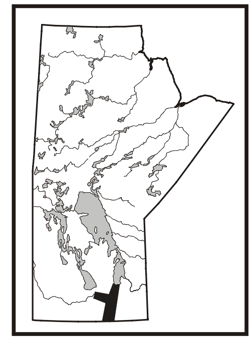
GS-36 PALEOENVIRONMENTAL HISTORY OF THE RED RIVER VALLEY SINCE AD 1463

by E. Nielsen and S. St. George[1]



Nielsen, E. and St. George, S. 2000: Paleoenvironmental history of the Red River valley since AD 1463; *in* Report of Activities 2000; Manitoba Industry, Trade and Mines, Manitoba Geological Survey, p. 220-222.

SUMMARY

The Manitoba Geological Survey and the Geological Survey of Canada have initiated a large, multidisciplinary research program to reconstruct the pre-instrumental flood history of the Red River, and to assess the importance of geological processes that may be increasing the flood hazard. The project is using a variety of geological and biological records to provide annual reconstructions of important hydroclimatic variables over the last several thousand years and provide a proxy record of high-magnitude floods in the Red River valley. The current tree-ring record was collected over a 100 km transect along the Red River and extends for 536 years from AD 1463 to 1999. This record contains anatomical signatures caused by Red River floods in 1950, 1852, 1826, 1811, 1778, 1747 and 1532. Complementary isotopic, chemical and ringwidth records will be developed to evaluate the relationship between climatic conditions within the Red River drainage basin and the flood record of the Red River.

INTRODUCTION

Flooding of the Red River is a significant recurring natural hazard in southern Manitoba. About 70 per cent of Manitoba's 1.1 million citizens live in the Red River valley, making the province particularly vulnerable to social and economic disruption during widespread flooding. During the so-called 'flood of the century' in 1997, costs for flood fighting and recovery in Manitoba were estimated at $500 million and 28 000 people were evacuated from high flood-risk areas. Without a series of measures protecting Winnipeg, losses due to flooding could have reached $5 to 7 billion.

Instrumental flood records for the Red River begin in 1912 but have been extended using historical records to cover most of the 19th century. In response to the 1997 Red River flood, the Manitoba Geological Survey (MGS) and the Geological Survey of Canada (GSC) have initiated a large, multidisciplinary research program to reconstruct the pre-instrumental flood history of the Red River, and to assess the importance of geological processes that may be increasing the flood hazard. A paleoflood record will increase the understanding of the recurrence interval of extreme floods (those having a magnitude equal to or larger than the flood of 1826). This record will aid decision-making about, for example, whether the capacity of the Red River floodway needs to be increased. A variety of proxy flood records will be developed from the analysis of Lake Winnipeg cores by L.H. Thorleifson (GSC–Ottawa) and M. Lewis (GSC–Atlantic), of Red River alluvium by G. Brooks (GSC–Ottawa) and of tree rings by S. St. George (GSC–Winnipeg) and E. Nielsen (MGS). These data will provide the primary information for determining how the frequency and magnitude of Red River floods have responded to long-term changes in climatological and environmental conditions over the past several centuries.

The tree-ring component of the project aims to:

1) provide annual reconstructions of important hydroclimatic variables within the Red River valley over the last 350–400 years;
2) provide a proxy record of high-magnitude floods of the Red River; and
3) place the flood of 1826 within a context of approximately 500 years.

SAMPLE COLLECTION

Since fall 1999, tree-ring samples were collected from 12 live oak sites along the Red River to supplement the six sites sampled previously (Table GS-36-1). Mild winter conditions in 1999 allowed sampling to continue until late December. The collection of subfossil oaks preserved in the alluvial sediment of the Red River continued but was limited by high water levels.

Table GS-36-1. Locations and characteristics of bur oak tree-ring sample sites.

