GSC Open File 3434

Geology of Lake Winnipeg:

Highlights of the Lake Winnipeg Project 1994 – 1996

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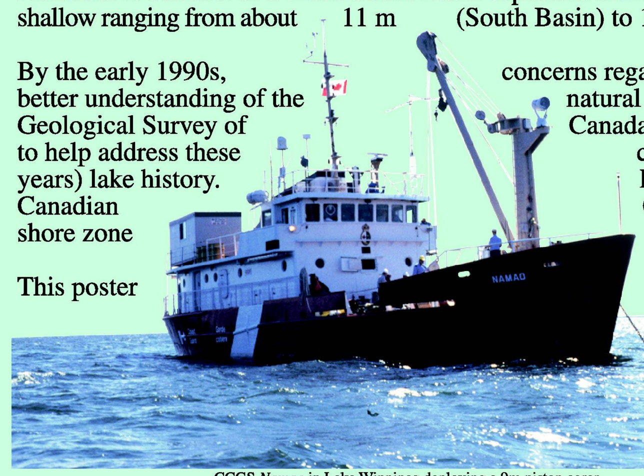
INTRODUCTION

Like glacial Lake Agassiz, its extensive predecessor, Lake Winnipeg overlies the boundary between the low-relief Interior Plains and the southwestern Canadian Shield in southern Manitoba. The lake extends 430 km south to north and reaches 100 km in width. In area, Lake Winnipeg is the seventh largest lake in North America. It consists of a small South Basin separated from a large North Basin by a constricted passage (The Narrows). Generally, the bathymetry is flat and shallow ranging from about 11 m (South Basin) to 16 m (North Basin).

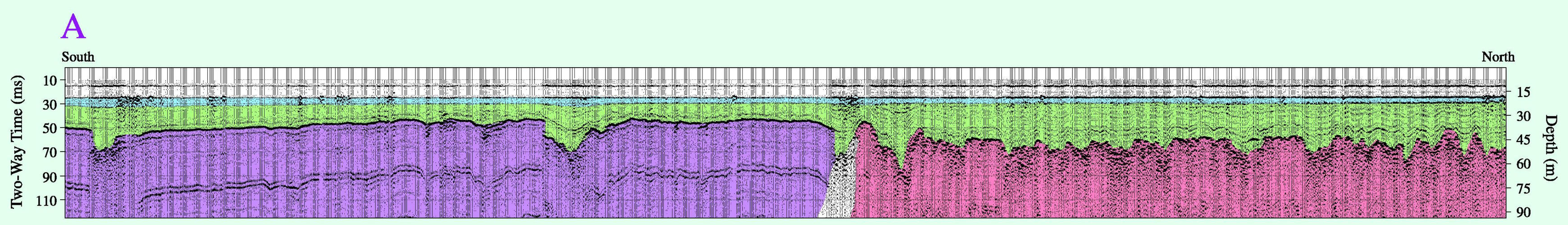
By the early 1990s, concerns regarding shoreline erosion and water quality in Lake Winnipeg drew attention to the urgent need for a better understanding of the natural history of this lake, in order to put recent changes into a long-term perspective. Scientists from the Geological Survey of Canada and Manitoba Energy and Mines proposed the first-ever regional geological study of the lake basin to help address these concerns by elucidating the postglacial (thousands of years) and geologically recent (hundreds of years) lake history. Regional geophysical transects, sediment coring and nearshore surveys were undertaken from the Canadian Coast Guard Ship *Namao* during 1994 and 1996. An aerial reconnaissance and classification of the shore zone was completed in 1994. The 1994 studies are reported by Todd et al. (1996).

