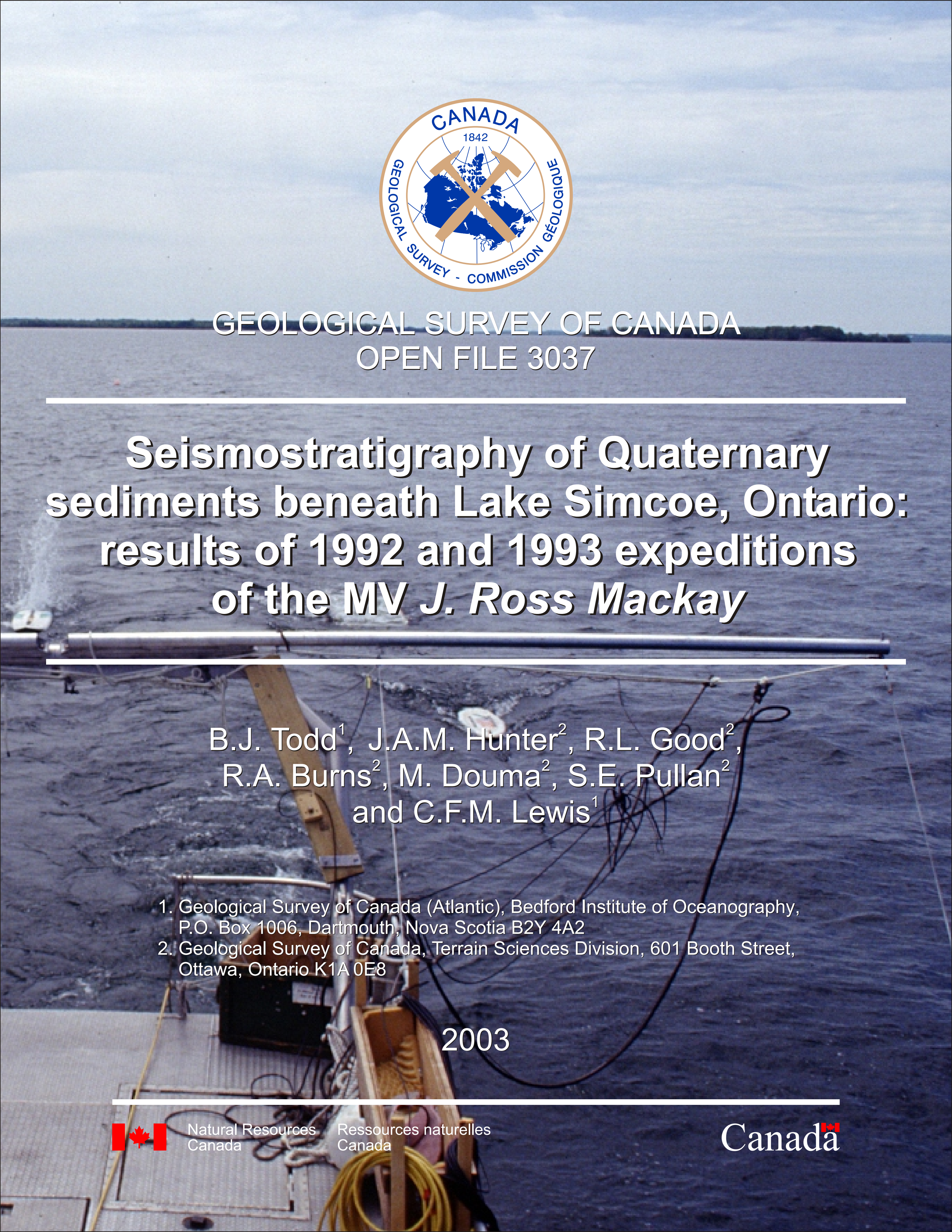

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# Seismostratigraphy of Quaternary sediments beneath Lake Simcoe, Ontario: results of 1992 and 1993 expeditions of the MV *J. Ross Mackay*


