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Seismic sequence boundaries, Lake Simcoe, Ontario

B.J. Todd, C.F.M. Lewis

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ABSTRACT

Seismic reflection data were collected in Lake Simcoe, Ontario in 1992 and 1993. Four regional reflectors were identified in the Lake Simcoe seismic data; in order of increasing depth and age, the seismostratigraphic column comprises Blue, Green, Purple and Red Sequences. The upper bounding reflection of the Blue Sequence is designated the Blue Sequence boundary, and the three deeper sequence boundaries are similarly denoted. These seismic sequences are provided in digital form.

1. INTRODUCTION

Lake Simcoe is the largest lake (726 km^2) within southern Ontario. In 1992 and 1993, the Geological Survey of Canada undertook a marine geophysical survey of Lake Simcoe to better understand the lake bottom and the sub-bottom geology. The seismostratigraphy of Quaternary sediments beneath the lake is given in Todd *et al.* (2003). This Open File describes and provides digital files of the seismic sequence boundaries interpreted from the seismic data collected in 1992 and 1993. These data will be crucial, for example, in compiling a future three-dimensional model of Quaternary sediment thickness in the Lake Simcoe area; such a model will be an important component in the study of regional groundwater flow.

2. STUDY AREA

2.1 Physiographic Setting

Lake Simcoe (219 m asl) is situated in the West St. Lawrence Lowland and lies 40 km southeast of Georgian Bay and 70 km north of the Lake Ontario shoreline at Toronto (Fig. 1). The lake extends 45 km both west to east and south to north; it drains northward to Georgian Bay (176 m asl) via Lake Couchiching and the Severn River. Lake Simcoe is surrounded by clay plain and sand plain of glacial Lake Algonquin (Chapman and Putnam, 1984). The Lake Simcoe drainage basin consists of a limestone plain with small scarps covered by thin till and drumlins in its eastern section; thicker glacial deposits dominate its western section.

2.2 Lake Simcoe bathymetry

Lake Simcoe has a smooth, regular lakefloor and contains few islands (Fig. 2) (Canadian Hydrographic Service, 1987). Most of Lake Simcoe is 5-9 m (16-30 feet) in depth but deepens to over 30 m (100 feet) to the west. Two prominent bays on Lake Simcoe were surveyed during this study: Kempenfelt Bay is a deep (>35 m) northeast-southwest trending bay on the west shore of the lake and Cook's Bay (~9 m deep) extends north-south on the south side of the lake (Fig. 2). Lake Simcoe chart datum is 218.7 m (717.5 feet) above Mean Sea Level (Canadian Hydrographic Service, 1987).

2.3 Marine geophysical surveys

A detailed description of the Lake Simcoe marine geophysical surveys is given in Todd *et al.* (2003); a summary is provided here.

The marine geophysical surveys were conducted in 1992 and 1993 aboard the MV *J. Ross Mackay*, a 12 m, 14,000 kg aluminum-hulled research vessel. Its draft of 0.75 m makes the vessel an ideal platform from which to conduct geophysical surveys in shallow inland waters. A system of deployable booms was constructed to enable the simultaneous towing of a suite of geophysical instruments. Electronic navigation used throughout the survey was the satellite-based Global Positioning System (GPS). At the time of the surveys, the GPS obtained position fixes at a rate of one per second. Accurate positioning was confirmed during the course of the survey by the successful reoccupation of survey tracks over distinct geological features and over identifiable bottom features visible through the water column from the lake surface. Estimated positional accuracy of the Lake Simcoe GPS data is 2 to 10 m.

In September of 1992, the MV *J. Ross Mackay* was used to complete a reconnaissance geophysical survey of Lake Simcoe (Fig. 2). One set of survey lines ran east to west across the lake from the mouth of the Trent Canal to the city of Barrie. Another set of survey lines ran south to north from Cook's Bay to the town of Orillia. The instruments deployed in 1992 included a Seistec IKB seismic reflection system, an air gun seismic reflection system, a sidescan sonar and an RTT 1000 sub-bottom profiler. The profiles obtained in 1992 enabled informed decisions to be made on the design for a more extensive marine geophysical survey in 1993.

In May and June of 1993, the MV *J. Ross Mackay* was back in Lake Simcoe for the crew to undertake a detailed, grid survey pattern (Fig. 3). The instruments deployed in 1993 included a Seistec IKB seismic reflection system, an air gun seismic reflection system, a sidescan sonar and a marine magnetometer. In the main body of the lake, north-south and east-west oriented lines, spaced approximately 4 kilometres apart, were planned based on the requirement for complete coverage of the lake and the extent of navigable waters. Cook's Bay and Kempenfelt Bay provided a more challenging survey environment because they are long and narrow bodies of water. Both bays were surveyed with a zigzag line pattern, with a considerable line coverage accumulated in Kempenfelt Bay.