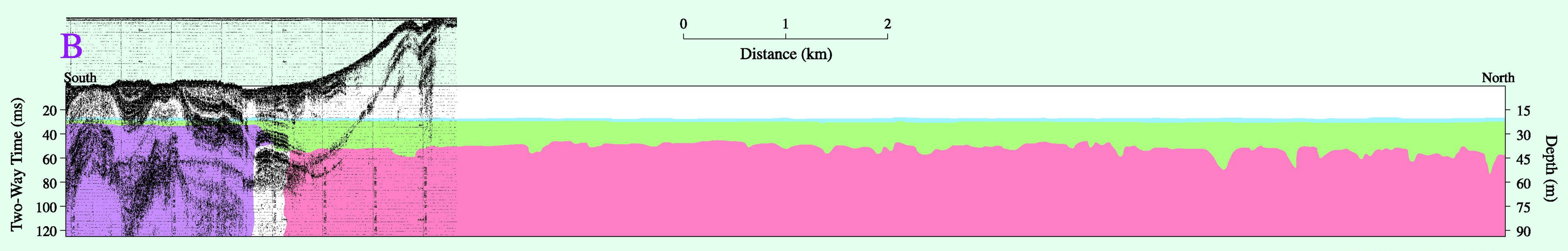
This poster presents highlights of the scientific results of the Lake Winnipeg Project, including recognition of the Precambrian-Paleozoic boundary beneath the lake, of submerged paleobeaches, of ice scouring of the lakefloor, and of extraordinarily thick glacial Lake Agassiz sediment. Insights gained from the project suggest shoreface erosion as a controlling mechanism for shore recession in unlithified clay-rich coastal settings. Finally, the poster presents a history of Lake Winnipeg development for the last 7700 years.



