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SEISMOSTRATIGRAPHY OF WESTERN LAKE ONTARIO, ONTARIO AND NEW YORK: QUATERNARY GEOLOGY AND IMPLICATIONS FOR GROUNDWATER DISCHARGE

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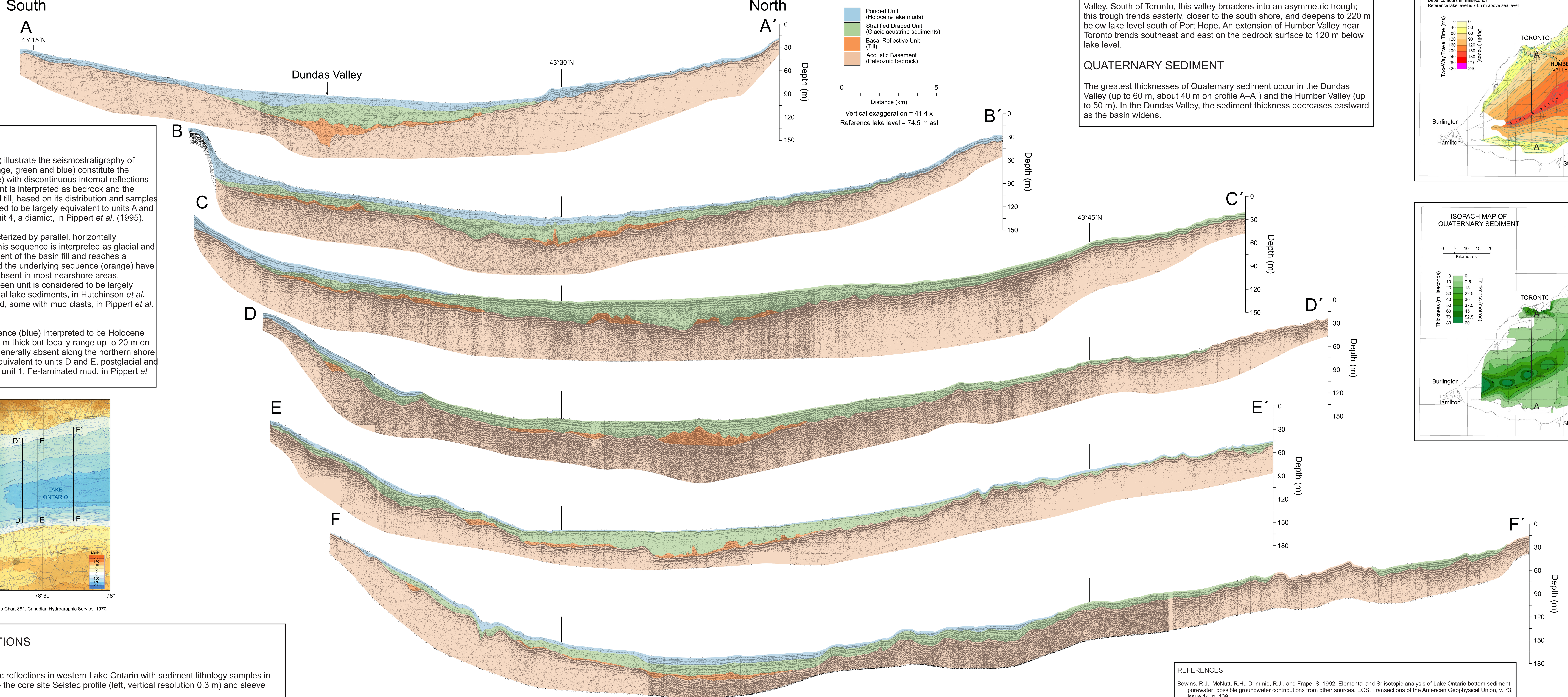
INTRODUCTION

Lake Ontario is located in the St. Lawrence Lowlands physiographic region of southern Canada and northeastern USA. The lake is the last in a chain of five Great Lakes which drain via the St. Lawrence River to the Atlantic Ocean. The long axis of Lake Ontario is oriented east–west. The lake basin is eroded into Lower Ordovician shale and carbonate strata which dip gently southward (Sanford and Baer, 1981; Sanford, 1995); it is partly filled with Quaternary glacial and lacustrine sediments. Western Lake Ontario is surrounded by highlands; the Oak Ridges Moraine rises almost 300 m above the lake to the north, and the Niagara Escarpment rises between 110 and 230 m above the lake to the south and west (see location map above).