3. SEISMOSTRATIGRAPHIC SETTING

3.1 Seismostratigraphic principles

The seismostratigraphic terms employed in this report are briefly described here. The terms "reflection" and "reflector" are applied in the following way: "reflections" are acoustic phenomena recorded in the seismic reflection profiles, and "reflectors" are the physical property changes (acoustic impedance contrasts) within the sediment column which cause the reflections. Reflectors are physical boundaries within the sediments which are thought to be geologically meaningful; they are inferred or interpreted from the acoustic reflections. Reflection amplitude is controlled by the magnitude of acoustic impedance contrast across a boundary. A high amplitude reflection appears as an intense (dark-toned) mark on a seismic record; conversely, a low amplitude reflection exhibits a less intense (light-toned) mark. Using geological examples, a high amplitude reflection would result at the boundary of a layer of mud overlying rock and a low amplitude reflection would result at the boundary between two layers of mud having slightly different physical properties. "Acoustic basement" refers to the deepest more-or-less horizontally continuous seismic reflection resolved on the seismic record. Finally, where reflections in a zone on a seismic profile are absent, the zone is referred to as "acoustically transparent".

3.2 Lake Simcoe seismostratigraphy

The Lake Simcoe seismic reflection profiles were interpreted following the seismostratigraphic principles outlined by Mitchum, Vail and Sangree (1977) and Mitchum, Vail and Thompson (1977) and as applied to large lakes by Moore *et al*. (1994) and Scholz (2001). Reflections are assumed to be conformable with sedimentary bedding and are chronostratigraphic horizons which can be traced from place to place and utilized for correlation between sites within depositional basins. Reflections which are regional in extent and which truncate underlying reflections define the boundaries of packages or "sequences" of sediment. Four such regional reflectors were identified in the Lake Simcoe seismic data. Commonly, sediment sequences between reflecting boundaries are named for their upper bounding reflector (Moore *et al*., 1994). In this report, we use the colour designations illustrated in Figure 4; in order of increasing depth and age, the seismostratigraphic column comprises Blue, Green, Purple and Red Sequences. The upper bounding reflection of the Blue Sequence is designated the Blue Sequence boundary, and the three deeper sequence boundaries are similarly denoted.

The sequence boundaries for all the profiles in Lake Simcoe were interpreted based on the seismic data, Knudsen 320M subbottom profiles, and associated sidescan sonar records (Todd *et al.*, 2003). An example of an interpreted airgun seismic profile, typical for Lake Simcoe, is shown in Figure 5. In much of Lake Simcoe, the deepest sequence detected is Red Sequence (Z3-RED column in Table 2). (In rare instances, discontinuous reflectors are interpreted beneath the Red Sequence Boundary and are the Z4-RED column in Table 2). The reflection configuration within the sequence is chaotic with some subtle suggestions here and there of coherent reflections. Although Red Sequence sediments are widespread in Lake Simcoe, they were not detected in Kempenfelt and Cook's bays (Fig. 2) due to the thickness of younger, overlying sediments. A striking characteristic of the Red Sequence is the rugged relief of its sequence boundary, with pronounced "peaks" commonly between 10 and 30 m in height (Todd *et al*., 2003). Some of these peaks outcrop to a height of 10 m above the lake floor. The cross-sectional morphology of these peaks and their outcrop orientation as observed in sidescan sonar records suggest that they may be drumlins related to the northeast-southwest oriented drumlin fields mapped on land around Lake Simcoe (Barnett *et al*., 1991). The distribution of the Red Sequence, its reflection configuration and its drumlinized, unconformable surface suggests that it is equivalent to the Newmarket Till mapped south of Lake Simcoe (Barnett *et al*., 1998; Pugin *et al*., 1999a; Pugin *et al*., 1999b; Sharpe *et al*., 2004).

Purple Sequence sediments, which overlie Red Sequence sediments, are widespread in Lake Simcoe and are generally less than 10 m thick but are locally thicker (Z2-PURPLE column in Table 2). These sediments outcrop on the lake floor in eastern and northern Lake Simcoe. The reflection configuration within the sequence is chaotic. The Purple Sequence boundary has peaks ranging from 10-40 m (Todd *et al*., 2003), mimicking the relief of the underlying Red Sequence. These sediments are interpreted, as in Pugin *et al*., 1999b, as coarse-grained glaciofluvial material deposited rapidly on the underlying unconformity.

In marked contrast to the underlying Red and Purple Sequences, the overlying Green Sequence exhibits a distinctive parallel internal reflection configuration (Z1-GREEN column in Table 2). The basal Green Sequence reflections conformably drape the irregular top of the Purple or Red Sequences and the drape becomes more subdued, or flattened, towards the top of the Green Sequence where internal reflections indicate a basin fill seismic facies form (Todd *et al*., in press). Green Sequence sediments extend over all of Lake Simcoe and the basal sediments are rhythmically-laminated clay mud with dropstones (Todd *et al*., 2004). Green Sequence sediments, greater than 30 m thick in places, were probably deposited in glacial Lake Algonquin which is known to have occupied the Lake Simcoe basin during late-glacial time (Deane, 1950; Karrow *et al*., 1975; Karrow, 1989). Truncated reflections of the uppermost Green Sequence sediments indicate a widespread erosional unconformity in shallower areas of the Green Sequence basin, and suggest that the lake fell to a low level (Todd *et al*., in press).

