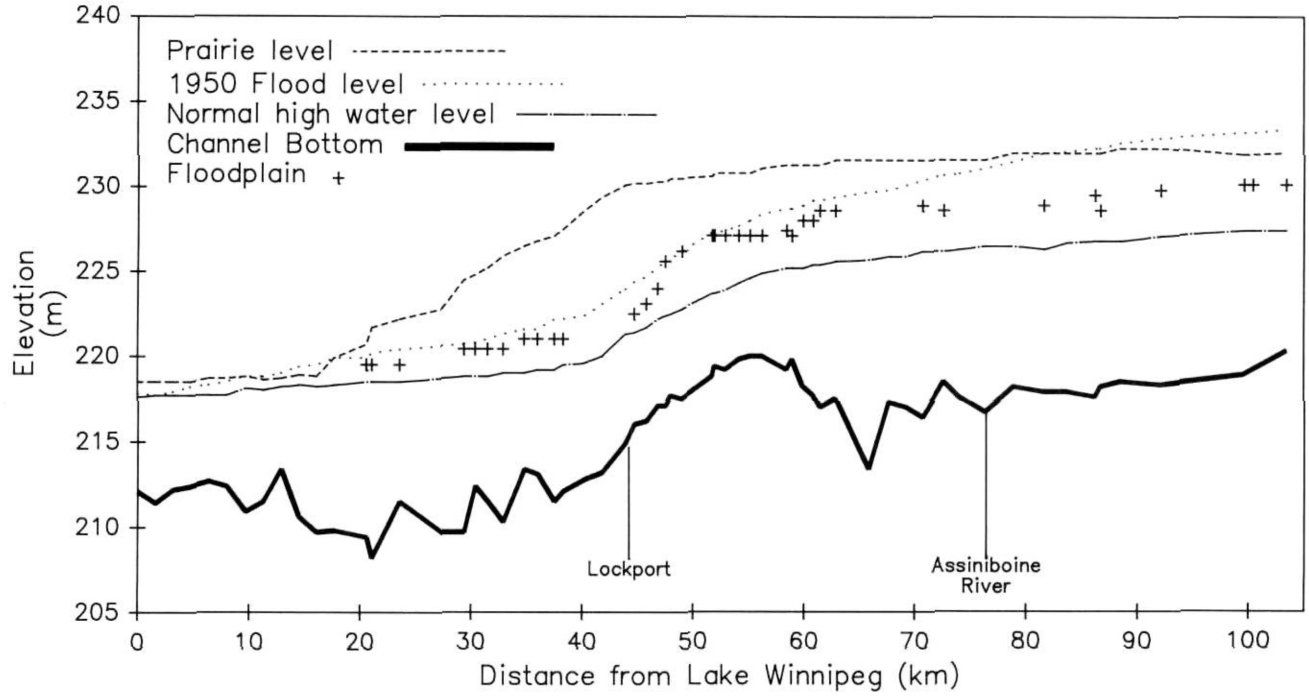


FIGURE 3. Profile along Red River from the south perimeter of Winnipeg to Lake Winnipeg showing the channel bottom, prairie level, floodplain, 1950 flood level and 1951 (normal) high water level (Environment Canada, 1951).

Profil le long de la rivière Rouge, à partir du périmètre sud de Winnipeg jusqu'au lac Winnipeg, montrant le fond du chenal, le niveau de la prairie, la plaine d'inondation, le niveau de la crue de 1950 et le haut niveau (normal) de 1951 (Environment Canada, 1951).

water reached heights of 10.5 m and 10.0 m respectively. The flood of 1776 is thought to have been higher than any flood in the 19th or 20th century (Clark, 1950).

RIVER ALLUVIUM AND DATING

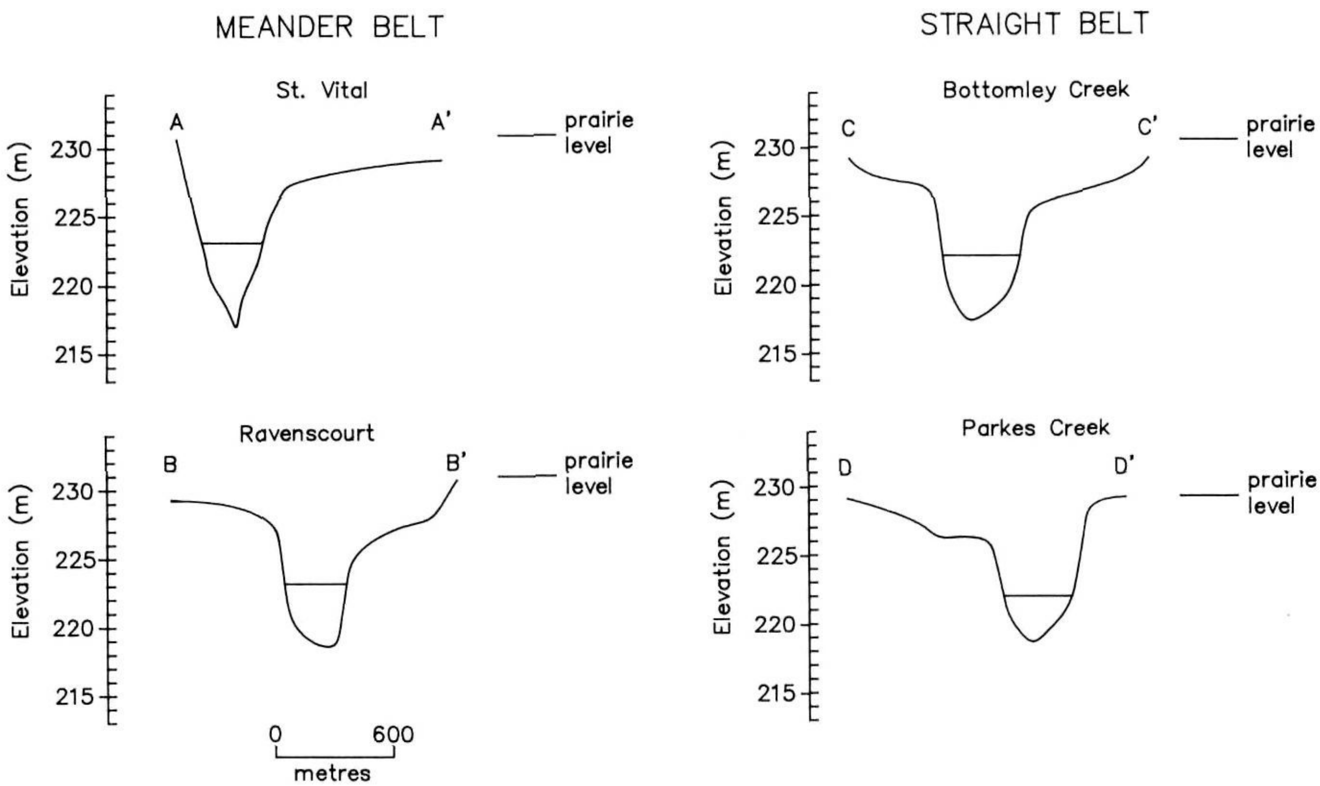
No single exposure shows a complete section of Holocene alluvial stratigraphy, due to erosion, vegetation cover and slumping. The Holocene history of the Red River has been reconstructed on the basis of detailed work on five exposed sections.

Absolute ages have been assigned on the basis of radiocarbon dates on wood, charcoal, bone and shells (Table I). The radiocarbon dates were all concordant and considered to be good age estimates. Nielsen *et al.* (1982) and Nielsen *et al.* (1987) found shell dates in southem Manitoba to be about 400 years older than the true ages due to the hard water effect. On the other hand, Klassen (*in* Dyck *et al.*, 1965) found good agreement between freshwater shells (GSC-215) and wood (GSC-216) from the same horizon along the Red River and concluded that dates on freshwater shells from this area are reliable (Table I).

North of Winnipeg two sites have previously been investigated. A detailed chronology of alluvial sedimentation based on 14 radiocarbon dates on charcoal and bone spanning the last 3300 years was constructed by Buchner (1989) for an archaeological site at Lockport (Table I). A single date of 2995 ± 105 BP on bone from a depth of 1.05-1.20 m is available for the Paddon archaeological site (Fig. 2 and Table I). Dyck *et al.*, (1965) report dates of 3650 ± 140 BP and 3660 ± 130 BP from a depth of 7.6 m at the entrance to the Red River Floodway and Rubin and Alexander (1960) report dates of 6200 ± 320 BP and 6750 ± 320 BP from just above the till in Fort Garry (Fig. 2). The estimated depth of this sample is about 14.0 m (Table I).