In 1992, about 2000 km of sleeve gun and Seistec (boomer) high-resolution seismic reflection profiles were acquired in western Lake Ontario on a 5 km (E–W) by 10 km (N–S) grid (as shown in maps below and at right). As well, six 12 to 15 m-long piston cores were collected (Lewis *et al*., 1992). Additional seismic profiles and piston cores were acquired in 1993 and 1994. The major elements of the sedimentary architecture as seen in selected N–S sleeve gun profiles (A to F) and a core (2) are presented in this poster with implications for groundwater discharge to the lake.

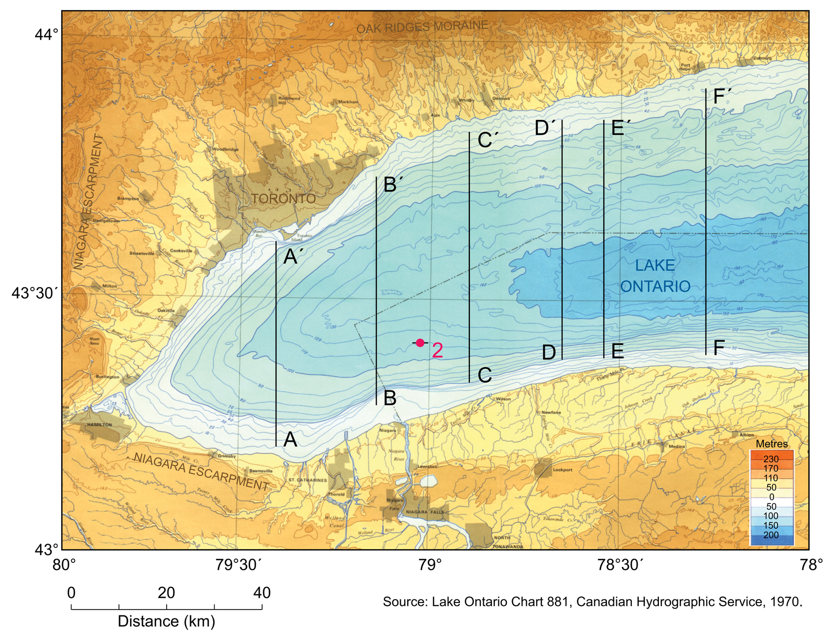


SEISMIC PROFILES

Six seismic profiles oriented south–north (A–F at right) illustrate the seismostratigraphy of western Lake Ontario. Three seismic sequences (orange, green and blue) constitute the Quaternary section. In places, a reflective unit (orange) with discontinuous internal reflections overlies acoustic basement (brown). Acoustic basement is interpreted as bedrock and the reflective unit (orange) as a widespread regional basal till, based on its distribution and samples recovered in piston cores. The orange unit is considered to be largely equivalent to units A and B, subglacial tills, in Hutchinson *et al*. (1993) and to unit 4, a diamict, in Pippert *et al*. (1995).

Overlying the till is a seismic sequence (green) characterized by parallel, horizontally continuous reflections which mimic underlying relief; this sequence is interpreted as glacial and glaciolacustrine sediments and constitutes ninety percent of the basin fill and reaches a maximum thickness of about 50 m. This sequence and the underlying sequence (orange) have been erosionally thinned on the basin flanks and are absent in most nearshore areas, especially along the northern shore of the lake. The green unit is considered to be largely equivalent to unit C, laminated proglacial and periglacial lake sediments, in Hutchinson *et al*. (1993), and to units 2 and 3, laminated to massive mud, some with mud clasts, in Pippert *et al*. (1995).