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**TABLE OF CONTENTS**

## ABSTRACT

A marine geophysical survey program was conducted in Lake Simcoe, Ontario in September 1992, and May and June, 1993 as part of a program to better understand the lake bottom and the sub-bottom geology. This Open File report provides a seismostratigraphic framework for the ongoing environmental assessment of Lake Simcoe and of similar lakes, and to assess seismic hazards in southern Ontario. A 4 km by 4 km survey grid covered the lake, with more closely-spaced survey lines in Kempenfelt Bay and Cook's Bay. High-resolution single- and multichannel seismic reflection profiling were used to delineate late- and post-glacial sedimentary strata, structures and lakefloor features. Acoustic basement is Ordovician sedimentary rock, overlain by three seismostratigraphic sequences within the unconsolidated sediments.

The lower, Purple Sequence sediments are widespread in Lake Simcoe and are shallowly buried, or outcrop on the lake floor, in eastern and northern Lake Simcoe. Prominent lake floor outcrops of Purple Sequence sediments up to 10 m in height occur throughout the lake . The steep cross-sectional shape of these mounds suggests that they may be drumlins related to the northeast-southwest oriented drumlin fields mapped by previous workers on land around Lake Simcoe. The distribution of the Purple Sequence, its reflection configuration and its drumlinized, unconformable surface suggests that it is analogous to the Newmarket Till mapped south of Lake Simcoe.

The middle, Green Sequence sediments extend over all of Lake Simcoe. Truncated reflections within the Green Sequence are widespread in the lake and characterize the Green Reflector sequence boundary as an erosional unconformity. In both Kempenfelt Bay and Cook's Bay, Green Sequence sediments reach a thickness of about 50 ms, or about 40 m. Seismic and borehole evidence from the Oak Ridges Moraine to the south of Lake Simcoe suggests that the relatively strong amplitude, parallel refection configuration of the Green Sequence corresponds to glaciolacustrine fine sand, silt and clay of Late Wisconsinan age. Green Sequence sediments were deposited in a sheet drape, probably during late-glacial time in the Lake Simcoe basin.

The upper, Blue Sequence sediments do not extend into the northeastern portion of Lake Simcoe, either as a result of non-deposition or of erosion subsequent to deposition. The maximum Blue Sequence thickness of about 16 ms (TWT), or 12 m, occurs in the western part of the Lake Simcoe and in Kempenfelt Bay. Elsewhere, these sediments are a few metres in thickness. Based on stratigraphic position, acoustic simplicity and transparency, and based on comparison to similar seismostratigraphy mapped elsewhere, Blue Sequence sediments are interpreted to be mud deposited in a sheet drape during Holocene (post-glacial) time in Lake Simcoe.

## 1. INTRODUCTION

The glacial history of the Great Lakes Basin in southern Ontario has been studied for over a century (Johnston, 1916; Spencer, 1890, 1891). The digital compilation of the Quaternary geology of southern Ontario (Ontario Geological Survey, in prep.) summarizes the present state of subaerial mapping. Offshore sediment sampling and mapping has taken place in the lower Great Lakes (Thomas *at al*., 1972a, 1972b, 1973a, 1973b ; Thomas, 1984; Hutchinson *et al*., 1993; Dobson *et al*., 1995; Lewis *et al*., 1992, 1995; Blasco, 2001) and in the Kawartha Lakes (Todd and Lewis, 1993). However, the onshore-offshore correlation of Quaternary sediments and glacially-derived landforms is not possible without a sufficient coverage of geophysical survey lines (Lewis *et al*., 1997).

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. This Open File report provides a seismostratigraphic framework for the ongoing environmental assessment of Lake Simcoe and of similar lakes. For example, aquatic ecosystems and groundwater are experiencing increasing scrutiny under the ever-rising recreational, municipal and industrial use of Canadian water resources.

In the 1990s, concern was raised about the identification and documentation of neotectonic activity and related geological features in southern Ontario, one of the most populated areas of Canada (Wallach and Mohajer, 1990; Mohajer *et al*., 1992). Although both subaerial and subaqueous geological evidence of neotectonism from several sites in eastern Canada have been reported (Adams, 1982a, 1982b, 1989; McFall and Allam, 1991; Shilts, 1984; Shilts *et al.*, 1989; Shilts *et al.*, 1992; Thomas *et al*., 1989), systematic geophysical mapping of potential neotectonic features in southern Ontario has been lacking.