Blue Sequence sediments overlie the Green Sequence boundary (Z0-BLUE column in Table 2). The Blue Sequence internal reflection configuration is parallel, but with a subdued amplitude compared with the Green Sequence (Todd *et al*., in press). Reflections within the Blue Sequence downlap on the Green Sequence boundary. Blue Sequence sediments, up to 8 m thick, are massive to faintly-laminated grey-brown mud deposited during Holocene (post-glacial) time in a sheet drape seismic facies form (lower sediments) changing to basin fill seismic facies form (upper sediments) (Fig. 4).

4. SEISMIC SEQUENCE BOUNDARY DATA

As an example, the interpreted seismic sequence boundaries for line 93-11 are shown in Figure 6. Similar interpretations are provided for all seismic lines in Todd *et al*. (2003). The interpreted seismic sequence boundaries were digitized at closely-spaced geographic positions (approximately 1.3 m horizontally) along the survey lines (Table 1) for a total of 277,138 locations with corresponding depths (measured from the lake surface in milliseconds) to the Blue, Green, Purple and Red Sequence boundaries (Table 2). Geographic positions are given in Universal Transverse Mercator (UTM) Zone 17, North American Datum (NAD) 27, in easting (X, metres) and northing (Y, metres).

All digital seismic sequence boundary data is provided in comma separated variable (CSV) format on the CD-ROM in the subdirectory **Seismic Sequence Boundary Data**. These data can be imported into a text editor or spreadsheet software.

The original paper seismic records and digital seismic data collected in 1992 and 1993 are archived at the Geological Survey of Canada in Ottawa. For information about these data, contact Dr. Susan Pullan at 613-992-3483, Sue.Pullan@NRCan.gc.ca.

5. ACKNOWLEDGEMENTS

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LIST OF REFERENCES

Barnett, P.J., Cowan, W.R., and Henry, A.P. 1991. Quaternary geology of Ontario, southern sheet. Ontario Geological Survey, Map 2556, scale 1:1 000 000.

Barnett, P.J., Sharpe, D.R., Russell, H.A.J., Brennand, T.A., Gorrell, G., Kenny, F., and Pugin, A. 1998. On the origin of the Oak Ridges Moraine. Canadian Journal of Earth Sciences, **35**: 1152-1167.

Canadian Hydrographic Service. 1987. Trent-Severn Waterway, Lakes Simcoe and Couchiching, Chart Number 2028, scales 1:20 000, 1:80 000.

Chapman, L.J., and Putnam, D.F. 1984. The Physiography of southern Ontario. Ontario Geological Survey, Special Volume 2, 270 p.

Deane, R.E. 1950. Pleistocene Geology of the Lake Simcoe District, Ontario. Geological Survey of Canada, Memoir 256, 108 p.

Karrow, P.F., Anderson, T.W., Clarke, A.H., Delorme, L.D., and Sreenivasa, M.R. 1975. Stratigraphy, paleontology and age of Lake Algonquin sediments in southwestern Ontario. Canada. Quaternary Research, **5**: 49-87.

Karrow, P.F., Anderson, T.W., Delorme, L.D., Miller, B.B., and Chapman, L.J.,1995. Late-glacial paleoenvironment of Lake Algonquin sediments near Clarksburg, Ontario. Journal of Paleolimnology, **14**: 297-309.

Mitchum, R.M. Jr., Vail, P.R., and Sangree, J.B. 1977. Seismic stratigraphy and global changes of sea level, part 6: stratigraphic interpretation of seismic reflection patterns in depositional sequences. *In* Seismic stratigraphy - applications to hydrocarbon exploration, *Edited by* Payton, C.E., American Association of Petroleum Geologists, Memoir 26, Tulsa, pp. 117-133.

Mitchum, R.M. Jr., Vail, P.R., and Thompson, S., III. 1977. Seismic stratigraphy and global changes of sea level, part 2: the depositional sequence as a basic unit for stratigraphic analysis. *In* Seismic stratigraphy - applications to hydrocarbon exploration, *Edited by* Payton, C.E., American Association of Petroleum Geologists, Memoir 26, Tulsa, pp. 53-62.

Moore Jr., T.C., Rea, D.K., Mayer, L.A., Lewis, C.F.M., and Dobson, D.W. 1994. Seismic stratigraphy of Lake Huron-Georgian Bay and post-glacial lake level history. Canadian Journal of Earth Sciences, **31**: 1606-1617.