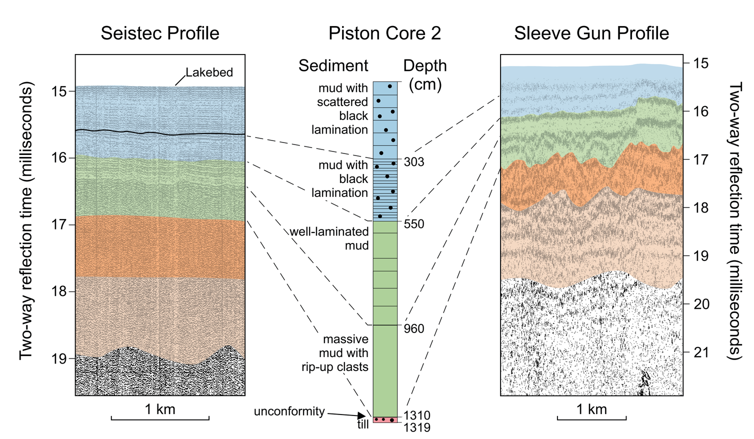
Overlying the glacial sediments is a thin seismic sequence (blue) interpreted to be Holocene lake muds. These sediments are generally less than 7 m thick but locally range up to 20 m on the western and southern flanks of the basin. Mud is generally absent along the northern shore of the lake. The blue unit is considered to be largely equivalent to units D and E, postglacial and modern sediments, in Hutchinson *et al*. (1993), and to unit 1, Fe-laminated mud, in Pippert *et al*. (1995).



Source: Lake Ontario Chart 881, Canadian Hydrographic Service, 1970.

CORRELATION OF SEISMIC REFLECTIONS WITH SEDIMENTS

The diagram at left illustrates the correlation of seismic reflections in western Lake Ontario with sediment lithology samples in piston core 2 (see location map above). Illustrated are the core site Seistec profile (left, vertical resolution 0.3 m) and sleeve gun profile (right, vertical resolution 1–3 m).



From the lake bed to a depth of 550 cm in the piston core, Holocene lake muds (Mud with black laminations) correlate with the blue seismic sequence. From 550 to 1310 cm, late glacial and periglacial well-laminated to massive muds and sands correlate with the green seismic sequence. At the base of the piston core, 9 cm of stiff, dark gray, sandy, pebbly diamict was obtained; this material resembles the Newmarket Till in Ontario (D.R. Sharpe and T.A. Brennand, pers. comm., 2005) and correlates with the orange seismic sequence. The upper contact of this sequence is a regional unconformity; over 7 m of the overlying green sequence have been removed at site 2 compared with other core sites in western Lake Ontario.

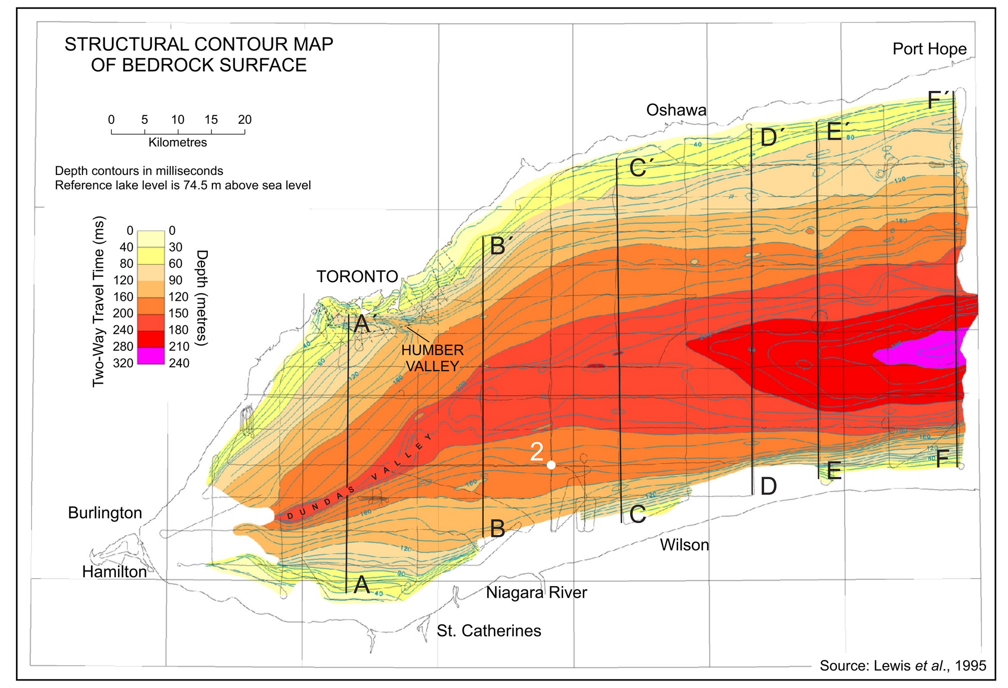
Sand-sized sediment commonly occurs at the base of the muddy sediment units above unconformities. The coarser zones may provide pathways for the movement of connate water and groundwater.

