Paleolimnology of Lake Winnipeg

Introduction and overview

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Lake Winnipeg lies in the centre of North America, straddling the physiographic boundary of the low relief terrain of the Interior Plains and the rugged rock outcrop of the Canadian Shield. The lake’s extensive watershed reaches from the Rocky Mountains 1200 km to the west, to northwestern Ontario 400 km to the east, and encompasses part of the adjacent northern United States. Water in this system drains through Lake Winnipeg (217 m asl) north to Hudson Bay at sea level. Lake Winnipeg extends 430 km from south to north and reaches 100 km in width. It consists of a smaller South Basin separated from a larger North Basin by a constricted passage known as The Narrows. Generally, the bathymetry is flat and shallow with maximum depths ranging from about 11 m in the South Basin to 16 m in the North Basin. The area of the lake, at 24 530 km², positions Lake Winnipeg as the seventh largest lake in North America and the eleventh largest lake in the world (Hutchinson, 1975).

Lake Winnipeg is a geologically young lake. It occupies a region formerly glaciated by the Laurentide Ice Sheet and subsequently inundated by glacial Lake Agassiz, a pro-glacial lake that accompanied the northward retreat of the ice sheet (Teller & Clayton, 1983). During the formation and existence of Lake Winnipeg the region was subjected to the effects of glacial rebound, which caused differential uplift of the lake basin. During the same period, the region was subject to swings in continental climate after deglaciation, ranging from the warmer and drier mid-Holocene climatic optimum to the present cooler and wetter regime.

The objective of the first phase of the Lake Winnipeg Project in 1994 was to obtain a regional geoscientific reconnaissance of the lake. Initially 450 line-km of geophysical data were collected and, subsequently, 18 piston and gravity cores as well as 10 box cores were obtained in strategic geological sites based on interpretation of seismic data. During Phase II in 1996, a further 240 line-km of geophysical data and 22 sediment cores were obtained in selected areas of Lake Winnipeg to enhance the regional understanding and to link to a shoreline geological component of the project, as well as geophysical surveys related to uplift. Phase III in 1997 concentrated on shoreline erosion in the South Basin using nearshore and onshore mapping.

Study of the geological record of glacial Lake Agassiz and Lake Winnipeg will provide insight into paleoenvironmental change in a major hydrological system of central North America. The lake presently serves...
multiple uses: hydroelectric power generation reservoir, commercial fishery, and recreation. Societal concerns regarding shoreline erosion and water quality required a better understanding of the natural history of the lake, in order to put recent lake changes into a long-term perspective. Building on limited previous work in the lake (Kushnir 1979; Brunsink & Graham 1979), the Lake Winnipeg Project was proposed to undertake a regional geological study of the lake basin to help address these concerns by elucidating the post-glacial (thousands of years) and geologically recent (hundreds of years) lake history.

Preliminary results of the first phase of the Project have been presented in a series of workshops and meetings (Manitoba Energy and Mines, 1995; GAC/MAC, 1996), and in a Geological Survey of Canada Open File Report (Todd et al., 1996). Most of the papers in this special issue of Journal of Paleolimnology arise from this first phase and from other closely affiliated studies which contribute complementary understanding of the development of lakes in the Lake Winnipeg Basin. Using seismic reflection surveys, the first paper by Todd, Lewis, Nielsen, Thorleifson, Bezys & Weber outlines two major seismostratigraphic sequences and the bedrock surface morphology. The Agassiz Sequence sediments are well-stratified, drape underlying relief and in some areas are over 100 m thick. A regional unconformity, thought to be formed by wave erosion in waning Lake Agassiz or early Lake Winnipeg, truncates this sequence. The overlying Winnipeg Sequence sediments are faintly stratified to massive and reach about 10 m in thickness.

The following four papers in this issue deal with the physical properties and geochemistry of Lake Winnipeg sediment cores. Moran & Jarrett present data on the physical properties of gravity and piston cores penetrating the Winnipeg and upper Agassiz Sequence sediments. They show methods to construct stratigraphic composite sections from individual cores. Some of the data are used to estimate sediment stress history. Rack, Balcom, MacGregor & Armstrong, using a newly-developed Magnetic Resonance Imaging technique, have imaged the Lake Agassiz to Lake Winnipeg transition for one core. The images reflect changes in local porosity and magnetic susceptibility. Henderson & Last conducted compositional and textural analyses of the Winnipeg Sequence sediment from thirteen cores. Based on mineralogical and elemental composition, they distinguish Precambrian, Paleozoic, and Cretaceous provenance for sediments derived from glacial deposits through shoreline erosion and fluvial transport. Basin-wide trends include up-core decreases in calcium and carbonate minerals, and increases in organic content. A basin-wide change in sedimentation is indicated by an up-core increase in grain size within the last approximately 900 years in the South Basin. Buhay & Betcher provide insight into the basin paleohydrology using oxygen isotopic compositions of organics and pore waters from one of the cores in the North Basin. Their findings are relevant to discussion of the role that Lake Agassiz discharge has played in the Great Lakes, as well as the history of discharge to the North Atlantic Ocean and the Gulf of Mexico.

Three papers address the paleoecology and biological paleolimnology of Lake Winnipeg. Kling interprets up-core changes in phytoplankton and protozoan assemblages as evidence of increasing phosphorous levels, warming summer temperatures and increasing summer nitrogen limitation. Human impact, in the form of eutrophication, is evident from the analyses of the upper 100 cm of the cores. In their study of nine cores, Burbidge & Schröder-Adams show that biologic productivity, indicated by the type of organic material in the sediment, is the main control on thecamoebian taxa in Lake Winnipeg. Thecamoebian assemblages show little change in the North Basin since the retreat of Lake Agassiz, whereas assemblages in the South Basin change up-core from hyposaline to eutrophic conditions. Vance and Telka show that plant and insect macrofossils are sparse in the offshore, especially in the North Basin. A rich assemblage of plant remains representing a nearshore marsh environment were found in the South Basin at the base of the Winnipeg Sequence, however, and dated by AMS at 4040 years BP.

Evidence of water level changes in Lake Winnipeg and the surrounding region is discussed in three papers. Based on radiocarbon dating of marsh facies peat and drowned trees, Nielsen estimates the water level at the south end of Lake Winnipeg has been rising 20 cm per century over the past 300 years. Tackman, Currey, Bills & James present paleoshoreline data from Lake Winnipegos and Dauphin Lake, immediately west of Lake Winnipeg. These shorelines are tilted up to the northeast as a result of glacioisostatic uplift. Lambert, James, and Thorleifson compare theoretical predictions of tilt based on a model of glacial loading and earth rheology with geomorphological data and geodetic and lake-gauge tilt data in Manitoba and adjacent regions of the United States. The analysis indicates that a thinner Laurentide Ice Sheet over the Prairies is more realistic than that assumed by the current glaciation.