PALEOECOLOGICAL METHODS

Although the larger freshwater pelecypods, the Unionidae, were hand picked in the field, most molluscs taken during the study were collected together with sediment. In the laboratory 100-150 g of sediment was searched under a wide field microscope and specimens were sorted, identified and stored. The total number of each species/100 g of sample was recorded (Table II). In the case of *Amnicola limosa* (Say) the length was also noted, thereby allowing construction of size frequency distribution curves (Table III). Using growth curves and methods developed previously from contemporary populations (McKillop, 1985; McKillop *et al.*, 1981; McKillop and Harrison, 1972) the size frequency distribution curves were transformed into age frequency distribution curves. The population structure was then used to determine environmental longevity. Thus the presence and relative number of a particular species, together with species diversity and size/age frequency analysis for *Amnicola limosa* provided the basis for the paleoecological interpretation. This interpretation was based on the assumption that the molluscs taken reflect the state of the environment at the time of the high water withdrawal, and that these environmental conditions reflect those occupied today by the species associations recorded. Although many of the small bivalves, the Pisidiidae, were not articulated, this finding was not considered evidence of fluvial transport because these shells are readily disartic-



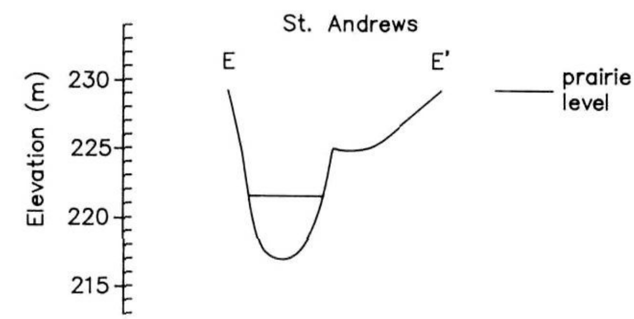


FIGURE 4. Topographic profiles across the Red River at the five sites investigated. For location see later figures (Environment Canada, 1951).

Profils topographiques de la rivière Rouge aux cinq sites étudiés (emplacements aux figures précédentes) (Environment Canada, 1951).

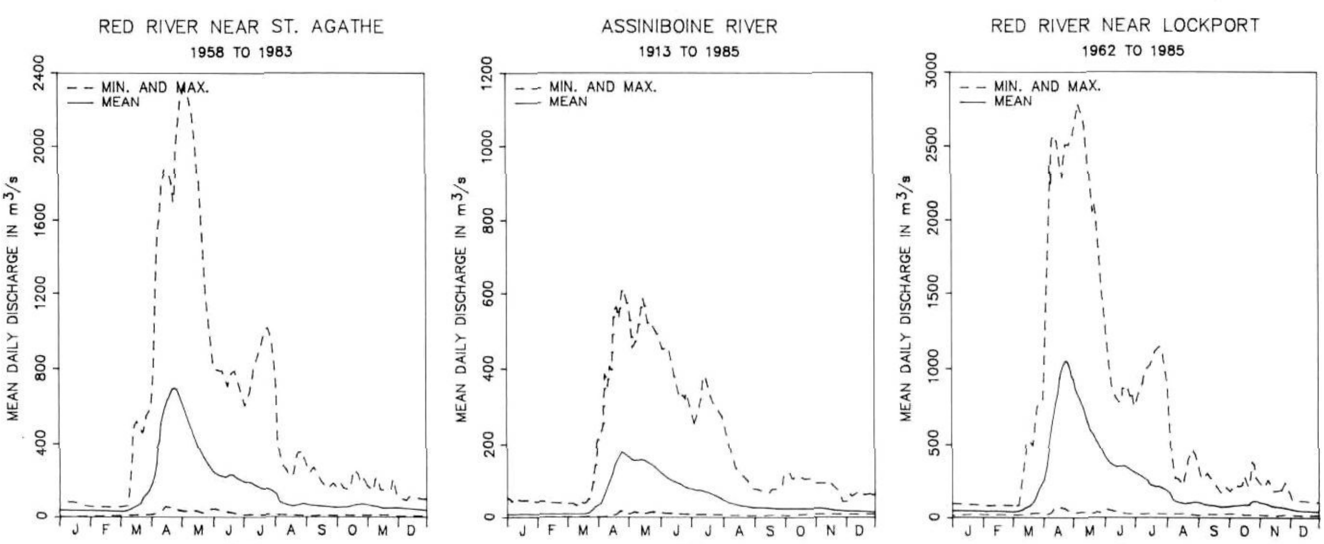


FIGURE 5. Mean hydrographic and discharge summaries for selected sites along the Red and Assiniboine rivers (Penner *et al.* 1987; Glavic *et al.*, 1988). Note the different scales.

Hydrogrammes de certains sites le long des rivières Rouge et Assiniboine (Penner et al. *1987; Glavec* et al.*, 1988). Noter les différentes échelles.*

TABLE I

Radiocarbon dates from the Red and Assiniboine rivers

Site	Age(BP)	Lab No.	Depth (m)	Material	Reference
St. Vital					
	260±70	BGS-1342	0.5	Charcoal	This report
	430±70	BGS-1343	0.9	Charcoal	This report
	2390±70	BGS-1344	3.3	Charcoal	This report
	2800±80	BGS-1345	9.2*	Shells	This report
	1400±80	BGS-1346	1.3	Charcoal	This report
Ravenscourt					
	180±100	BGS-919	3.2	Charcoal	This report
	770±100	BGS-922	2.3	Shells	This report
	1530±100	BGS-918	2.4	Charcoal	This report
	3120±90	BGS-1423	5.7	Shells	This report
Bottomly Creek					
	2370±100	BGS-925	0.9	Bone	This report
	4540±100	BGS-924	1.3	Bone	This report
	5260±110	BGS-923	5.5	Shells	This report
Parkes Creek					
	3560±100	BGS-926	1.4	Bone	This report
	5000±100	BGS-921	3.4	Shells	This report
	4980±125	BGS-920	4.5	Shells	This report
St. Andrews					
	3630±100	BGS-927	2.0	Bone	This report
	4900±100	BGS-917	3.2	Charcoal	This report
Assiniboine River					
Site 1	7490±80	GSC-4839	10.7	Wood	This report
Site 2	325±100	BGS-1410	2.0	Bone	This report
North Kildonan					
	1220±70	BGS-1409	9.0	Wood	This report
St. Boniface					
	1380±80	BGS-1422	7.0	Wood	This report
Floodway					
	3650±140	GSC-215	7.6	Shells	Dyck *et al.*, 1965
	3660±130	GSC-216	7.6	Wood	Dyck *et al.*, 1965
Paddon					
	2995±105	S-588	1.05-1.2	Bone	Rutherford *et al.*, 1975
Ft. Garry					
	6200±320	W-860	14.0	Wood	Rubin and Alexander, 1960
	6750±320	W-862	14.0	Wood	Rubin and Alexander, 1960
Lockport					
	470±270	S-2850	0.37	Charcoal	Buchner, 1989
	705±75	RIDDL-1273	0.57	Bone	Buchner, 1989
	315±235	S-2852	0.63*	Charcoal	Buchner, 1989
	1005±280	S-2851	0.75	Charcoal	Buchner, 1989
	595±80	RIDDL-1272	0.78	Bone	Buchner, 1989
	620±105	GX-10866	0.82	Charcoal	Buchner, 1989
	635±90	S-2849	0.83	Charcoal	Buchner, 1989
	1185±255	S-2848	0.83	Charcoal	Buchner, 1989
	1185±255	S-2854	0.93	Charcoal	Buchner, 1989
	1410±290	GX-10865	1.42	Bone	Buchner, 1989
	1095±250	S-2853	1.53	Charcoal	Buchner, 1989
	2315±140	GX-10864	1.57	Bone	Buchner, 1989
	2515±140	GX-10863	1.90	Bone	Buchner, 1989
	3300±295	S-2847	2.10	Charcoal	Buchner, 1989