CCGS *Namao* in Lake Winnipeg deploying a 9m piston corer

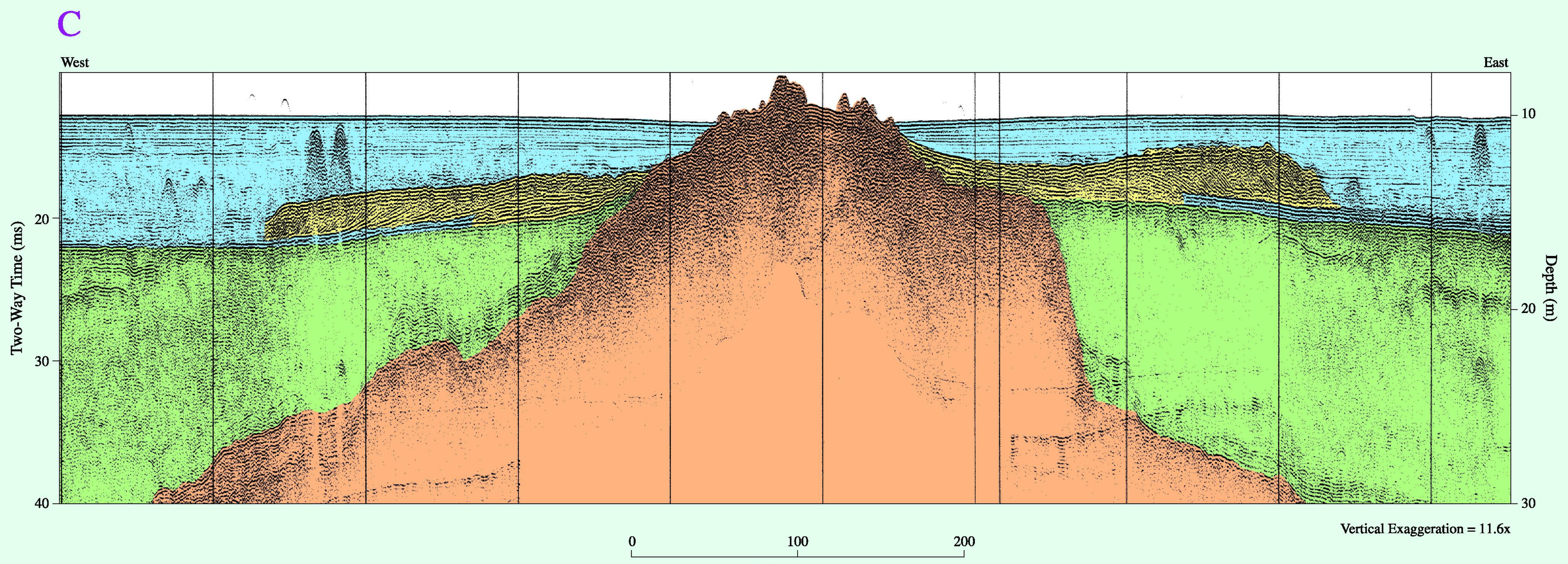
PRECAMBRIAN-PALEOZOIC BOUNDARY



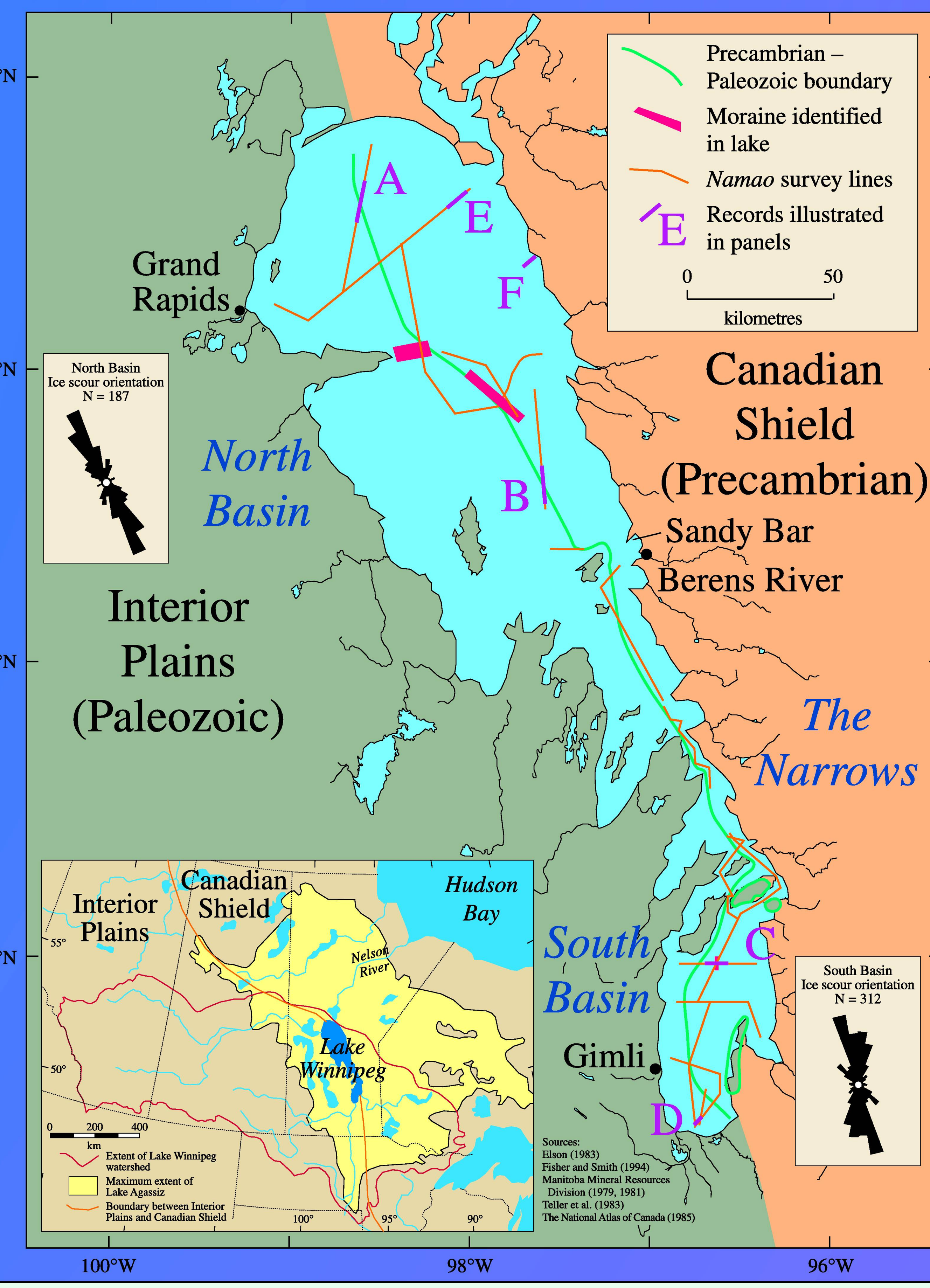


These two sleeve-gun seismic reflection profiles (0.25-2 kHz) from the North Basin (A, B) illustrate the regional seismic stratigraphy. A thin sequence of Lake Winnipeg sediment (blue) unconformably overlies a thick sequence of Lake Agassiz sediment (green). These sediments overlie bedrock. Bedrock exhibiting low relief (purple) is interpreted as Paleozoic sedimentary rock. In contrast, bedrock exhibiting high relief (red) is interpreted as Precambrian metamorphic rock of the Canadian Shield. In places, the contact is marked by a nearby escarpment in the Paleozoic section as illustrated in the lower profile. In previous geological interpretations, the contact was inferred to lie close to the eastern shore of the North Basin. However, the interpretation based on the seismic data places the contact up to about 40 km farther west as shown on the map at right. (Processed records courtesy R.A. Burns and S.E. Pullan, Geological Survey of Canada)