Site	Type	No. of trees	Span
Birds Hill Park	Living		NA
Hyland Park	Living		NA
Kildonan Park	Living		NA
Winnipeg	Living	20	1822-1994
	Historical	14	1644-1872
Assiniboine Park	Living		NA
Bruce Park	Living		NA
Monson Park	Living		NA
Barber House	Historical	35	1648-1864
St. Vital Park	Living	12	1830-1998
St. Norbert	Living	10	1855-1998
LaBarriere Park	Living	11	1892-1998
Shay	Living	14	1907-1999
Rat River House	Historical	6	1659-1859
Ste. Agathe	Living	11	1866-1998
Parker Farm	Living	12	1884-1998
Morris	Living	3	1874-1988
Horseshoe Lake	Living	15	1907-1999
St. Jean Baptiste	Living	10	1883-1997
Remus Farm	Living	10	1879-1998
Marais River	Living	11	1850-1998
Fort Dufferin	Living	9	1866-1997
	Historical	2	1723-1872
Red River alluvium	Subfossil	25	1463-1997
NA, not available			

ANALYSIS

Anatomical Flood Signatures

Dendrochronological analysis of bur oak (*Quercus macrocarpa*) growing along the Red River has developed a continuous tree-ring record that extends for 536 years from AD 1463 to 1999. Two hundred

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and thirty tree-ring samples were taken from living trees, historical buildings and alluvial deposits in the Canadian portion of the Red River valley. The sampling locations extend more than 100 km along the Red River from Emerson to Birds Hill Provincial Park. The collection of samples from historic buildings and living trees maintains good sample depth back to 1650, but the sample depth from 1463 to 1650 is relatively poor, consisting of a limited number of subfossil logs.

Detailed examination of the specimens has revealed that thirteen trees from four sites along the river contain isolated annual rings with distinctive anatomical anomalies (Fig. GS-36-1; St. George and Nielsen, 2000). These anomalies are characterized by a marked reduction in the size of earlywood vessels for the rings formed in the years 1950, 1852, 1826, 1811, 1778, 1747 and 1532. While the rings from 1950 document the influence of the well-known flood of that year, the 1852 and 1826 rings correspond to the occurrence of the second largest and largest, well documented Red River floods, respectively. The anomalous rings are interpreted to be the result of inundation of the trees by floodwaters during the spring and early summer. By extension, the anatomical anomalies in 1811, 1778, 1747 and 1532 are interpreted as signatures of major, and previously unknown, floods of the Red River.

The results so far have yielded extremely encouraging results regarding the identification of past major floods along the Red River. The collection and analysis of tree samples and the identification of rings with anatomical anomalies are ongoing and work will continue into 2000–2001.

Precipitation Reconstruction

The incidence of heavy-precipitation events, thunderstorms and cyclones in north-central North America has been on the increase since 1920 (Changnon and Kunkel, 1995). However, most instrumental records are too short to provide an accurate assessment of the relationship between changing climates and flood frequencies. Studies in western North America have demonstrated that long records of precipitation may be derived from long-lived, climatically sensitive trees growing at forest-prairie ecotones (e.g. Case and MacDonald, 1995; Woodhouse and Meko, 1997). Up to this point, however, dendroclimatic reconstructions in Canada have largely been restricted to alpine sites in British Columbia and western Alberta (Case and MacDonald, 1995; Luckman et al., 1997; Watson and Luckman, in press; St. George and Luckman, in prep.). Although these reconstructions provide high-quality, high-resolution records of past climate, they cannot be considered representative of conditions experienced in the central and eastern Prairies. This is particularly true for reconstructions of precipitation, as drought has been regionally asynchronous in North America during the 20th century (Woodhouse and Overpeck, 1998; MacDonald and Case, 2000). While the relative scarcity of long-lived trees within the Canadian Prairies has been a significant obstacle to developing local dendroclimatic reconstructions, the recovery of well-preserved subfossil trees from the alluvium of prairie rivers holds great promise for developing long, moisture-sensitive, tree-ring chronologies.

Preliminary analysis suggests that bur oak ringwidth is highly correlated with annual precipitation in the Red River valley during the 20th century (St. George and Nielsen, in prep.). Therefore, the oak network should provide an accurate reconstruction of hydrological conditions in southern Manitoba since the middle of the 15th century.