BEDROCK SURFACE

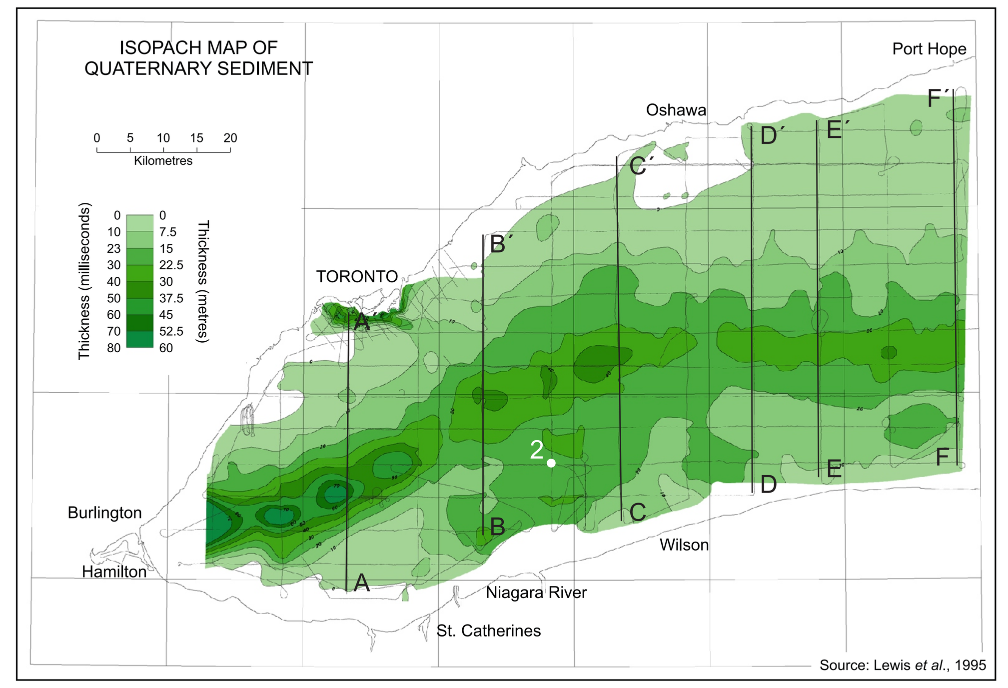
In westernmost Lake Ontario, the Paleozoic bedrock surface slopes to an east-northeast trending bedrock valley. The valley floor, 2–3 km wide, is about 170 m below lake level and is an extension of the onshore Dundas Valley. South of Toronto, this valley broadens into an asymmetric trough; this trough trends easterly, closer to the south shore, and deepens to 220 m below lake level south of Port Hope. An extension of Humber Valley near Toronto trends southeast and east on the bedrock surface to 120 m below lake level.

QUATERNARY SEDIMENT

The greatest thicknesses of Quaternary sediment occur in the Dundas Valley (up to 60 m, about 40 m on profile A–A´) and the Humber Valley (up to 50 m). In the Dundas Valley, the sediment thickness decreases eastward as the basin widens.