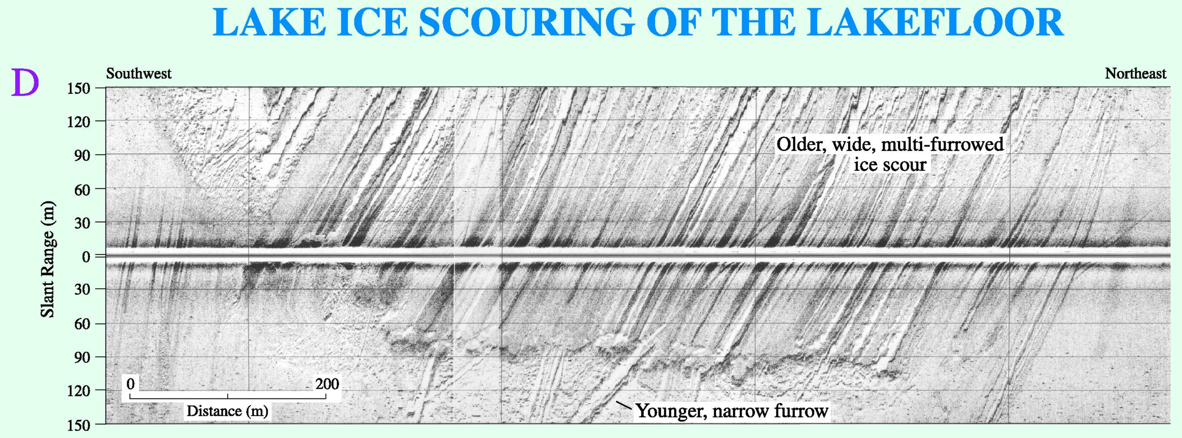
PEARSON REEF PALEOBEACH



This high-resolution seismic reflection profile (2-6 kHz) across Pearson Reef (C) shows the seismic stratigraphy mentioned above. Sediments of Lake Winnipeg (blue) unconformably overlie sediments of Lake Agassiz (green). A presumed unit of till (orange) forming the Pearson Reef Moraine underlies these sediments and rises to outcrop on the lakefloor in the centre of the profile. Flanking the moraine but buried under the Lake Winnipeg sediments are two deposits of fine to medium sand (yellow), as seen in piston cores. The deposits exhibit internal sloping reflections typical of progradational beach structures. These deposits are interpreted as paleobeaches formed when water level was about 13 m lower than at present in an early low-level phase of southern Lake Winnipeg. A mollusc shell from the sand deposit has been radiocarbon-dated at 4820 ± 80 years BP (CAMS 32193, R.E. Vance, Geological Survey of Canada).



LAKE ICE SCOURING OF THE LAKEFLOOR



Lakefloor sediments in Lake Winnipeg exhibit linear to curvilinear furrows. These furrows are about 1 m deep, tens to hundreds of metres wide and up to kilometres in length. Berms of sediment deposited on the furrow sides rise about 0.5 m above the lakefloor. Other attributes of the furrows include cross-cutting relationships, changes in orientation, and abrupt terminations.

This disruption of lakefloor sediments is attributed to scouring by lake ice. The scouring process is initiated by the accumulation, or stacking, of slabs of lake ice into pressure ridges under the influence of wind. The combined weight of the stacked ice slabs depresses pressure ridge keels, in places into the lakefloor. Wide ice sheets encompassing many pressure ridges have wide, multiple-ridged keels which produce wide multi-furrowed ice scours in the lakefloor as shown in the 330 kHz sidescan sonar image (D). In this example (7.3 m water depth), a younger, narrower furrow cross-cuts the older, wide scour.

Furrows are prevalent in the southern South Basin and in northwestern North Basin. It is likely that, in these regions, ice-accumulation conditions, meteorological patterns and water depth combine to favour scouring of the lakefloor. Ice scour orientations are dominantly NNW-SSE (see rose diagrams on central map). This trend is similar to the orientation of prevailing winds in late winter and spring (McKinnon, 1996).