The lakes of southern Ontario contain a record of sedimentation in late-glacial (since about 14-12 ka) and postglacial time. Because of their clayey or organic composition and high water content, lacustrine sediments are highly deformable and are susceptible to disturbance during earthquakes (Shilts and Clague, 1992). Structural or sedimentological features may be created by movement resulting from earthquakes, and these features may be preserved in the sediments (Doig, 1991). Therefore, the lakes of southern Ontario should be potential sites for the detection and mapping of neotectonic features resulting from past seismic and faulting events. This paleoseismic geological record can be used to enhance the evaluation of the nature of future potential seismic activity in southern Ontario. The Lake Simcoe marine geophysical survey addresses the geological history and neotectonic record of the sediments in this southern Ontario lake near metropolitan

Toronto. The Greater Toronto Area (GTA) encompasses not only a high population density, but also a highly developed transportation corridor, industrial base and power generation and distribution system.

## 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 of 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 forms a limestone plain with small scarps and thin sediment forming till plains.

### 2.2 Bedrock Geology

Lake Simcoe overlies Middle Ordovician limestone between 15 km and 60 km south of its contact with Precambrian (Grenville) metasedimentary and gneissic rocks (Fig. 1) (Ontario Geological Survey, 1991). The Precambrian bedrock surface is highly irregular (relief of 15-25 m), whereas the surface of the younger Ordovician carbonate rock strata is planar. These Ordovician rocks dip gently on a regional scale at 4-6 m $km^{-1}$ southwesterly (Johnson *et al.*, 1992). Local dips of Paleozoic rocks are greater where they are draped over Precambrian relief. The Paleozoic rock section thickens downdip towards the Appalachian and Michigan Basins south of Lake Ontario and west of Georgian Bay, respectively (Liberty, 1969; Johnson *et al.*, 1992; Sanford, 1992).

### 2.3 Surficial Geology

The Lake Simcoe area was glaciated by the Laurentide Ice Sheet with predominantly south to southwest ice flow (Chapman and Putnam, 1984; Karrow, 1989; Barnett, 1992). Subaerially exposed glaciogenic deposits in the study area are Wisconsinan in age and are undifferentiated tills with minor exposures of glaciofluvial ice-contact and outwash deposits (gravel and sand) and glaciolacustrine deposits (silt and clay, sand) (Deane, 1950; Gravenor, 1957; Barnett *et al.*, 1991). These deposits cover bedrock in the western Lake Simcoe area, but form a relatively thin to discontinuous veneer over bedrock in the eastern Lake Simcoe area.

South of Lake Simcoe in the Oak Ridges Moraine and Greater Toronto Area (Fig. 1), coordinated geoscience studies over the last decade have resulted in new concepts of the sedimentary architecture and event sequences in this region, and are key to understanding the seismostratigraphy beneath the lake. The Oak Ridges Moraine is built on a high-relief, erosional surface (unconformity) consisting of drumlin uplands and a network of deep, steep-walled, interconnected valleys (tunnel channels) (Barnett *et al*., 1998). The erosion surface/unconformity forms a distinct time datum in the Quaternary sequence and is attributed to regional-scale, subglacial meltwater flow events (Sharpe *et al*.,1997, 2002, in prep.). The development of the moraine occurred in four stages: I - subglacial sedimentation; II - subaqueous fan sedimentation; III - fan to delta sedimentation; and IV - ice marginal sedimentation (Barnett *et al*., 1998).

Following the erosion of the tunnel channels, major lake basins (Lake Ontario and Georgian Bay), the Niagara Escarpment (Fig. 1) and the retreating ice front combined to create deep, ice-marginal-lake conditions (Barnett *et al*., 1998). Water levels and sedimentation were controlled first by glacial hydrology and later by regional outlet channels along the Niagara Escarpment. Subaqueous deposition in the Lake Simcoe Basin probably began at this time, prior to drainage through the Campbellford outlet (REF - Karrow, 1989). A water level decline with time is recorded within the moraine sediments.