Ontario Geological Survey. 1991. Bedrock geology of Ontario: southern sheet. Ontario Geological Survey, Map 2544, scale 1:1 000 000.

Pugin, A., Pullan, S.E., and Sharpe, D.R., 1999a. Seismic facies and regional architecture of the Oak Ridges Moraine area, southern Ontario. Canadian Journal of Earth Sciences, 36*:* 409-432.

Pugin, A., Pullan, S.E., Burns, R.A., Douma, M., and Good, R.L. 1999b. High-resolution, multichannel, marine seismic surveying using a small airgun. *In* Proceedings, SAGEEP 99, Symposium on the Application of Geophysics to Environmental and Engineering Problems, March 14-18, 1999, Oakland, California, pp. 255-264.

Scholz, C.A. 2001. Applications of seismic sequence stratigraphy in lacustrine basins. *In* Tracking Environmental Change Using Lake Sediments. Volume 1: Basin Analysis, Coring, and Chronological Techniques, *Edited by* Last, W.M., and Smol, J.P., Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 7-22.

Sharpe, D.R., Pugin, A., Pullan, S.E., and Shaw, J. 2004. Regional unconformities and the sedimentary architecture of the Oak Ridges Moraine area, southern. Canadian Journal of Earth Sciences, **41**: 183-198.

Slattery, S.R. 2003. 25. Project Unit 03-021. Subsurface mapping of the Barrie area, central Ontario. *In* Summary of Field Work and Other Activities 2003, Ontario Geological Survey, Open File Report 6120, p. 25-1 to 25-8.

Todd, B.J., and Lewis, C.F.M. 1993. A reconnaissance geophysical survey of the Kawartha Lakes and Lake Simcoe, Ontario. Géographie, Physique et Quaternaire Special Publication, Neotectonics of the Great Lakes Area, **47**: 313-323.

Todd, B.J., Lewis, C.F.M., and Anderson, T.W. 2004. Sedimentology of Quaternary sediments beneath Lake Simcoe, Ontario: results of 1997 and 1998 sampling operations. Geological

Survey of Canada, Open File report 4667, 90 p.

Todd, B.J., Lewis, C.F.M., and Anderson, T.W. In press. Quaternary features beneath Lake Simcoe, Ontario: drumlins, tunnel channels, and records of proglacial to postglacial closed and overflowing lakes. Canadian Journal of Earth Sciences.

Todd, B.J., Hunter, J.A.M., Good, R.L., Burns, R.A., Douma, M., Pullan, S.E. and Lewis, C.F.M. 2003. Seismostratigraphy of Quaternary sediments beneath Lake Simcoe, Ontario: results of 1992 and 1993 expeditions of the MV *J. Ross Mackay*. Geological Survey of Canada, Open File report 3037, 105 p.

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Table 1: Lake Simcoe seismic sequence boundary depth value totals per line