* originating in a higher level

TABLE II

*Mollusc species collected/100 g of sample**

	Gastropoda														Pelecypoda				
	Pulmonata												Prosobranchia		Unionidae			Pisidiidae	
	Stylommatophora						Basommatophora												
	C. lubrica	*V. gracilicosta*	*G. tappaniana*	*O. retusa*	*D. cronkhitei*	*R. binneyana*	*C. exiguum*	*S. elodes*	*P. gyrina*	*G. parvus*	*H. anceps*	*F. rivularis*	*V. tricarinata*	*A. limosa*	*A. plicata*	*L.r. siliquoidea*	*L. ventricosa*	*S. striatinum*	*P. compressum*
St. Vital																			
Section D																			
0.3 m						2								1					
0.5 m				2	2														
0.9 m	1	4		3		1													
1.1 m		1		1	2	5								1					
Section G																			
0.6 m		7		3	2	3	1												
9.2 m																1			
Ravenscourt																			
Section B																			
2.3 m		1			1					1				56	1	6	3	6	
Section A																			
1.9 m		2	1	2	5				13	3	1	3	1	480				46	1
2.1 m	9			9	1	3			7	8		10	12	588				52	5
2.3 m					3							5		217				44	
2.9 m				6										33	1			18	
4.7 m		1		1										213				24	
4.9 m					2				1	3		2		136				40	
5.2 m		1		4	3					2		3	1	138				15	
5.4 m		1		1						2		1	1	97				11	1
5.6 m				1	1					1		1		5	1			1	
5.7 m		2		1	2	1		1	1	3		2		323		1		20	1
Bottomly Creek																			
4.5 m														51				10	
5.5 m								1						162		1		25	1
Parkes Creek																			
Section A																			
1.5 m										2				11				5	
3.8 m	1													174		4	1	20	
4.2 m																1			
St. Andrews																			
1.0 m				1								1		36				2	
1.1 m						1			2	1		2	1	122				24	
1.5 m			3									4	1	54				11	
1.8 m					1					1		2		53				21	
1.9 m												1		28				8	
2.1 m													1	24				12	

*The Unionids *A. plicata*, *L.r. siliquoidea* and *L. ventricosa* were hand picked.

TABLE III

Amnicalo limoso *size/age distribution*

	Depth	Size (mm) Age (mo.) Status	0.79 May-June ..Hatchling..........	1.58 July ..Juvenile.........	2.37 Aug ...Adult..................................	3.16 Sept	3.95 Oct-Apr	4.74 May	5.53 July>June
St. Vital									
Section D	0.3		0	0	1	0	0	0	0
	1.1		0	0	1	0	0	0	0
Ravenscourt									
Section B	2.3		0	9	15	23	9	0	0
Ravenscourt									
Section A	1.9		35	224	119	83	19	0	0
	2.1		24	148	184	204	28	0	0
	2.3		36	130	28	20	3	0	0
	2.9		0	21	6	6	0	0	0
	4.7		13	95	54	44	7	0	0
	4.9		4	75	36	20	1	0	0
	5.2		14	63	38	20	3	0	0
	5.4		13	41	27	14	2	0	0
	5.6		1	1	1	1	1	0	0
	5.7		13	133	120	52	5	0	0
Bottomly Creek									
Section C	4.5		5	22	8	8	3	4	1
	5.5		20	28	65	40	7	2	0
Parkes Creek									
Section A	1.5		10	1	0	0	0	0	0
	3.8		5	19	57	76	17	0	0
St. Andrews	1.0		1	15	13	6	1	0	0
	1.1		10	73	27	9	3	0	0
	1.5		2	24	17	11	0	0	0
	1.8		3	23	12	14	1	0	0
	1.9		0	10	9	5	1	1	2
	2.1		0	7	7	9	0	1	0

ulated upon death. Furthermore, analysis of small volumes of sediment showed matching valves were frequently in close proximity. In addition, since the shells were not worn, and since many of the larger bivalves were articulated, postmortem transport seems insignificant. It is therefore concluded that the specimens are *in situ*.

RESULTS

ST. VITAL PARK SECTION

Sedimentology

Several good exposures were found along the meander loop near St. Vital Park in the south of Winnipeg. Three sections, outcropping over a distance of approximately 0.7 km, were examined in detail (Fig. 6).

Section H, located furthest upstream, exposes 2.7 m of poorly laminated silt. A single thin charcoal horizon occurring at a depth of 1.3 m was radiocarbon dated at 1400 ± 80 BP (Table I).

Section G located 0.2 km downstream exposes 4.1 m of blocky silt at the top of a 9.2 m high bluff (Fig. 6). Seven prominent charcoal layers (Fig. 7), two minor bone layers and two shell layers are exposed in the upper part of the section. A 0.55 m thick dark soil occurs between 0.24 and 0.80 m below the surface. The presence of aluminum foil near the top of section G indicates that 0.25 m of overbank sedimentation occurred in this century, possibly in the large flood of 1950.

The base of the section is sandy and badly slumped but a single *Lampsilis radiata siliquoidea* (Barnes) exposed at river level (9.2 m depth) was radiocarbon dated at 2800 ± 80 BP. The charcoal layer at 3.3 m was dated at 2390 ± 70 BP (Table I). As the base of section G had slumped, the 2800 ± 80 BP date is considered anomalous for this depth. The true stratigraphic position of this sample probably lies closer to the 2390 ± 70 BP dated sample, higher up in the section.

On the north side of the meander lobe a small 1.2 m high section (Fig. 6, section D) exposes interbedded silt and sand. The lower part of the section is mainly silt whereas the upper part is sandy. Charcoal horizons at depths of 0.50 m and 0.90 m were radiocarbon dated at 260 ± 70 BP and 430 ± 70 BP respectively.

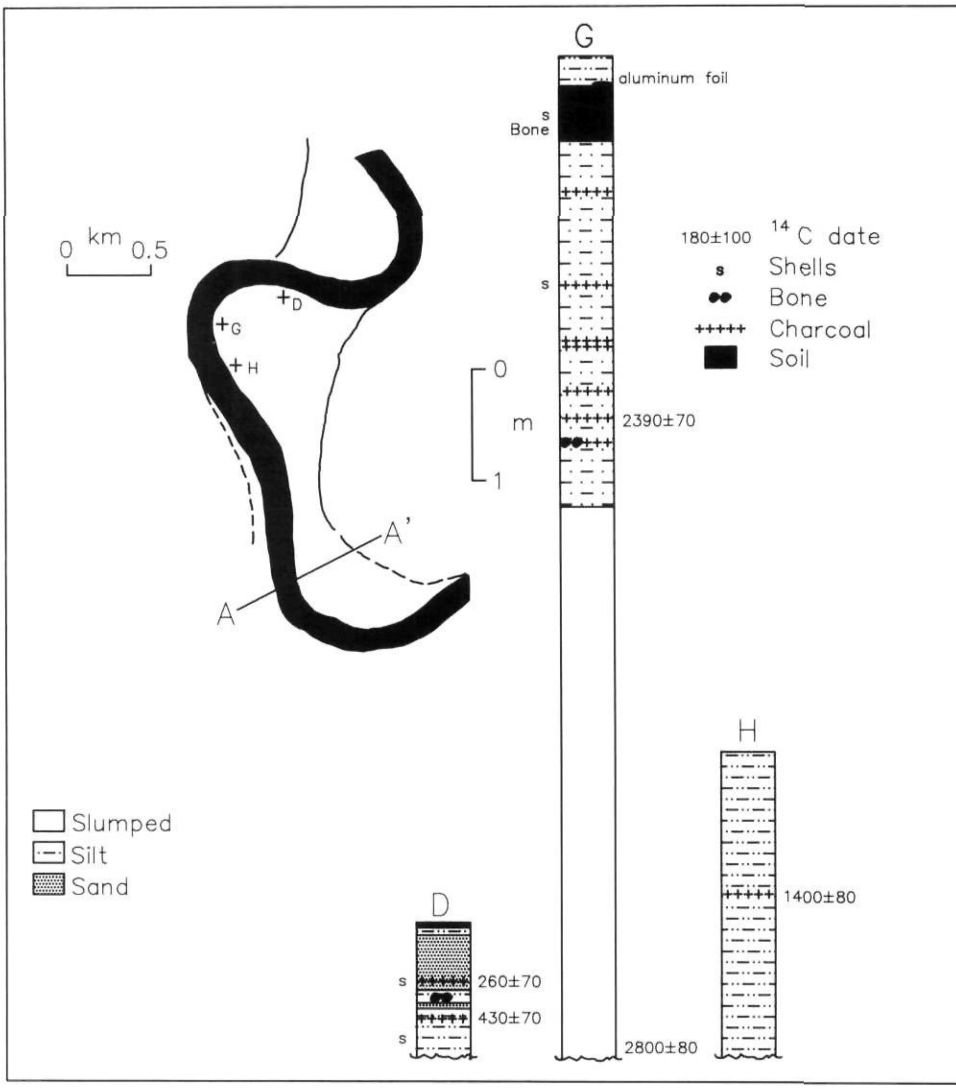


FIGURE 6. Stratigraphic sections measured at St. Vital. Insert map shows the location of the sections and topographic profile.

Les coupes stratigraphiques de St. Vital, ainsi que la localisation des coupes et du profil topographique.

The blocky silt, paleosol and abundant charcoal beds suggest overbank sedimentation during recurrent flooding. The low elevation and relatively young age of deposits in section indicate deposition on the downstream limb of the meander.