Based on analysis of seismic reflection profiles with borehole control, sediments in and beneath the Oak Ridges Moraine are characterized by four seismic facies (Pugin, Pullan and Sharpe, 1999). High reflectivity facies (I) can be traced regionally and related to the eroded Newmarket Till. Medium (II) reflectivity facies are associated with coarse-grained glaciofluvial deposits. Low (III) reflectivity facies are associated with laterally-extensive, glaciolacustrine sequences of sand, silt, and clay. A chaotic facies (IV) is common within buried channels and is attributed to instability and/or rapid tunnel channel-fill deposition. Seismic profile interpretations are consistent with the scenario of sheet flow and channel cutting (facies I) by high-energy subglacial meltwater followed by channel infilling (facies IV) and regional deposits of gravel, sand and silt in succession (facies II and III) as the flows waned.

**2.4 Lake Simcoe bathymetry**

Lake Simcoe has a smooth, regular lakefloor and contains few islands (Fig. 2) (Canadian Hydrographic Service, 1987). The majority of the Lake Simcoe lakefloor is 5-9 m (16-30 feet) in depth; the northern and eastern portions of the lake are shallower than 18 m (60 feet). The lake 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). Waters shoal gradually around Thorah and Georgina Islands in eastern Lake Simcoe. At the north end of Cook’s Bay, water depths reach 21 m (70 feet) adjacent to the west shores of Fox and Snake

Islands.

## 3. SURVEY METHODS

### 3.1 Survey vessel

The marine geophysical survey was conducted aboard the MV *J. Ross Mackay*, a 12 m, 14,000 kg aluminum hull research vessel (Fig. 3). 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 (Figs. 4, 5). Table 1 lists the instruments deployed in 1992; Table 2 lists those deployed in 1993. The following sections describe the instrument functions.

### 3.2 Navigation

Electronic navigation used throughout the survey was the satellite-based Global Positioning System (GPS). In 1992, the navigation data were logged at a 60 second interval and stored in the GPS instrument (Trimble NavTrak XL). The data were transferred daily to portable computer and the ship's track was plotted. In 1993, a GPS antenna was mounted on the bridge of the survey vessel and a Magnavox MX 4200D GPS receiver and an IBM compatible 486 computer logged position, velocity and raw satellite data for each tracked satellite using the program GPSLOG (D. Heffler, Geological Survey of Canada Atlantic). Both navigation and raw data were written to disk every 30 seconds.

At the time of the surveys, the GPS obtained position fixes at a rate of one per second with an accuracy of 25 m (circular probable error, or CEP). The U.S. Department of Defence purposely degraded the accuracy of the system to 125 m (CEP) by initiating selective satellite availability at any time (King *et al*., 1987). 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.

ASCII files of the 1992 and 1993 navigation data are provided on this Open File CD-ROM under the folder Appendix B. The file names are 92NAV.ASC and 93NAV.ASC.

### 3.3 Boomer seismic system

A high-resolution single channel seismic reflection system was used to obtain detailed cross sections of the Quaternary sediments (Table 3). The system consisted of an ORE Geopulse power supply (300 joules) connected to a Huntec 4425 boomer mounted under a surface-towed surfboard. The receiver was an IKB Seistec "line-in-cone" array towed near-surface in a catamaran. The system operated over a frequency range of 1800 Hz to 6-8 kHz and was fired at a 0.75 s interval with a survey speed of 3.0 to 3.5 km $hr^{-1}$ (1.6-1.9 knots) thereby sampling the subsurface 1.2-1.35 m horizontally. Data were displayed on two EPC 1600 graphic recorders, one with a 100 ms sweep and one with a 50 ms sweep, and were recorded with a Hewlett Packard 3968 8-channel analogue tape recorder at 3.75 in $s^{-1}$ (9.5 cm $s^{-1}$). In ideal geological settings in unconsolidated sediments, the Seistec system nominally resolves strata with thicknesses approximately 0.25 m in water depths of 2-100 m accompanied by depth penetration of up to 80 m (Simpkin and Davis, 1993). In the consolidated sediments beneath Lake Simcoe, depth penetration of the Seistec system was less, attaining a maximum of 40 m in some locations. This penetration, combined with the high degree of both vertical and horizontal resolution, made the Seistec system an excellent tool to delineate Quaternary sedimentary strata and structures throughout Lake Simcoe.