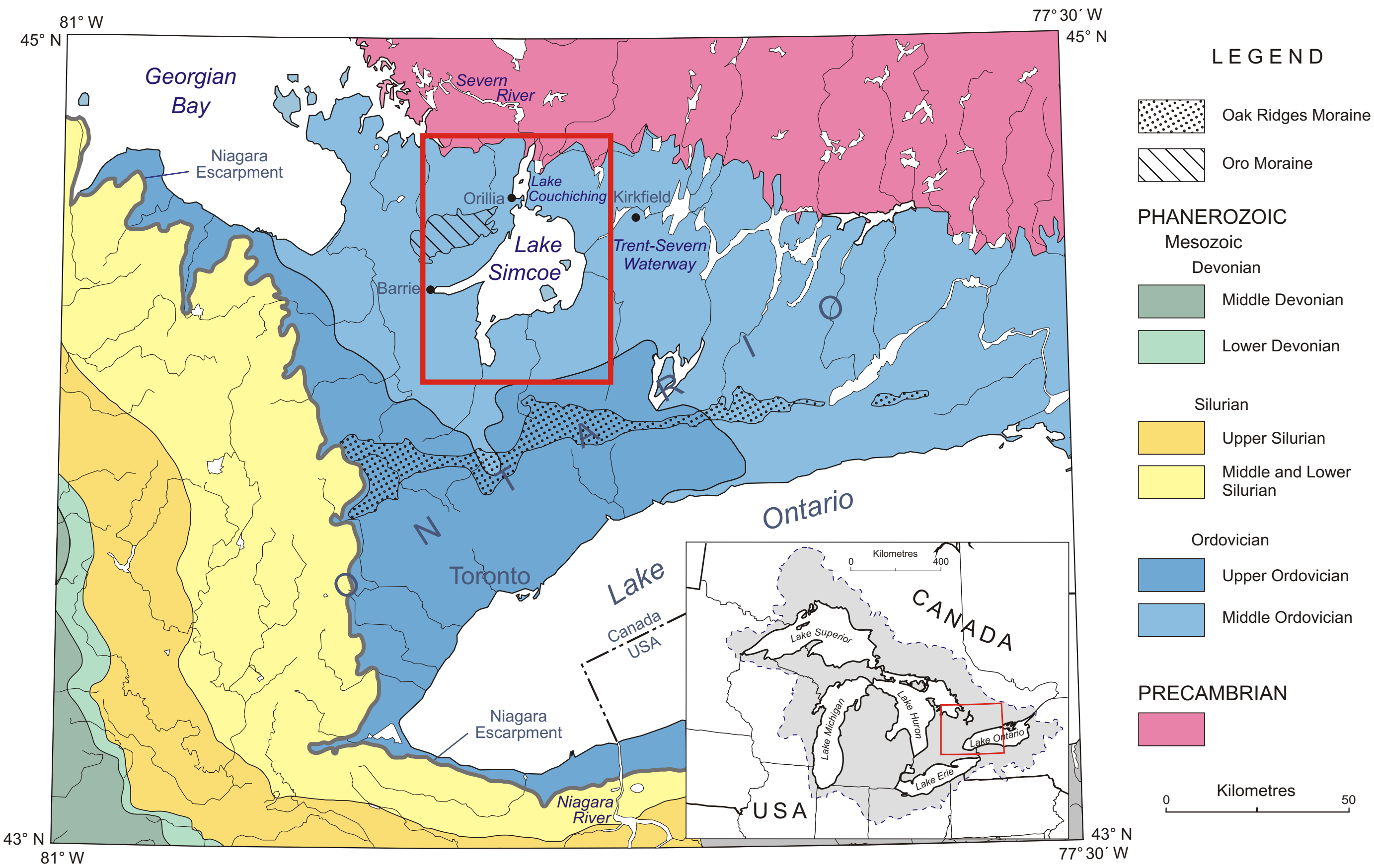
Line Number	Number of Values
92-1	8653
92-2	5209
92-3	12618
92-4	8208
92-5	9827
93-1A	9780
93-1B	3481
93-2	12870
93-3	14400
93-4	14940
93-5	12000
93-6	11580
93-7	2640
93-8A	9810
93-8B	2153
93-9	12240
93-10	15630
93-11	16383
93-12W	7620
93-12E	3210
93-13	9960
93-14A	10290
93-14B	16383
93-15A	15450
93-15B	15420
93-16	16383

Table 2: Example of CSV data file for Lake Simcoe seismic sequence boundary depths

LAKE SIMCOE LINE 93-7						
X	Y	Z0-BLUE	Z1-GREEN	Z2-PURPLE	Z3-RED	Z4-RED
627708.3	4935964	15.76	17.66	29.54	34.78	0
627709.6	4935964	15.76	17.66	29.48	34.77	0
627710.9	4935965	15.76	17.66	29.42	34.75	0

Notes:

1. First row denotes the year (e.g. 1993) and line number (e.g. 7)
2. Second row denotes position in UTM Zone 17, NAD 27 in easting (X, metres) and northing (Y, metres), and depth in milliseconds from the lake surface to the Blue (Z0), Green (Z1), Purple (Z2) and Red (Z3) Sequence boundaries. The column at the right (Z4-RED) denotes reflectors identified within the Red Sequence.
3. Zero values in the Z columns indicate no data.
4. The depths Z0 to Z4 (in milliseconds) are relative to the lake level on the day of the seismic survey. No correction has been applied for lake level variation from the Low Water Datum of 218.7 m above Geodetic Datum.