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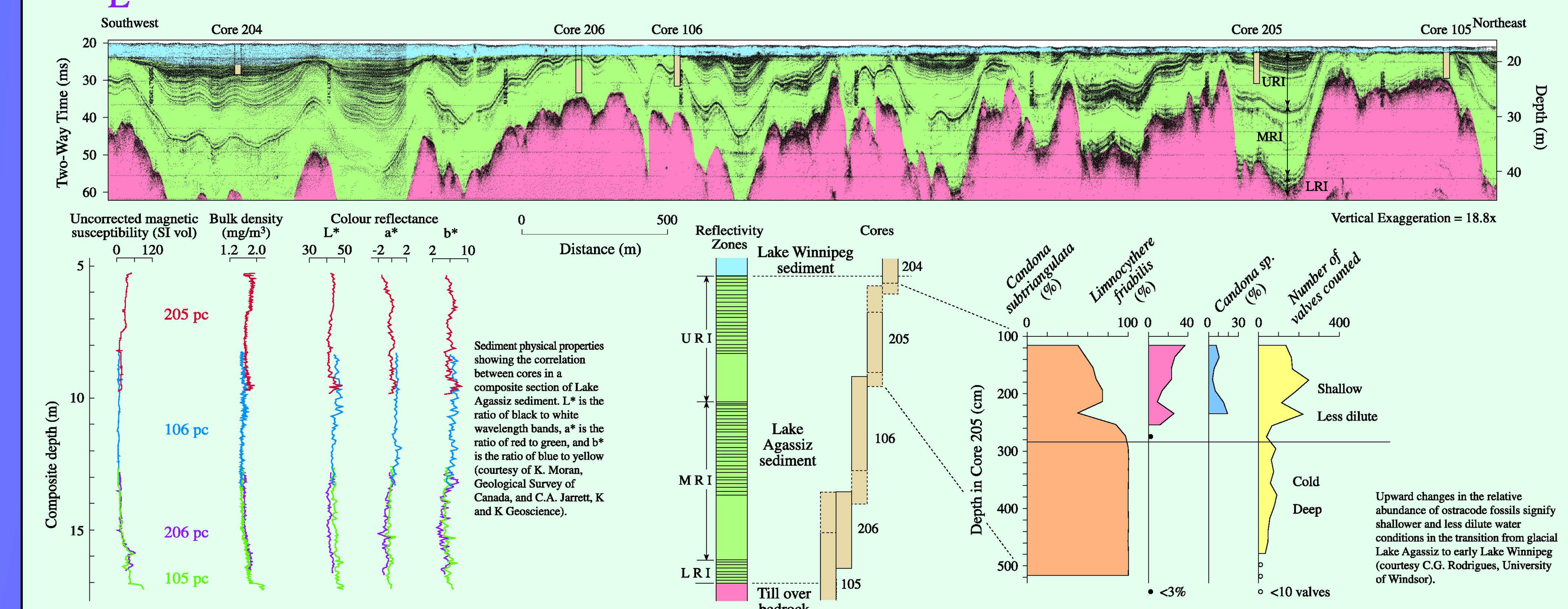
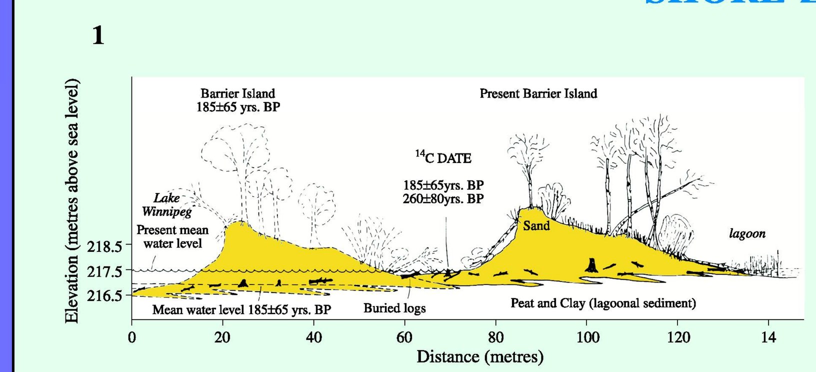
LAKE AGASSIZ SEDIMENTS, COMPOSITE SECTION