### 3.4 Compressed air seismic system

A high-resolution compressed air seismic reflection system was used in Lake Simcoe to penetrate unlithified Quaternary sediments more deeply than the boomer seismic system. The frequency of the seismic energy source (tens to hundreds of hertz) does not attenuate with depth as quickly as that of the higher frequency Seistec boomer source. Consequently, the depth of penetration of sound energy into the subsurface is greater, but the vertical resolution of the reflecting horizons is less than that of the boomer system. In 1992, the seismic energy source was a 10 $in^3$ (164 $cm^3$) Bolt 600B airgun operated at a pressure of 1800 psi and fired at a 15 second rate at a towed depth of 1.5 m. At the survey speed of 3.0 to 3.5 km $hr^{-1}$ (1.6-1.9 knots), airgun shots were spaced 15.4 m horizontally. In 1993, a 20 $in^3$ (328 $cm^3$) Bolt airgun was used for the first few survey lines. Penetration was not improved with this larger volume source, therefore the 10 $in^3$ (164 $cm^3$) airgun was reinstalled.

The seismic reflection data were digitally recorded using an EG&G ES2401 engineering seismograph. The record length was 400 ms using a 0.2 ms sampling rate. Frequency spectra of shot records showed a frequency content of 400-600 Hz. The data were stored on hard disk on the seismograph and processed each day. The vertical resolution of this system was 1.5-2.5 m with a depth penetration of almost 100 m. The compressed air seismic reflection system provided details of the sediment/bedrock interface which were beyond the capability of the Seistec system on the majority of the survey lines.

The multi-channel seismic reflection profiling system was composed of an EG&G R24 Strataview seismograph recording signals received from a seismic eel. Power was supplied to the seismograph by a Lambda EWS 300-12 switching regulator DC power supply fed by ship's power. The seismograph contains instantaneous floating point amplifiers with a 32 bit floating point digital signal processor. Preamplifier gain was set at 36 dB with a maximum input signal of 300 mV peak-to-peak. When operating in its marine mode, the seismograph operates with a replace function and an autosave function. These features allow recording and storage of records in less than 5 seconds. Each seismic record consists of 24 channels with 1024 samples per channel at a 0.2 millisecond (ms) sample rate. The record length was 400 ms and the file size is 106 kilobytes. Using a 0.25 ms sample rate provides a recorded bandwidth of 2-1200 Hz with a dynamic range of 104 dB. To avoid clipping the recorded seismic signal, the seismograph used a trigger lockout time of 4.8 seconds that prevented the seismograph from triggering on the Seistec pulse. The Seistec was disabled as the airgun shot was received by the seismograph, and the Seistec was then enabled. The Seistec firing rate was 0.25 seconds.

Within the seismograph is an IBM-compatible computer using an 80486 processor with a data storage capacity of 340 megabytes and 8 megabytes of RAM. A SCSI interface allowed external data storage on a 1.2 gigabyte drive, thereby allowing storage of a large number of records without leaving the "record" mode on the seismograph. In the evening, seismic data were downloaded from the 1.2 gigabyte drive to 150 megabyte Bernoulli disks in an external twin Bernoulli drive. Approximately 1400 records were stored on each Bernoulli disk.