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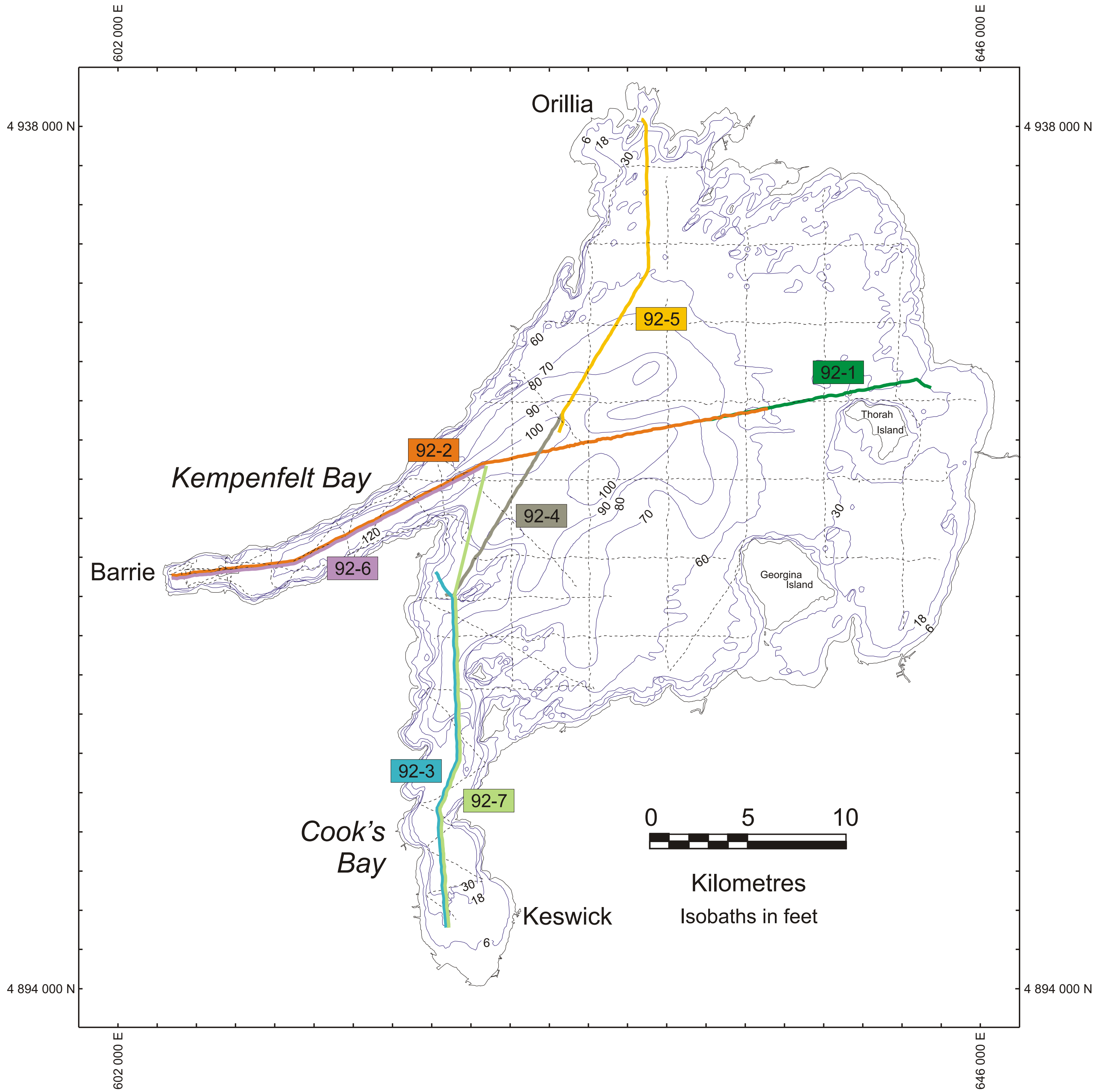


Figure 2. Lake Simcoe 1992 survey lines. Coordinates are UTM Zone 17, NAD 27.