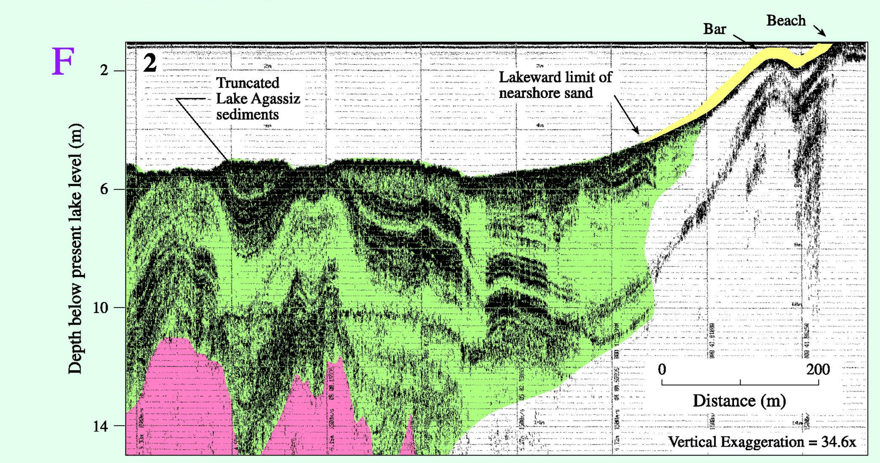


The Lake Winnipeg Project afforded an opportunity to sample the sediments of glacial Lake Agassiz. On the seismic reflection profile from northeastern Lake Winnipeg (E), the Lake Agassiz sediments (green) are draped over an irregular surface (red) of mostly Precambrian bedrock (till, in places), and are truncated by a relatively flat regional unconformity beneath a thin cover of Lake Winnipeg sediment (blue). This configuration made it possible to recover cores from specific stratigraphic intervals below the unconformity by careful core site selection as highlighted on the seismic profile.

The composite diagram (centre, below seismic profile) indicates that these cores collectively sample most of the Lake Agassiz sediment section; the schematic column (green) of reflectivity zones in the Agassiz seismic sequence illustrates the Lower Reflective Interval (LRI), Middle Reflective Interval (MRI) and Upper Reflective Interval (URI) as defined by arrows on the right side of the seismic profile (top). The sampled section represents deposition in glacial Lake Agassiz (mostly silty clay rhythmites) starting with ice margin conditions, continuing through ice retreat, and ending with the onset of early Lake Winnipeg about 7,000 to 8,000 years ago based on preliminary radiocarbon age determinations. Detailed correlation of the cores based on their physical properties is shown at left below the seismic profile. A relative abundance diagram (lower right) illustrates changes in the ostracode assemblage in the transition from glacial Lake Agassiz to early Lake Winnipeg.