Paleoecology

Aquatic molluscs were poorly represented at the St. Vital site although the more common terrestrial species were found. At section D, the mollusc association was composed mainly of terrestrial species and the amphibious snail *Oxyloma retusa* (Lea). Only two *Amnicola limosa* were taken, one from the sand unit at 0.3 m and the other in the lower silt unit at 1.1 m below the surface. The presence of the terrestrial and amphibious snail species suggests that these were moist, grassy, low-lying environments while the occurrence of the gill bearing *Amnicola limosa* indicates brief periods of high water (Table II). This environment probably stemmed trom spring flooding over a low-lying grassy area. Water depth was negligible and for the most part it was a terrestrial environment that has changed little in the past 430 years.

Within the thick dark paleosol, at a depth of 0.6 m, 5 species were collected. Besides the amphibious snail *Oxyloma retusa* the remaining four species were land snails including *Discus cronkhitei* (Newcomb), *Retinella binneyana* (Morse), *Vallonia gracilicosta* Reinhardt and *Carychium exiguum* (Say). Since no aquatic molluscs were taken this flood was of short duration. Grasses and litter would have provided the land snails with cover needed to protect them from desiccation as the site probably dried rapidly. It was not a long lived aquatic environment but rather a moist area resulting from a spring spate.

RAVENSCOURT SECTION

Sedimentology

Three sections outcropping along a 50 m stretch of the upstream end of this prominent meander lobe reveal a widely varying stratigraphy (Fig. 8).

Section B, a 4.5 m high section, exposes cross-bedded sand overlying silt and minor gravel which in turn overlies silt and sand at the base of the section. A 0.30 m thick gravel bed

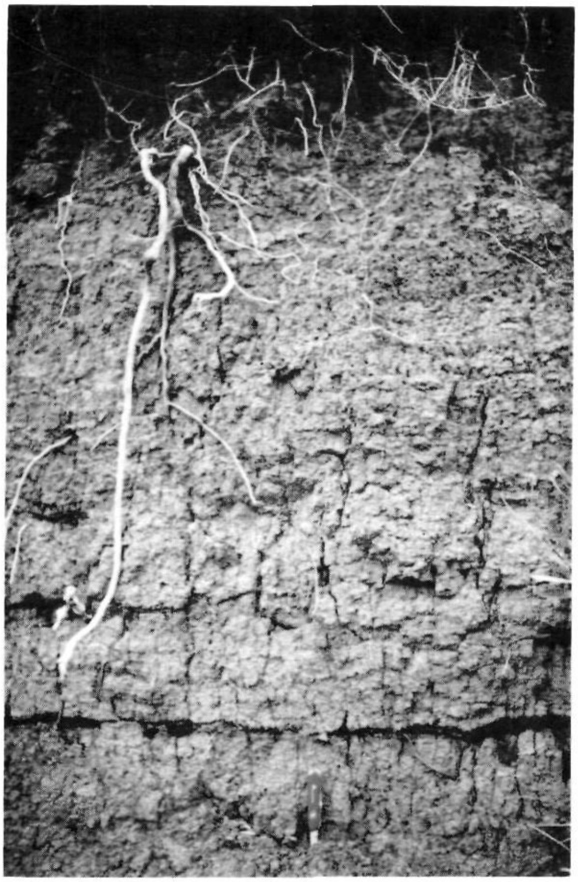


FIGURE 7. Upper part of the profile in the St. Vital G section showing blocky silt and two charcoal layers. The paleosol is obscured under the overhang. Note the knife for scale.

Partie supérieure de la coupe G de St. Vital montrant un silt blocailleux et deux couches de charbon de bois. Le paléosol est masqué sous le surplomb. Le canif donne l'échelle.

outcropping 2.3 m below the surface, contained large articulated unionid shells (Fig. 10 and Table II) dated to 770 ± 100 BP (Table I).

Twenty metres downstream, section A exposes 6.3 m of laminated silt. Ten shell bearing horizons occur in the lower 4.5 m of the section. Two prominent paleosols were found near the top of the section and several lesser ones below. Charcoal layers are common in the lower part of the section but occur throughout. A shell from the 5.7 m level was dated at 3120 ± 90 BP and charcoal from a depth of 2.4 m was dated at 1530 ± 100 BP (Table I).

Section C, located 30 m further downstream, exposes 3.5 m of horizontally bedded silt and silty clay. A charcoal lens near the base of the section, at a depth of 3.2 m dated to 180 ± 100 BP (Table I).

The presence of charcoal and paleosols in laminated fine sediments in sections A and C indicate sedimentation by repeated overbank deposition. The relatively young radiocarbon dates (1530 ± 100 BP and 180 ± 100 BP) suggest the meander has undergone rapid vertical aggradation. The variable texture of the sediments in section B, the location of the section relative to the other sections, and the recent radiocarbon date (770 ± 100 BP) suggest that this is a lateral accretionary deposit laid down possibly during a major flood.

Paleoecology

At section B three species ot Unionidae were taken, namely *Lampsilis ventricosa* (Barnes), *Lampsilis radiata siliquoidea* and *Amblema plicata* (Say) (Fig. 9). In addition to the purely aquatic gill bearing *Amnicola limosa* and *Sphaerium striatinum* (Lamarck), specimens of *Gyraulus parvus* (Say) were collected. The fact that only two land snails were collected here, coupled with the lack of young *Amnicola limosa* (Table II, Table III), suggests that the aquatic environment persisted until late summer and possibly became perennial. In addition, the presence and diversity of molluscs usually associated with currents indicates that the flood was of major proportion.

Section A contained 10 shell bearing layers. The lowest at 5.7 m depth contained 12 mollusc species including *Sphaerium striatinum, Pisidium compressum* Prime, *Lampsilis radiata siliquoidea* (dated at 3120 ± 90 BP), *Amnicola limosa, Ferrissia rivularis* (Say), *Gyraulus parvus, Physa gyrina* Say, *Stagnicola elodes* (Say), the amphibious snail *Oxyloma retusa* and three land snails (Table II). The presence of several species of Pelecypoda and that of the freshwater limpet *Ferrissia rivularis*, usually associated with rapid flowing water, indicates that a large flood with significant currents occurred. Nevertheless, the diversity of the other Pulmonata, together with the presence of such species as *Physa gyrina* and *Stagnicola elodes* suggests that the currents dropped by late spring allowing aquatic vegetation to develop in backwater sites by early summer. The aquatic nature of the site persisted into July before the site dried by which time *Oxyloma retusa* and the three species of land snail would have moved in occupying the margins, backwaters and damp sections of the site as they became available through further drying of the habitat.

Five additional snail horizons, approximately 0.2 m apart, occur above the 5.7 m level described above. The horizons immediately above were similar to the 5.7 m level but near the top of the sequence at 4.7 m, the diversity dropped to only 4 species, *Amnicola limosa, Sphaerium striatinum,* the amphibious *Oxyloma retusa* and the land snail *Vallonia gracilicosta*, indicating a gradual lessening in severity and duration of the floods (Table II). This finding was supported by the population structure of *Sphaerium striatinum* which showed a loss of the larger classes in the upper horizons. Similarly, at the 4.7 m level the large number of young *Amnicola limosa* that characterize the truncated age frequency curve suggests the site dried by late June (Table III).

Between the 4.7 and 2.9 m levels minor floods occurred with minimal shell bed deposition. At 2.9 m a single *Amblema plicata* was taken, indicative of more major flooding. The mollusc association and the lack of the more mature *Amnicola limosa* size classes indicates it was short lived and that the site dried rapidly.