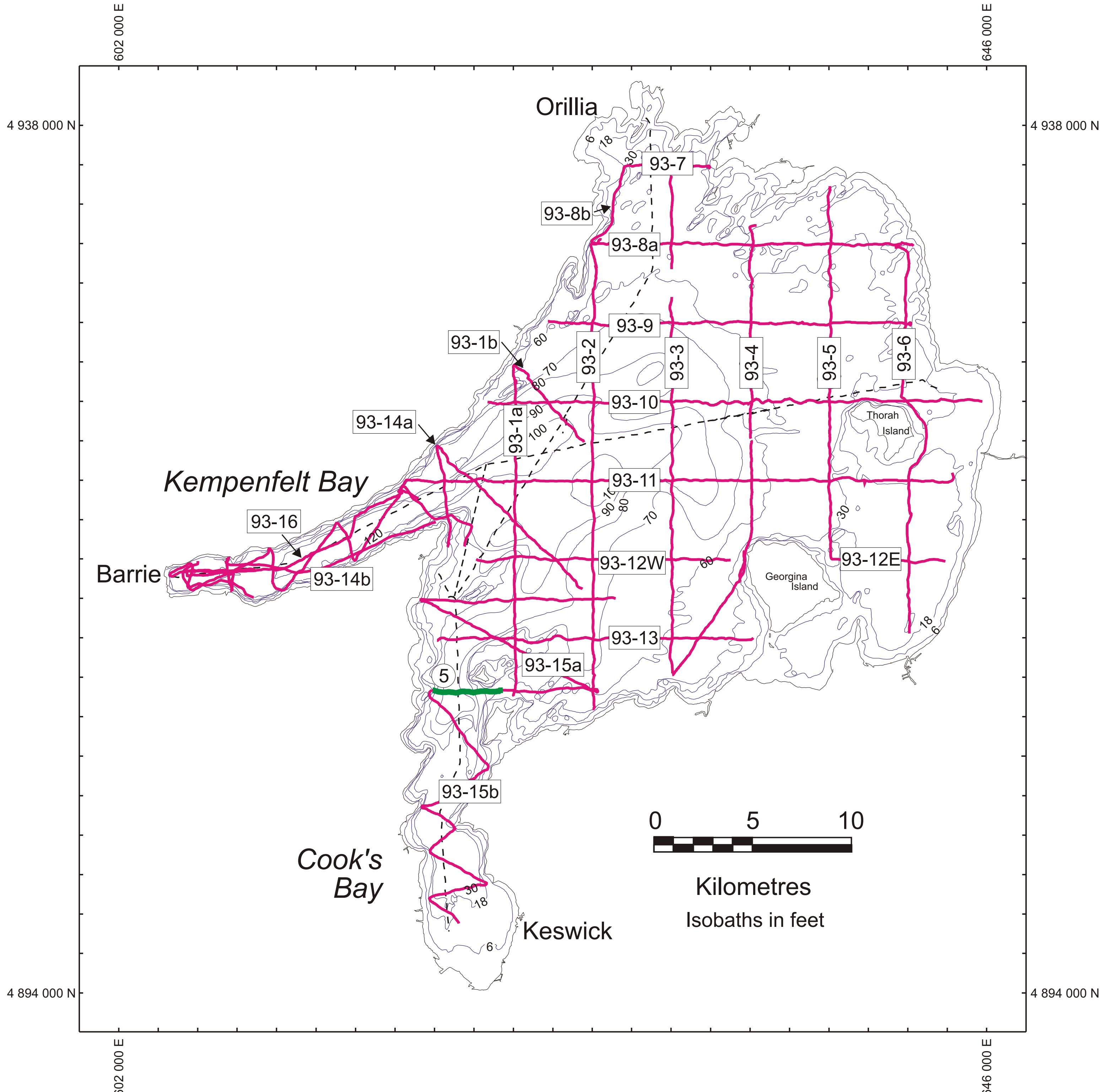
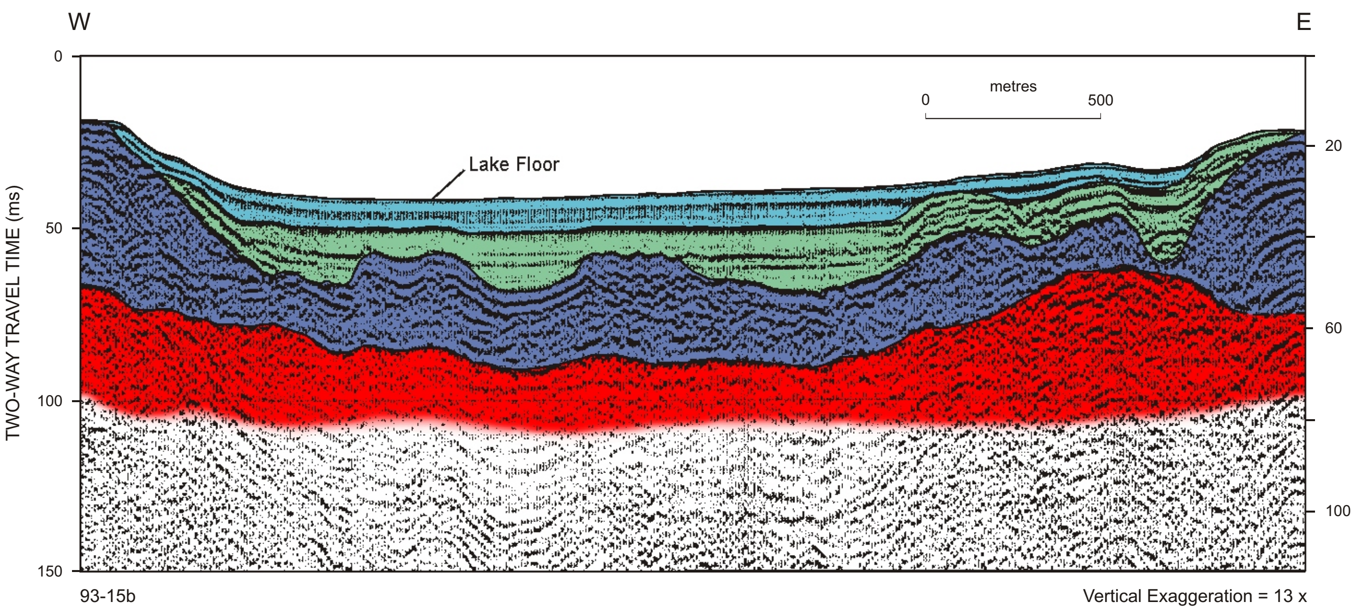


Figure 3. Lake Simcoe 1993 survey lines. The highlighted section of line 93-15b (green) indicates the location of the seismic profile illustrated in Figure 5. Coordinates are UTM Zone 17, NAD 27.