The receiver was a refraction/reflection 12-channel eel developed by the Geological Survey of Canada (Good *et al.*, 1984). The layback from the GPS antenna was 21.5 m to the airgun/sleeve gun, and 29 m to group 1 on the eel. The seismic eel consists of 24 receivers spaced at a 5 metre interval (115 m live section) The hydrophone array is housed inside a neutrally-buoyant oil-filled hose having an outer diameter of 3.2 cm. Each receiver consists of 2 AQ-16 hydrophones wired in parallel with a 0.5 metre separation. Each hydrophone has a frequency response of ± 0.5 dB from 0.5 Hz to 3 kHz, a sensitivity of -97 dB referenced to 1 V per microbar, a capacitance of 3500 picofarads, and a depth rating of 1828 metres. The output signal from each pair of hydrophones passes into an AQ-300 differential input/output preamplifier. The preamplifier has an input impedance of 30 MΩ, a gain of 20.8 dB with a 20 kΩ resistor installed, a bandwidth of 3 dB points 0.3 Hz to 14 kHz, a current of 750 microamps, a voltage of 8-30 V and a common mode rejection ratio of greater than 80 dB.

The seismic information was also recorded using a Nova Scotia Research Foundation

(NSRF) 7 m eel (Nova Scotia Research Foundation, 1981) and displayed on an EPC recorder while underway (Table 4).

### 3.5 Other geophysical methods

In addition to the two seismic systems described above, shallow, high-resolution data were recorded using a Raytheon RTT 1000 subbottom profiler with a frequency of 7 kHz at a rate of 534 soundings per minute. A vertical resolution of about 1 m was obtained with this profiler but its depth penetration was only a few metres (Table 5). Sidescan sonar data were also collected using an EG&G 260 sidescan sonar (Table 6). The sidescan images provided a plan view of the lakefloor morphology and information on the type and distribution of sediment in a swath 200 or 400 m wide, centred on the ship's track.. The sidescan images were, in general, featureless because most of the lakefloor is mantled with unconsolidated sediment (Blue Sequence sediments described in Sections 4.2 and 5.1) which does not lend itself to sidescan sonar imaging because of signal attenuation. However, where more consolidated sediments of the Green Sequence (Sections 4.2 and 5.2), the Purple Sequence (Sections 4.2 and 5.3), and the Red Sequence (Sections 4.2 and 5.4) outcrop on the lakefloor, the more signal is reflected and the resulting sidescan sonar information enabled determination of the strike of the outcropping layers as well as other structural details. As well, slumped sediments in Kempenfelt Bay and gas-venting pockmarks in Cook's Bay were imaged by the sidescan sonar. Sidescan sonar evidence of these, and other, features is presented graphically and discussed in Todd *et al*. (in prep.).

To investigate the magnetic signature of the Quaternary sediments beneath Lake Simcoe, a GSM-19D marine magnetometer manufactured by GEM systems Inc. (Richmond Hill, Ontario) was deployed on all the 1993 geophysical survey lines except line 93-16. The sealed fish contained an Overhauser sensor; signals generated in the sensor were processed in a fish-mounted microprocessor and transferred digitally through the tow cable (which also served as the power cable). The value of the magnetic field was logged each second and magnetometer profiles were plotted. The data were processed and mapped subsequent to the survey. Although not presented in this Open File focussing on seismostratigraphy, the magnetic survey results will be discussed in a subsequent report.

### 3.6 Survey design

In September of 1992, the MV *J. Ross Mackay* was used to complete a reconnaissance geophysical survey of Lake Simcoe (Fig. 6). One set of survey lines ran east to west across the lake from the mouth of the Trent Canal to the city of Barrie (lines 92-1, 92-2, 92-6). Another set of survey lines ran south to north from Cook's Bay to the town of Orillia (lines 92-3, 92-7, 92-4, 92-5). The instruments deployed in 1992 are given in Table 1. The Seistec record inventory is provided in Table 3 and the sidescan sonar inventory is provided in Table 6. The Raytheon RTT 1000 subbottom profiler records are tabulated in Table 5. Intersections of the 1992 survey lines with the 1993 survey lines are given in Table 7. The seismic 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. 7). 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. Both bays were surveyed with a zigzag line pattern, with a considerable line coverage accumulated in Kempenfelt Bay (Fig. 8). The combination of zigzag and gridded survey patterns was designed to detect and map the lateral limits of offshore extensions of north-south trending channels mapped south of Lake Simcoe (Barnett *et al*., 1998). Cook's Bay in southern Lake Simcoe (Fig. 1) is the northern end of a deep, glacially- incised channel which was rapidly filled with thick sand sequences (Russell, 2001) and now hosts Holland Marsh.