Isotopes

Work has been initiated to determine changes in $\delta^{13}C$, $\delta^{18}O$ and $\delta^{2}H$ isotope levels over the last 350 years for *Quercus macrocarpa* tree-ring specimens collected in Winnipeg. These analyses, which are being

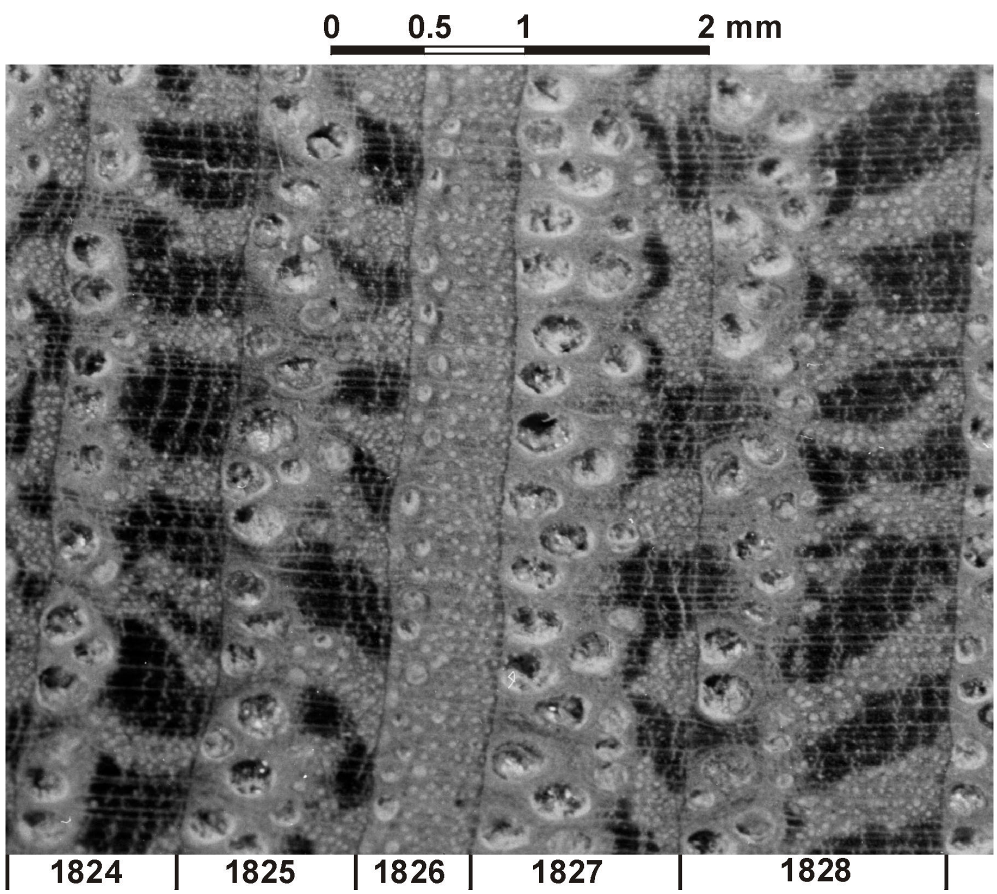

Figure GS-36-1: Flood ring from 1826 in bur oak (Quercus macrocarpa) from central Winnipeg. Vessels appear as light-coloured circles in the left part of each annual ring. The flood ring is distinguished by the reduced area of its earlywood vessels.

done in collaboration with W. Buhay (Department of Geography, University of Winnipeg), will provide a record of climate change independent from that reconstructed from ringwidth. Preliminary results suggest that $\delta^{18}O$ in Red River oaks may be related to variations in summer precipitation.

Chemistry

Analysis of the elemental composition of tree rings is being carried out in conjunction with P. Outridge (GSC-Ottawa), with the aim of identifying chemical flood signatures in tree-rings. These analyses will also attempt to identify anthropogenic influences in the Red River basin. Laser-ablation ICP-MS has previously been widely applied in the geological and materials sciences to retrieve microspatial elemental data from solid materials such as minerals and synthetic products. This technique offers the potential for measurement of more than 50 elements, with sampling spot sizes down to 5 µm diameter.

Our initial investigations have focused on determining whether the technique is sensitive with respect to sampling trace elements in tree rings, and whether trees respond to flood events by laying down rings with significantly perturbed chemistry. Preliminary results suggest that trees from Fort Dufferin contain a dramatic increase in iron levels coincident with the 1997 flood. If the 1997 Red River flood caused this increase, chemical analysis may provide independent confirmation of past flood events in support of the anatomical flood-signature analysis.

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