Sequence	Sequence boundary	Reflection configuration	Geological interpretation	Geological correlation
				lake floor
Blue	Blue: low amplitude	Parallel to subparallel, lower amplitude reflections than in Green Sequence; transparent in places	Basal sediments are sheet drape, changing to basin fill in upper sediments	Lake Simcoe sediments
Green	Green: high amplitude	Parallel to subparallel, higher amplitude reflections than in Blue Sequence; in places tangential oblique progradational reflections	Mainly sheet drape (relatively uniform rate of deposition of strata over underlying topography); upper sediments display basin fill in deepest basin	glacial lake sediments (Lake Algonquin)
Purple	Purple: high amplitude	Generally chaotic, with local evidence of internal reflections; high-relief upper boundary	Variable, high energy setting	tunnel channel sediments
			Unconformity	
Red	Red: high amplitude	Chaotic; high-relief upper boundary	Variable, high energy setting	glacial sediments (Newmarket Till)

Figure 4. Lake Simcoe seismostratigraphic sequences, sequence boundaries, reflection configuration, geological interpretation and geological correlation.



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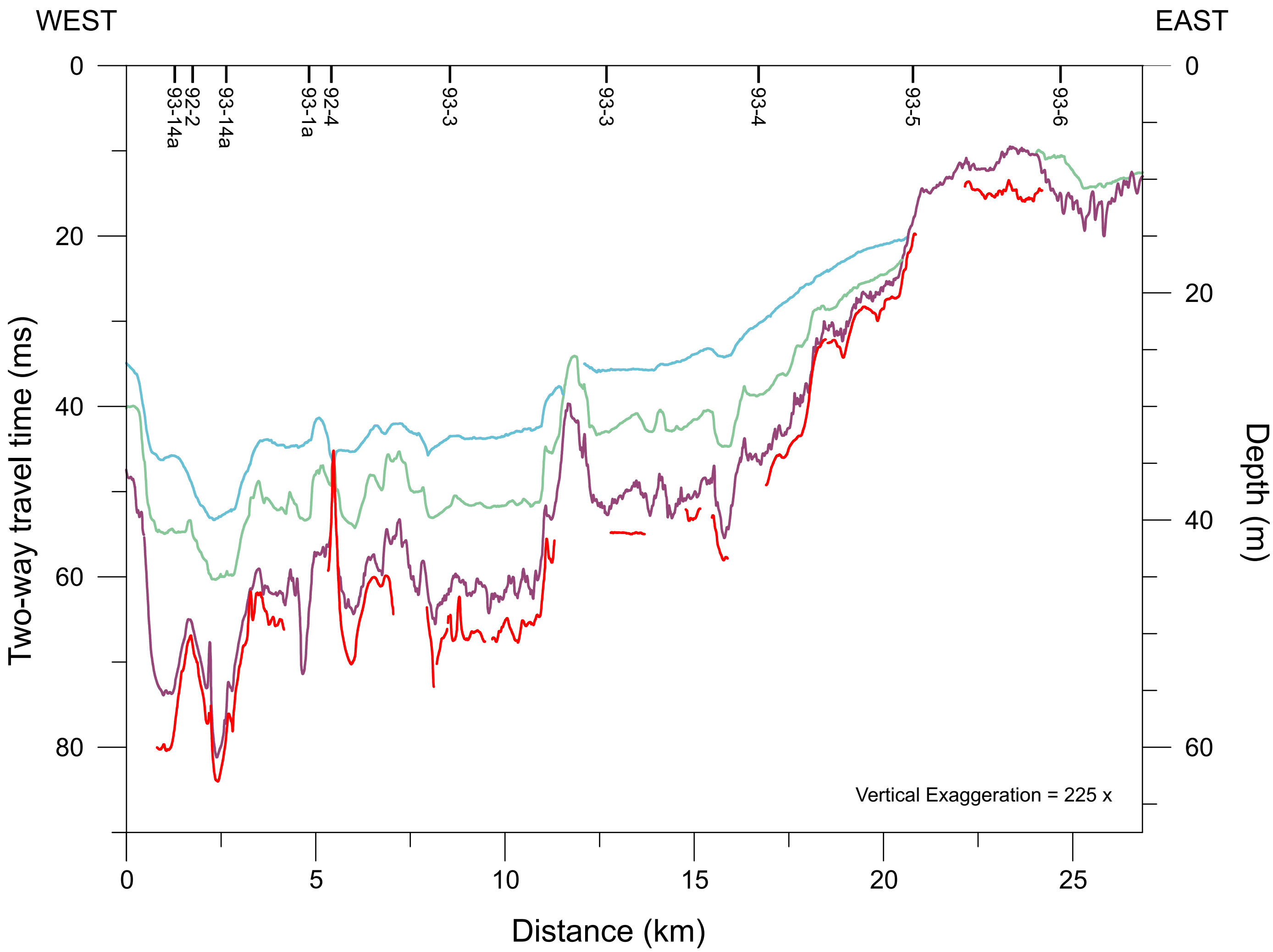

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