SHORE-ZONE PROCESSES



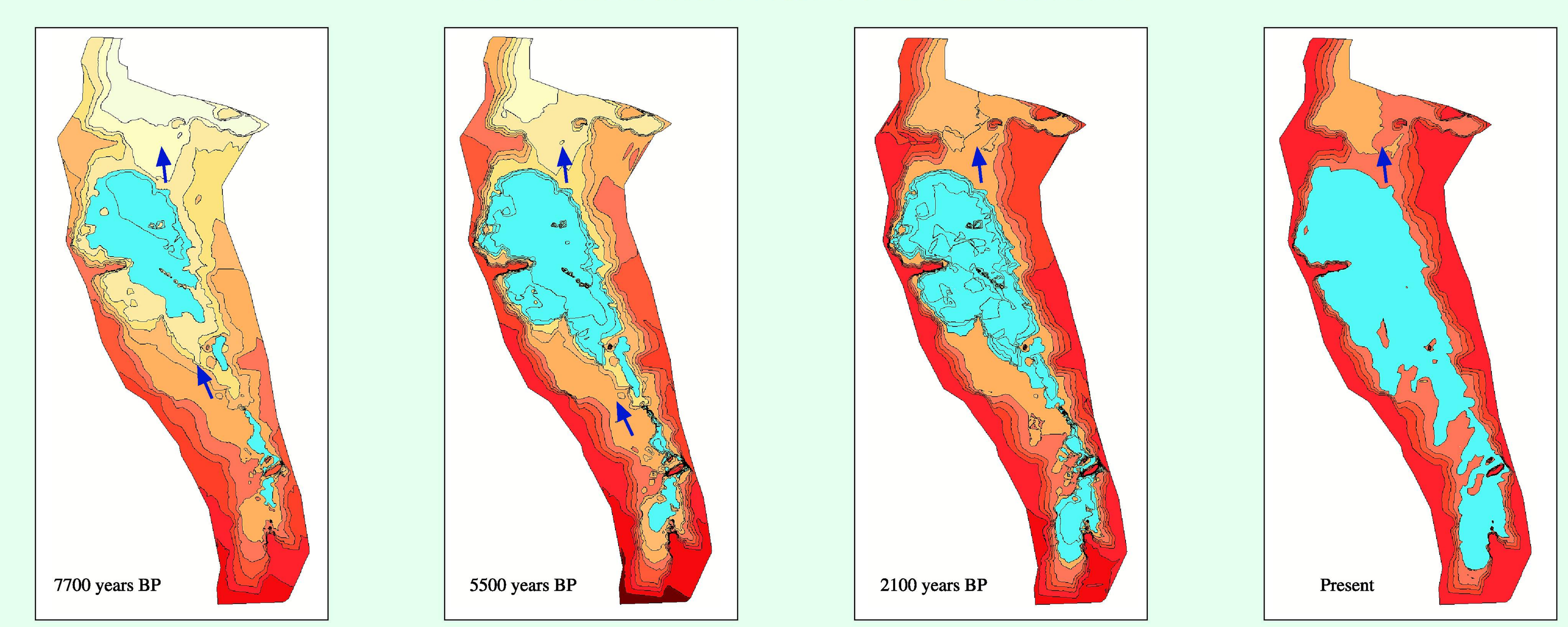


1 This schematic diagram shows the way in which thin barrier sands at the south end of Lake Winnipeg are migrating landward over underlying marsh and lagoon deposits. This represents the leading edge of the southward advance of the lake, in response to isostatic tilting (glacial rebound) of the lake basin (see panel below). Similar shore-zone stratigraphy and coastal retreat processes are found at many sites around the South and North Basins.

2 Shoreline retreat may also be promoted, independent of lake-level change, by erosion of the shoreface profile, which is cut into exposed Lake Agassiz sediments in many places. The bathymetric and subbottom profile (28 kHz) illustrated here, from Spider Islands in the northeastern corner of the North Basin (F), shows the restricted lakeward extent of nearshore sands (yellow) and the irregular nearshore lakebed profile, reflecting varying strength and erodibility of the exposed Lake Agassiz deposits (green).

3 Large spit deposits, such as the Sandy Bar (Disbrowe Point) complex near Berens River, seen in this aerial oblique photograph, reflect longshore transport of beach and nearshore sediments, as well as a complex history of coastal realignment that may hold clues to changes in lake level and coastal processes.

LAKE WINNIPEG PALEOGEOGRAPHY



These four panels represent stages in the growth of Lake Winnipeg following its isolation from the declining phases of glacial Lake Agassiz and the inception of its drainage to the north. Throughout its history the lake has been supplied with inflow from a large catchment comprising the southern prairie provinces, and parts of northwestern Ontario and northern U.S.A. Its outflow is to the north down the Nelson River (arrow). The lake basin is tilting upward under the influence of glacial rebound. The rebound is differential, occurring at a faster rate in the north. It can be inferred that Lake Winnipeg initially formed as a small water body which transgressed southward as its outlet rose more rapidly than other parts of the basin. The illustrated model of lake history and expansion is based on the rate of basin tilting deduced from uplifted glacial lake shorelines, trends in modern lake gauge differences, submerged tree stumps and other evidence of crustal tilt. New estimates of present day uplift rates are being generated by the Geological Survey of Canada from absolute gravity measurements and satellite-referenced elevations at sites ranging from central North America to Hudson Bay.

For most of the Lake Winnipeg basin, the changes in relative elevation have been tens of metres ranging up to 50 m in the south. An independent southern and central Lake Winnipeg were first impounded behind local sills (see panels for 7700 and 5500 years). These lakes drained northward (blue arrows) over the sills into northern Lake Winnipeg. By 2100 years BP, northern and southern Lake Winnipeg had coalesced to a common water level. Regional tilting and the concomitant submergence of the South Basin are predicted to continue.

RECOMMENDED CITATION

Todd, B.J., Forbes, D.L., Lewis, C.F.M., Matile, G.L.D., Nielsen, E., and Thorleifson, L.H. 1997: Geology of Lake Winnipeg: highlights of the Lake Winnipeg Project, 1994-1996. Geological Survey of Canada, Open File Report No. 3434, 1 sheet.

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