The instruments deployed in 1993 are given in Table 2. The Seistec record inventory is provided in Table 3 and the sidescan sonar inventory is provided in Table 6. The NSRF eel records are tabulated in Table 4. Intersections of the 1993 survey lines with all other lines are given in Table 8.

# 4. DATA ANALYSIS

## 4.1 Seismostratigraphic principles

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. Another seismostratigraphic term commonly used in the description of reflections is "amplitude". Amplitude is controlled by the magnitude of acoustic impedance contrast across a boundary. A high amplitude reflection appears as a large excursion on a seismic trace; conversely, a low amplitude reflection exhibits a small excursion. For example, a high amplitude reflection would be recorded across a mud/rock interface and a low amplitude reflection would be recorded across the boundary between two muds. "Acoustic basement" refers to the deepest more-or-less horizontally continuous seismic reflection; acoustic basement is often an unconformity below which seismic energy returns are poor or absent. Finally, an absence of reflections on a seismic profile is referred to as "transparent".

## 4.2 Digitizing and interpretation of reflections

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). 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/or which truncate underlying reflections define the boundaries of packages or sequences of sediment. Five such regional reflectors were identified in the Lake Simcoe seismic data. Commonly, sediment sequences between reflecting boundaries are named for their upper bounding reflector. In this report, we use the colour designations illustrated in Figure 9; in order of increasing depth and age, the seismostratigraphic column comprises Blue, Green, Purple, Red and Brown Sequences. The top of the Blue Sequence is designated the Blue Horizon, and the four other horizons are similarly denoted.

An example interpreted Seistec IKB high-resolution seismic profile from Cook's Bay is shown in Figure 10. For comparison of seismic system results, an example airgun seismic profile, also from Cook's Bay, is shown in Figure 11. Acoustic basement is, in the Seistec example of Figure

10, Purple Sequence, whereas the airgun seismic system penetrates the Purple Sequence and the Red Sequence is acoustic basement (Fig. 11). The top of Red Sequence is uneven and the reflection configuration within the sequence is chaotic with some subtle suggestions here and there of coherent reflections. The Red Sequence is interpreted to be till and its upper surface, the Red Reflector, is interpreted to be an unconformity. The same reflection configuration and geological interpretation pertains to the Purple Sequence. In marked contrast, the overlying Green Sequence exhibits a parallel internal reflection configuration. The Green Sequence reflections conformably drape the irregular top of the Purple Sequence and the drape becomes more subdued, or flattened, towards the top of the Green Sequence.

In the centre of the Seistec IKB high-resolution seismic profile (Fig. 10) is a feature within the Green Sequence consisting of a tangential oblique progradational reflection configuration. This is described as a prograding clinoform pattern comprising steep-dipping reflections terminating updip near a nearly-flat upper surface and downdip by passing into gently-dipping underlying reflections. This seismic reflection geometry can be interpreted as a barrier complex which would have formed in southern Lake Simcoe when the lake level was approximately 25 to 30 metres lower than at present, due presumably to some combination of either tilting of the basin prior to postglacial isostatic recovery, and/or a climatic period in which there was no overflow, or reduced overflow, from the lake. Within both the Purple and Green Sequences, gas in the sediments has masked the horizontal continuity of reflections. Based on the overall geometry of the seismic profile, and the regional interpretation, it is assumed that reflectors of the Green Sequence are continuous across the masked zone.

Sediments of the Blue Sequence overlie the top of the Green Sequence in Figures 10 and 11. The internal reflection configuration is parallel, but with a subdued amplitude compared with the Green Sequence. Reflections within the Blue Sequence downlap on the Green Reflector, therefore this surface is interpreted to be an unconformity.