Slightly above a charcoal layer dated at 1530 ± 100 BP, a mollusc bed at 2.3 m provided evidence that a spring flood with rapid currents had occurred. This was followed by a

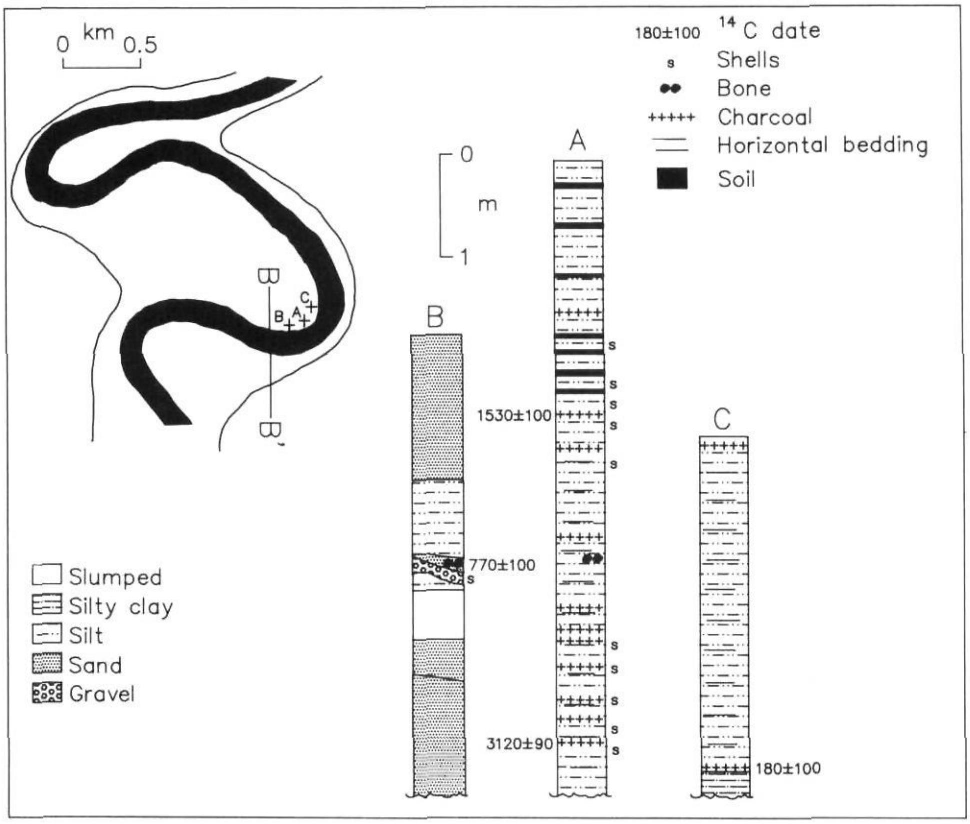


FIGURE 8. Stratigraphic sections measured at Ravenscourt. Insert map shows the location of the sections and topographic profile.

Les coupes stratigraphiques de Ravenscourt, ainsi que la localisation des sites et du profil topographique.

FIGURE 9. Details of large unionids from the middle of the Ravenscourt B section dated at 770 ± 100 BP.

Gros plan sur des unionidés au milieu de la coupe B de Ravenscourt datés à 770 ± 100 BP.

prolonged wet period that lasted well into June, as the population curve of *Amnicola limosa* indicated a significant build-up of young (Table III). The land snail *Discus cronkhitei* probably persisted in the remnant moist areas following the prolonged period of high water.

At the 2.1 and 1.9 m levels, well developed mollusc horizons show stable community structure and a high degree of diversity, with about a dozen species being collected from each layer. Although no unionids were observed, the pisidiids *Sphaerium striatinum* and *Pisidium compressum* were taken with *Ferrissia rivularis* and *Valvata tricarinata* (Say), each of these species being indicative of flowing water. The presence of *Physa gyrina, Helisoma anceps* (Menke) and *Gyraulus parvus* and mature *Amnicola limosa* are further evidence that the site remained under water well into the summer. At the 2.1 m level and less so at the 1.9 m level, mature *Amnicola limosa* represented an especially large portion of the population (Table III), suggesting the site may have become perennially submerged. The occurrence of *Cionella lubrica* (Müller) suggests inundation of a grassy shoreline. On both occasions as the waters receded, three species of terrestrial snail moved in about the margin and on higher and drier portions of the site. Although this was a period of prolonged high water it is unlike that described previously for the 5.7 m level as strong currents were lacking. There were no molluscs in the top 1.9 m of the section.

BOTTOMLY CREEK SECTION

Sedimentology

Five sections were examined along a 200 m exposure where Bottomly Creek joins the Red River (Fig. 10). This stretch is relatively straight and a well developed terrace occurs on both sides of the river. The top of the two northern sections is one to two metres lower than the other sections. The five sections comprise only blocky fine textured silty clay and clayey silt. The upper part of the sections exposes two and in places three prominent soils, the thickest measuring 0.4 m (Fig. 11). A bone bed and up to six thin charcoal horizons occur in the upper half of the sections (Fig. 12). Much of the lower part of the sections is slumped due to active

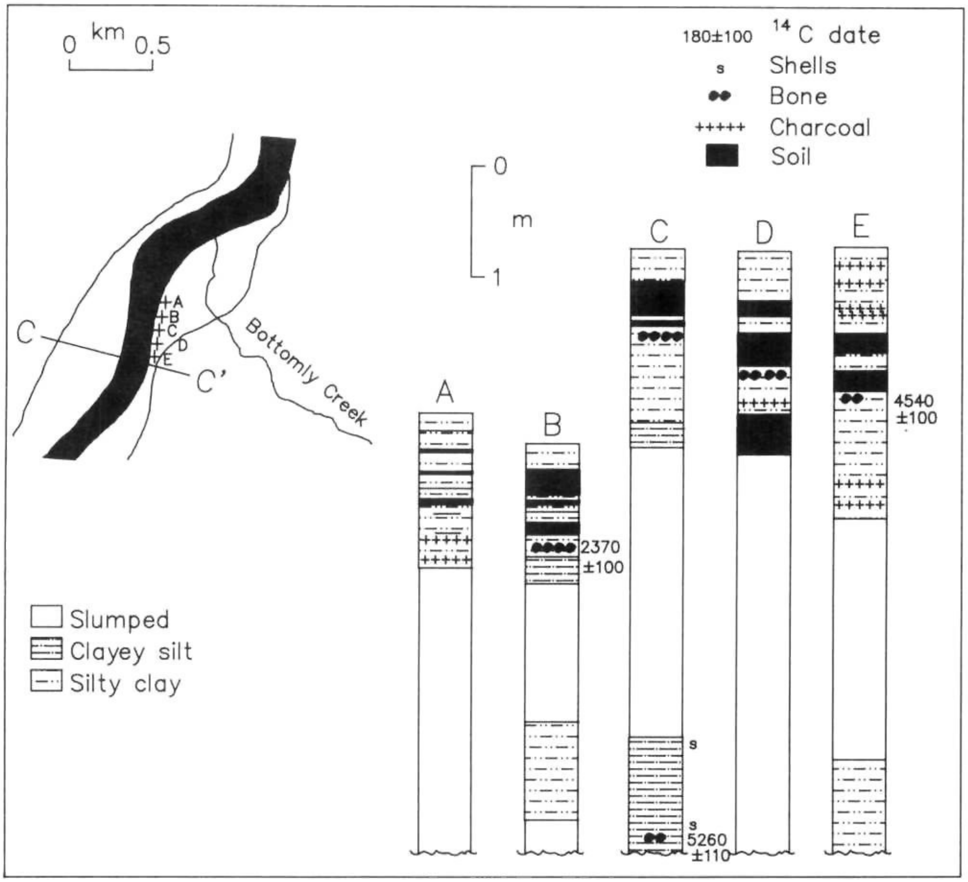


FIGURE 10. Stratigraphic sections measured at Bottomly Creek. Insert map shows the location of the sections and topographic profile.

Les coupes stratigraphiques de Bottomly Creek, ainsi que la localisation des sites et du profil topographique.

FIGURE 11. Truncated paleosols in the vicinity of section A at Bottomly Creek. Note the trowel for scale.

Paléosols tronqués dans les environs de la coupe A de Bottomly Creek. La truelle donne l'échelle.

FIGURE 12. Typical exposure of bison bone fragments under a paleosol at Bottomly Creek.

Coupe montrant des fragments d'os de bison sous un paléosol du Bottomly Creek.

erosion at the base of the cliff and only minor exposures of silty clay occur along the water's edge. Radiocarbon dates on bones and shells from this site are shown on Figure 10 and listed in Table I. A small piece of Indian pottery was observed in the upper 0.15 m silt unit of section B.

The 1-2 m difference in the elevation of the tops of the sections is believed to be due to differences in erosion and deposition during flooding, a conclusion that is supported by the presence of scour chutes in places along the banks of the Red River between Kildonan Park and Parkes Creek.

The fine texture and blocky structure of the sediment, the numerous well developed soils, the charcoal horizons and the presence of bison bones all suggest an origin from overbank deposition. The large shells in the lower part of the sequence suggests deposition under more normal fluvial conditions.

Numerous well developed soils in the upper part of the section and the antiquity of the bison bones as well as the presence of Indian pottery, further suggest a decrease in the number of floods having affected the area during relatively recent times. Correlation of soil units and bone beds across even small distances is tenuous as the soils merge and diverge along the exposures (Fig. 11). The similarity in position and number of soils in the upper part of the section suggest they may be correlative across the exposure, but this conclusion is not substantiated by the markedly different radiocarbon ages obtained on the bones underlying the soils in sections B and E (Fig. 10).