Source: Lewis *et al*., 1995



Source: Lewis *et al*., 1995

CONCLUSIONS REGARDING GROUNDWATER DISCHARGE

The seismic profiles presented in this poster demonstrate that the offshore Quaternary sediment sequences in Lake Ontario are rarely continuous with onshore deposits in most areas, especially on the northern flank of the basin. Therefore, groundwater flow to the lake would be likely restricted to shore-zone seepage and discharge via buried valley fill and bedrock fractures and aquifers. On the southern flank of the basin where Quaternary sediments in the lake are thicker and more continuous, there is a greater likelihood of continuity of groundwater pathways between onshore and offshore sediments. Within the sediment fill of the lake basin, groundwater could be conducted along possible coarse sediment zones, for example, those associated with widespread unconformities between seismostratigraphic sequences.

REFERENCES

Bowins, R.J., McNutt, R.H., Drimmie, R.J., and Frape, S. 1992. Elemental and Sr isotopic analysis of Lake Ontario bottom sediment porewater: possible groundwater contributions from other sources. EOS, Transactions of the American Geophysical Union, v. 73, issue 14, p. 139.

Drimmie, R.J., Frape, S.K., and Thomas, R.L. 1994. Lake Ontario and Lake Erie, sediment interstitial water – autochthonous or allochthonous. Abstracts of the Eighth International Conference on Geochronology, Cosmochronology and Isotope Geology, 5–11 June 1994, Berkeley, California, US Geological Survey Circular 1107, p. 85.

Frape, S.K., Drimmie, R.J., Harvey, F.E., Rudolph, D.L., Thomas, R.L., McNutt, R.H., and Bowins, R.J. 1991. Regional groundwater inputs to the lower Great Lakes of eastern North America. American Geophysical Union Fall Meeting, San Francisco, California, 9–13December 1991, EOS, Transactions of the American Geophysical Union, v. 72, issue 44, p. 174.

Hutchinson, D.., Lewis, C.F.M., and Hund, G.E. 1993. Regional stratigraphic framework of surficial sediment and bedrock beneath Lake Ontario. Géographie, physique et Quaternaire, v. 47, p. 337–352.

Lewis, C.F.M., Cameron, G.D.M. and Todd, B.J., 1997a. Seismostratigraphy of western Lake Ontario: Quaternary geology and implications for groundwater discharge. In: GAC/MAC Ottawa'97 Annual Meeting May, 19-21, Ottawa, Ontario. Geological Association of Canada, Ottawa, p. A-89.

Lewis, C.F.M., Cameron, G.D.M., King, E.L., Todd, B.J., and Blasco, S.M. 1995. Structural contour, isopach and feature maps of Quaternary sediments in western Lake Ontario. Atomic Energy Control Board Report INFO-0555, 67 p.

Lewis, C.F.M., Sherin, A.G., Atkinson, A.S., Harmes, R.H., Jodrey, F.D., Nielsen, J.A., Parrott, D.R., and Todd, B.J. 1992. Report of cruise 92–800, CCGS *Griffon*, Lake Ontario. Geological Survey of Canada, Open File Report 2678, 76 p.

Martini, I.P., and Bowlby, J.R. 1991. Geology of the Lake Ontario basin: a review and outlook. Canadian Journal of Fisheries and Aquatic Sciences, v. 48, p. 1502–1516.

Pippert, R.G., Morris, W.A., and Brown, G.R. 1995. Paleomagnetic chronostratigraphy of Holocene sediments, Niagara basin, Lake Ontario, Canada. Journal of Quaternary science, v. 11, p. 217–232.

Sandford, B.V. 1995. Stratigraphy and structure of Paleozoic rocks beneath western Lake Ontario. Atomic Energy Control Board Report INFO-0613, 21 p.

Sandford, B.V., and Baer, A.J. 1981. Geology – southern Ontario, Sheet 30S. Geological Survey of Canada, Map 1335A, scale 1:1 000 000.

Sly, P.G., and Prior, J.W. 1984. Late glacial and postglacial geology in the Lake Ontario basin. Canadian Journal of Earth Sciences, v. 21, p. 802–821.

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