Paleoecology

Two shell beds were located in the lower levels of section C (Fig. 10). The lowest bed, just above the water level at 5.5 m, was dated at 5260 ± 110 BP. Here five mollusc species were collected (Table II). A preponderance of juvenile *Amnicola limosa* suggested that the habitat was flooded briefly in spring and dried by July (Table III).

One metre above, only *Sphaerium striatinum* and *Amnicola limosa* were taken. Age frequency curves for the latter species are indicative of a population persisting only until June (Table III), about a month earlier than described for the lower horizon.

PARKES CREEK SECTION

Sedimentology

Six sections outcropping along an approximately 20 m stretch of the west side of the river south of Parkes Creek expose sand and gravel overlain by blocky laminated silt and silty clay (Figs. 13 and 14). The river bed is bedrock overlain by till which is the source of the sand and gravel exposed in the lower metre of the section. Large unionids commonly found in this lower unit at depths of 4.5 and 3.4 m were radiocarbon dated at 4980 ± 125 and 5000 ± 100 BP respectively (Table I).

In section A, the southernmost section, relatively coarse material in the lower part of the section is overlain by approximately 3 m of silt whereas the upper part of the other five sections is slumped. Section A exposes four prominent soils, four bone horizons, two charcoal layers and two reddish-brown zones formed by burning. A bone sample from a depth of 1.4 m, associated with the prominent soil at this level, was radiocarbon dated at 3560 ± 100 BP (Table I).

The coarse texture of the lowest one metre of the sections, the proximity to the underlying till and the presence of large unionid shells identifies this unit as bed load sediment deposited within the main channel of the river about 5000 BP.

The overlying sediment exhibits the characteristics of overbank sedimentation, namely fine texture, buried soils, vertebrate fossils, charcoal and evidence of periodic burning, as observed in other sections.

Paleoecology

In section A, at a depth of 3.8 m two Unionidae species were found while the age frequency curves for *Amnicola limosa* show a stable, developed population indicating these sites were inundated until at least late summer and are considered perennial. In the upper portion of the section, approximately 0.07 m below the bone at 1.4 m (3560 ± 100 BP), a thin layer ot molluscs contained only three species and only very young *Amnicola limosa* were taken, suggesting the population died out in early spring. The lack of clay in the

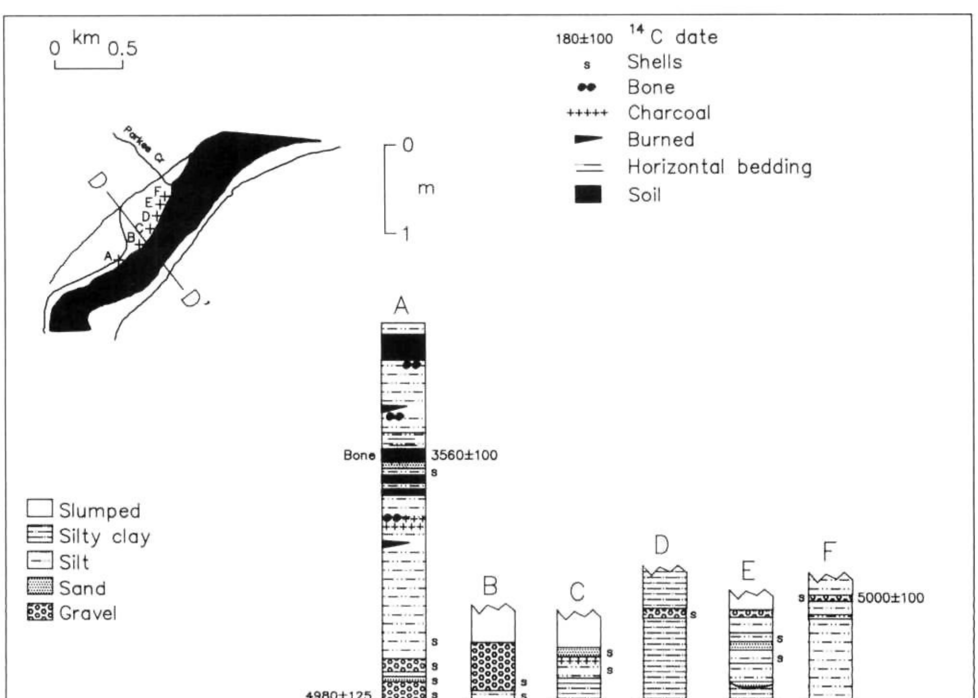


FIGURE 13. Stratigraphic sections measured at Parkes Creek. Insert map shows the location of the sections and topographic profile.

Les coupes stratigraphiques de Parkes Creek, ainsi que la localisation des sites et du profil topographique.

FIGURE 14. Section A at Parkes Creek showing paleosols. Bison bone from the uppermost exposed paleosol was dated at 3560 ± 100 BP. Note the knife for scale.

Coupe A du site de Parkes Creek montrant des paléosols. Un os de bison recueilli dans le paléosol supérieur à nu a été daté à 3560 ± 100 BP. Le canif donne l'échelle.

sediment suggests shallow waters with moderate current. These data are indicative of a single major flood. As the water receded, the site apparently dried rapidly as no amphibious or moisture-loving terrestrial snails were found here (Tables II and III).

ST. ANDREWS SECTION

Sedimentology

On the east side of the Red River opposite St. Andrews a 3.2 m high section of silty clay and silty sand is exposed (Fig. 15). The lowest 0.50 m of the section comprises brown silty clay with a prominent charcoal horizon exposed at the base. The charcoal was dated at 4900 ± 100 BP, and bison ribs and vertebrae 1.2 m higher up were dated at 3630 ± 100 BP (Table I).

The entire section is believed to have been deposited by overbank sedimentation during floods spanning the last 5000 years. The mean sedimentation rate in the lower 1.2 m of the section, deposited between 4900 and 3600 BP, was initially high. However, the presence of thick and well developed paleosols in the upper part of this interval indicates the sedimentation rate had decreased significantly by 3600 BP. Overbank sedimentation decreased significantly during the last 3600 years, when approximately 2 m of sediment was deposited. Sand beds up to 0.15 m thick, interbedded with relatively thin soils in the upper part of the section, indicate the size and frequency of the floods remained relatively uniform during this interval. There is little evidence for significant vertical aggradation during historic time.

Paleoecology

The mollusc horizon 2.1 m below the surface in a silty sand layer, and 0.10 m below the bones dated at 3630 ± 100 BP, contained the aquatic species *Valvata tricarinata, Amnicola limosa* and *Sphaerium striatinum*. Ten centimetres above the bone layer, at 2.0 m, *Ferrissia rivularis* in addition to *Sphaerium striatinum* and *Amnicola limosa* was collected. Age frequency curves for *Amnicola limosa* in both beds indicate that stable populations had developed as both young and adults were represented (Table III). Thus, a period of persistent high water is envisaged with the environment remaining aquatic until at least early September and possibly even becoming perennial.

Mollusc layers at 1.8 m and 1.5 m contained *Valvata tricarinata, Ferrissia rivularis* and *Gyraulus parvus*, in addition to *Amnicola limosa* and *Sphaerium striatinum*. Age frequency structure indicated prolonged high water levels while the land snails *Discus cronkhitei* and *Gastrocopta tappaniana* (Adams) were probably associated with drying backwater pockets or perimeter sites as water levels subsided and the area dried.

The lower portion of the shell bed found at the 1.1 m level contained 8 species while the upper few centimetres at 1.0 m had less diversity and fewer specimens. It appears that a major spring flood with associated rapid currents swept the area bringing 6 aquatics including *Amnicola limosa, Sphaerium striatinum, Ferrissia rivularis, Gyraulus parvus, Physa gyrina* and *Valvata tricarinata*. The land snail *Retinella binneyana* was also collected. The age frequency curve for *Amnicola limosa* showed that the population was composed mainly of younger specimens. This suggests that the flooding was brief with backwaters probably lasting only to June. Nevertheless, the presence of *Valvata tricarinata* and *Ferrissia rivularis* and the predominantly sandy sediment indicates a significant current swept the area. Near the end of the flood, as evidenced by the shells at the 1 m level, *Oxyloma retusa* had moved in to the moist areas but the rapidly dropping waters precluded moisture loving land snails.

ASSINIBOINE RIVER - SITE 1

In 1969, an 11 m deep excavation on a terrace of the Assiniboine River 3.2 km west of the Red River (Fig. 2) exposed approximately 1 m of fine gravel near the bottom of the hole. The gravel overlies clay and was in turn overlain by silty clay containing water-worn bison bones, wood, and large articulated freshwater pelecypod shells (G. Lammers, pers. comm., 1989). Wood from the base of this site has been radiocarbon dated at 7490 ± 80 BP (Table I).

The description of the gravel with water worn bones and large pelecypod shells is consistent with other occurrences of gravel deposited as bedload sediment at other sites.

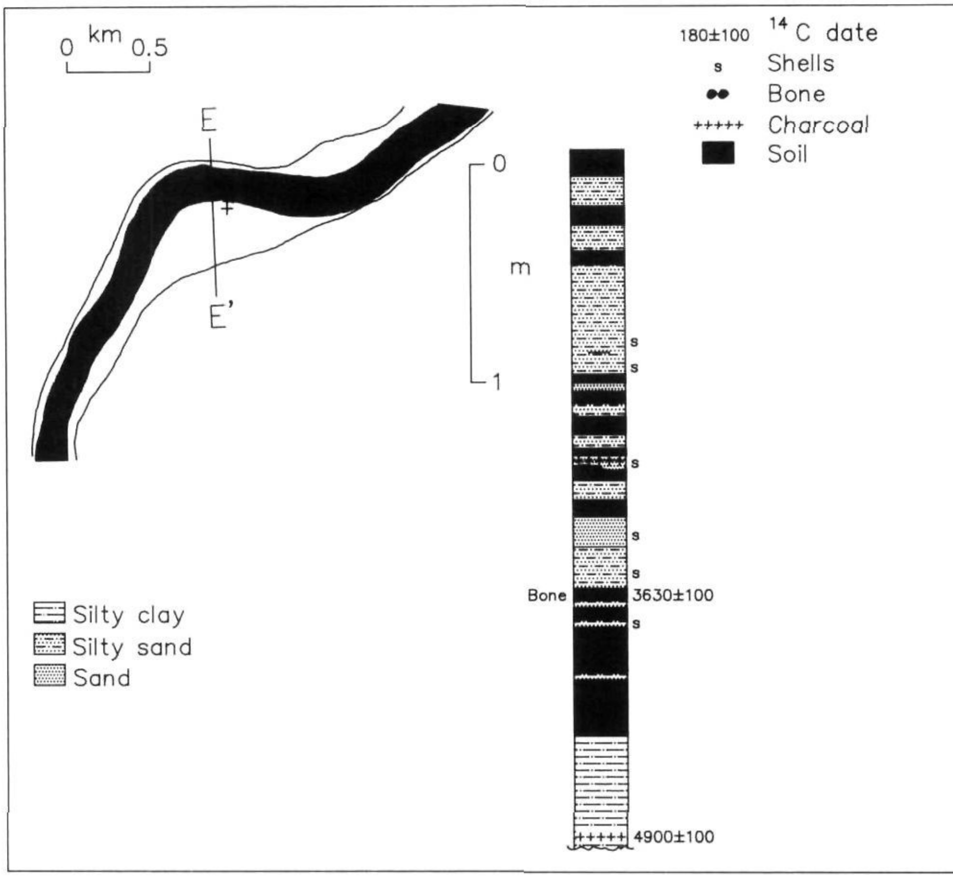


FIGURE 15. Stratigraphic sections measured at St. Andrews. Insert map shows the location of the sections and topographic profile.

Les coupes stratigraphiques de St. Andrews, ainsi que la localisation des sites et du profl topographique.

Although no record of the overlying sediments was made, it is assumed they were deposited by vertical and lateral accretion on the Assiniboine River floodplain at various times during the past 7500 years. The depth and age of the gravel indicate the Assiniboine River currently occupies the same position as it did 7500 years ago.

ASSINIBOINE RIVER – SITE 2

A second site on the same Assiniboine River terrace, 7 km west of the Red River, exposed approximately 4 m of poorly laminated silt and clayey silt at the top of the section. Part of a bison skull recovered from a depth of 2 m in the upper alluvial terrace was radiocarbon dated at 325 ± 100 BP (Table I).

The stratigraphic position in the alluvial terrace and the age, including both the radiocarbon date and the taxonomic assignment to *Bison bison bison* (Linnaeus), suggest the Assiniboine River reoccupied the present valley in late Holocene time after flowing into Lake Manitoba for much of the middle Holocene as demonstrated by Rannie *et al.* (1989). This conclusion is further supported by other relatively young radiocarbon dates of 575 ± 70 BP (BGS-1436) and 920 ± 70 BP (BGS-1437) for Assiniboine River alluvial sediments immediately west of Winnipeg.

ADDITIONAL RED RIVER SITES

Wood from 7 and 9 m deep excavations in alluvium in St. Boniface and North Kildonan (Fig. 2) were radiocarbon dated to 1380 ± 80 BP and 1220 ± 70 BP respectively (Table I).

Evidence for recent flooding is common in sections within the city of Winnipeg, notably in the south. Live trees (*Fraxinus* sp.), initially rooted a metre below the surface and subsequently buried by overbank sediment, were noted at several sites between the Assiniboine River and the south end of the city (Fig. 16). Bottles, roofing shingles, aluminum foil and other twentieth century refuse commonly occurs in the upper 0.5-1.0 m of these sections. This is in marked contrast to the Indian pottery found at a depth of only 0.15 m from the surface at Bottomly Creek, north of the city.

SEDIMENTATION RATE

Plots of depth versus radiocarbon age for samples collected along the Red River are shown in Figure 17. Dates of 6750 ± 320 BP from the Red River in the south end of Winnipeg at a depth of 14 m and 7490 ± 80 BP from the Assiniboine River at 10.7 m indicate both rivers had eroded significant channels and the Red River was incised in the clay plain. Vertical aggradation rates are not easily determined for the meandering part of the river because only two sections were dated in detail and other dates represent single determinations from isolated sections with little or no stratigraphic information. At least one sample (BGS-1345) is thought to have originated from a higher level. The data from the Ravenscourt and St. Vital sites show a period of high (2.0 mm/yr) overbank sedimentation from *ca.* 3000 BP (or earlier) to *ca.* 1500 BP, followed by a sharp decline to 0.1 to 0.4 mm/yr in the next 800-1000 years. In the last 430 years the overbank sedimentation rate has increased to 2.4 mm/yr although this is based on a single determination. Rannie *et al.* (1989) showed that the Assiniboine began to flow into the Red via the contemporary La Salle River course upstream of these sites shortly before *ca.* 3000 BP and would have significantly increased the water and sediment discharge of the Red; this would presumably have produced an increase in flood frequency and may account for the relatively higher sedimentation rate. This increase in flow was, however, not large enough to affect overbank sedimentation rates in the straight belt further downstream. This phase terminated sometime before *ca.* 1300 BP (or perhaps as early as 1500 BP?) by which time the junction had moved to its present location, 14 km downstream. The loss of this water and sediment input (and possibly decreased incidence of bankfull or overbank flow) may have produced the drop in sedimentation rates at these sites. This high sedimentation rate, during the last 430 years, is supported by observations of rapid sediment accumulated during the last century (Fig. 16).

FIGURE 16. Layering in ash (*Fraxinus* sp.) in response to high overbank sedimentation in the south end of Winnipeg. Note the trowel for scale.

*Marcottage chez un frêne (*Fraxinus *sp.) en réponse à une forte sédimentation d'inondation dans la partie sud de Winnipeg. La truelle donne l'échelle.*

In the straight belt of the river the sedimentation rate has been markedly different from that of the meander belt. Overbank sedimentation was initially very rapid at 7.4 mm/yr between 5000 and 4600 BP. About 4600 BP the overbank sedimentation rate dropped to 0.1 mm/yr and continued uninterrupted until *ca.* 1400 BP. After 1400 BP the overbank sedimentation rate increased again to 1.1 mm/yr as recorded at Lockport, where approximately 1.6 m of sediment has accumulated in the last 1400 years. The apparent discontinuity in sedimentation rate, in the straight belt, at about 1400-1500 BP coincides with, and may be attributed to, the shift in the Assiniboine location and its greater proximity to that reach.

DISCUSSION

The sediments along the Red River are primarily mixtures of sand, silt and clay with little or no coarse sand or gravel. The generally fine texture of the alluvium reflects the fine grain size of the Lake Agassiz clay plain, which constitutes the bulk of the eroded sediment transported by the river. Due to the fine texture, poor exposure and general lack of diagnostic sedimentary structures, depositional environments are difficult to interpret. Where minor gravel or coarse sand is present it generally occurs in the lower part of the sedimentary sequence, and if present, large unionids also occur near

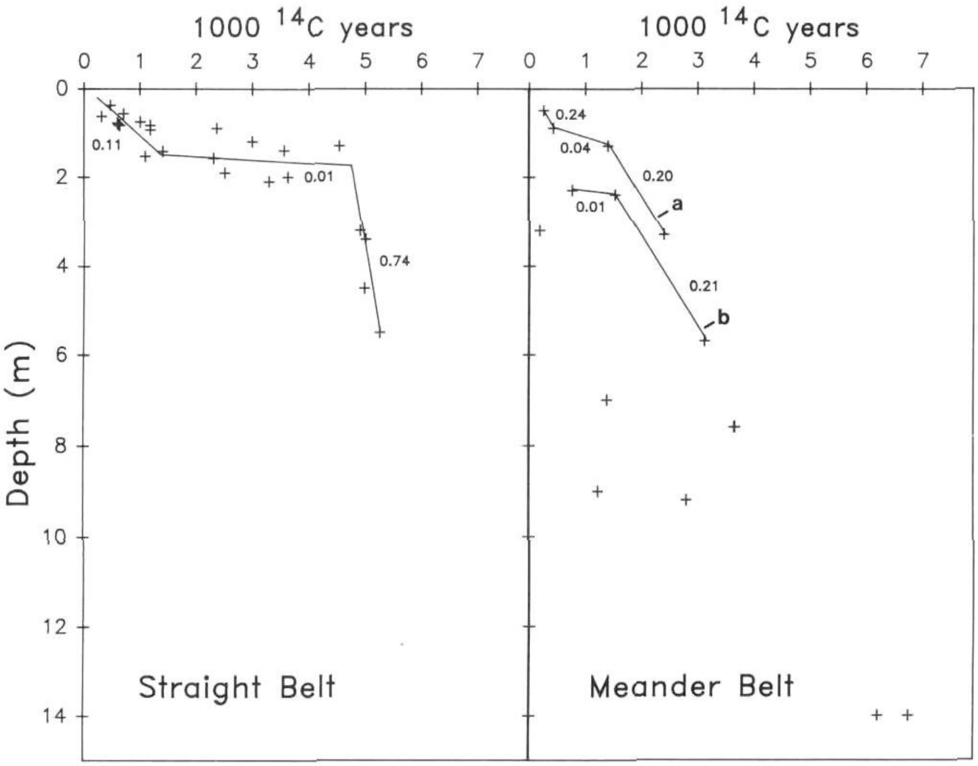


FIGURE 17. Plots of radiocarbon age versus depth for samples listed in Table I for the straight and meandering belts of the Red River. Sedimentation rates in mm/yr are indicated for the straight belt, St. Vital (a) and Ravenscourt (b) sections.

Diagrammes des âges au radiocarbone par rapport à la profondeur pour les échantillons donnés au tableau I dans les tronçons rectilignes et à méandres. Les taux de sédimentation (mm/an) sont donnés pour la partie rectiligne ainsi que pour les tronçons de St. Vital (a) et de Ravenscourt (b).

the base of the sections. The upper part of the stratigraphy comprises poorly laminated sediments with small shells, bones, charcoal layers and buried soil profiles, indicative of overbank deposition.

Between 9200 BP (Teller and Last, 1981) and 8310 ± 180 BP (GSC-1679) (Ringrose, 1975) glacial Lake Agassiz regressed into northern Manitoba subaerially exposing the Red River basin and at least part of the south basin of Lake Winnipeg (Ringrose, 1975). The Red River flowing into the south end of Lake Agassiz followed the regression northward and had excavated the present channel to a depth of 10-15 m by 7500 BP and possibly earlier. The Assiniboine River flowed into the Red River and occupied the same channel at least near the confluence that it occupies today. In its early history, base level for the Red River was determined initially by the level of Lake Agassiz and later by the level of Lake Winnipeg. Upstream in the Winnipeg area base level was controlled by the resistant till and the bedrock sill at Lockport, which became exposed once the river had cut through the Lake Agassiz sediment. On the basis of the present gradient of late Lake Agassiz beaches, approximately 5-8 m of differential uplift is estimated to have occurred over the 37 km distance between the south end of Winnipeg and Lockport (Johnston, 1946; Teller and Thorleifson, 1983). This would suggest that in the early Holocene the valley in the Lockport area may not have been excavated to the depth it is now, a conclusion supported by the much older radiocarbon dates from the Assiniboine River and the area south of the Assiniboine (7490 ± 80 BP, 6750 ± 320 BP; Table I) compared to the oldest radiocarbon dates north of the city (5260 ± 110 BP, 5000 ± 100 BP; Table I).

The history of overbank sedimentation exposed in the sediments of the Red River north of the confluence with the Assiniboine is markedly different from those exposed to the south.

South of the confluence with the Assiniboine the Red River is characterized by a wide flood plain, looping meanders and relatively high sedimentation rates. In the straight belt where there is a relatively narrow floodplain and little evidence of meandering, the sedimentation rates have been variable. Initial high sedimentation rates of 7.4 mm/yr between *ca.* 5300 and 4800 BP occur within the time period in which Rannie *et al.* (1989) speculated that the Assiniboine may briefly have joined the Red and is coincident with the time of gradual change to cooler and moister climate conditions. Work by Teller and Last (1981), Ritchie (1987), Ovenden (1990) and Kuhry *et al.* (1992) indicated that the climate prior to *ca.* 5000 BP was significantly drier than after that time. Lake Manitoba was on occasions completely dry, and prairie grassland vegetation extended much further to the east and northeast during the warm and dry middle Holocene. Cooler and moister conditions at the end of the middle Holocene, coincident with the shift in the Assiniboine to its present location, as suggested by Rannie *et al.* (1989) (their Long Lake-Flea Island Phase dated at *ca.* 4800-5200 BP), lead to bankfull and overbank conditions and high sedimentation rates. Sedimentation rates were initially high, but as the Assiniboine changed course and once again flowed into Lake Manitoba, overbank conditions only rarely occurred. The frequency of overbank conditions would have gradually increased through the late Holocene due to isostatic uplift of the sill at Lockport and the resulting decrease in the grade of the river. This condition may have been offset by increased precipitation and vegetation cover, resulting in decreased erosion after 4500 BP (Kuhry *et al.*, 1992). Also, by 4500 BP when Figure 17 shows a sharp drop in the sedimentation rate on the Red, the Assiniboine was again flowing into Lake Manitoba and no longer contributing to the Red. The increase in sedimentation rate to 1.1 mm/yr at 1400-1500 BP may be attributed to the shift in the Assiniboine drainage from Lake Manitoba back to the Red, or alternatively, a shift northward from the La Salle and consequently greater proximity to the straight belt. The low sedimentation rates along the straight belt of the Red between 4800 and 1500 BP suggests the Assiniboine may have flowed into Lake Manitoba during this time. This conclusion is not supported by sedimentation rates along the meander belt nor by the work of Rannie *et al.* (1989) who concluded that the Assiniboine had joined the Red south of Winnipeg at the present site of the La Salle River about 3000 BP and did not reoccupy the present location until about 1300 BP.

The molluscan record provided insight into the magnitude and duration of highwater stands. The intensity of these floods varied, and while some were spring events with variable currents, others showed evidence of rapid currents and major flooding lasting well into mid-summer. At other times high water with little or no current extended into late summer and sometimes perennial high waters became the norm. It was this latter category that was most significant as it showed evidence of long term high water or backwaters frequently serving as bench marks for floods at other sites.

The two southern exposures provided information on the more recent periods of high waters while the three northern sites provided older records. The molluscan record supports the stratigraphic interpretation with large unionids and molluscs frequently associated with flowing waters commonly being found in coarse sandy layers, while backwater species were associated with finer sediments. When taken alone, the terrestrial species normally associated with damp woodland areas were found in horizons frequently showing soil development.

CONCLUSIONS

Sedimentological and paleontological studies in association with radiocarbon dating indicate:

— the Red River has occupied the present position since the regression of Lake Agassiz between 9200 and 8310 ± 180 BP;

— the Assiniboine and Red rivers had excavated their respective valleys by 7500 BP;

— the Red River is entrenched throughout the study area and sedimentation is by vertical accretion during periods of flooding;

— in the straight belt, vertical accretion of sediments on the floodplain started about 5200 years BP, in response to increased precipitation and a brief eastward excursion of the Assiniboine River. At *ca.* 4800 BP the course of the Assiniboine changed and it flowed north into Lake Manitoba; as a result the overbank sedimentation rate dropped to 0.1 mm/yr until *ca.* 1400 BP;

— *ca.* 3000 BP the Assiniboine River flowed eastward again to where the La Salle River joins the Red River today. This appears to have had little effect on the sedimentation rate in the straight belt farther downstream;

— the northward shift in the position of the Assiniboine River to its present position at *ca.* 1400 BP and its closer proximity to the straight belt lead to an increase in the sedimentation rate to about 1.1 mm/yr;

— the overbank sedimentation rate in the meander belt, though based on limited data, was approximately 2 mm/yr between 3000 and 1400 BP. After 1400 BP the rate fell to between 0.1 and 0.4 mm/yr as the Assiniboine River shifted northward to its present position.

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