The upper bounding reflections, or sequence boundaries, for all the profiles in Lake Simcoe were interpreted based on the single- and multichannel seismic data, Raytheon RTT 1000 subbottom profiles, and associated sidescan sonar records. The interpreted sequence boundaries were digitized. and are provided in Figure 12 (a-z). The vertical and horizontal scales in Figure 12 vary from line to line. The vertical scale on the left is two-way reflection travel time in milliseconds. This was converted to approximate depth in metres below lake surface (right vertical scale) assuming a sound velocity of 1500 $ms^{-1}$ in both water and sediments. The horizontal scales for lines oriented south-north are UTM Northing in metres. Similarly, the horizontal scales for lines oriented west-east are

UTM Easting in metres. The horizontal scale for the remaining lines is distance along line in metres.

Accompanying this report are fifteen sheets of uninterpreted seismic profiles recorded with the multichannel seismic system (Appendix A). It is important to note that these sheets display only one channel (channel 4) of the 24 channels recorded digitally. The offset from the airgun source was 20 m. An automatic gain control with an 80 ms window and a 100-600 Hz bandpass filter were applied to the data. Processing costs did not allow multichannel processing of the entire suite of data; nonetheless the fifteen seismic profile sheets harbour an abundance of geological information.

### 4.3 Structural contour and isopach maps

Although it is not possible to include the voluminous original field data in the Open File report, the distilled information contained in Figure 12 (a-z) is computationally more useful. The digitized interpreted profiles were processed to produce structural contour maps of horizons and isopach maps of sequences using software developed by the Ocean Mapping Group at the Geological Survey of Canada (Atlantic). This software utilizes GRASS (Geographic Resources Analysis Support System) software, now in the public domain, developed by the US Army Constructional Engineering Research Laboratories. The structural contour and isopach maps are described in Section 5.

## 5. DESCRIPTION AND INTERPRETATION OF SEISMOSTRATIGRAPHIC SEQUENCES

In the following description, the Lake Simcoe seismostratigraphic sequences are discussed from youngest (Blue Sequence) to oldest (Brown Sequence). It is important to note that, in Cook's Bay at the south end of Lake Simcoe, masking of reflections by gas affects the accuracy within the bay of the maps described in this section. Interpretation of the single- and multichannel seismic reflection profiles indicates that Cook's Bay contains, in places, 40 m (or more) of Blue and Green Sequence sediments; this thickness is under-represented in the maps. Gas also masks Green Sequence sediments east of Georgina Island (Fig. 12t).

### 5.1 Blue Sequence

Blue Sequence sediments do not extend into the northeastern portion of Lake Simcoe (Figure 13a), either as a result of non-deposition or of erosion subsequent to deposition. The maximum Blue Sequence thickness of about 16 ms (TWT), or 12 m, occurs in the western part of the Lake Simcoe and in Kempenfelt Bay (Fig. 13b). Elsewhere, these sediments are a few metres in thickness.

Based on stratigraphic position, acoustic simplicity and transparency, and based on comparison to similar seismostratigraphy mapped in the Kawartha Lakes (Todd and Lewis, 1993) and in Lake Winnipeg (Lewis and Todd, 1996; Todd *et al*., 1998), Blue Sequence sediments are interpreted to be mud deposited in a sheet drape during Holocene (post-glacial) time in Lake Simcoe.

### 5.2 Green Sequence

Green Sequence sediments extend over all of Lake Simcoe (Figure 13c) except along Line 8a in northern Lake Simcoe (Fig. 12n). Here, truncated reflections within the Green Sequence indicate that material was removed by erosion. In fact, truncated reflections within the Green Sequence are widespread in the lake and characterize the Green Reflector sequence boundary as an erosional unconformity. In both Kempenfelt Bay and Cook's Bay, Green Sequence sediments reach a thickness of about 50 ms (TWT), or about 40 m.

Seismic and borehole evidence from the Oak Ridges Moraine to the south of Lake Simcoe (Pugin, Pullan and Sharpe, 1999) suggests that the relatively strong amplitude, parallel refection configuration of the Green Sequence corresponds to glaciolacustrine fine sand, silt and clay of Late Wisconsinan age. Green Sequence sediments were deposited in a sheet drape, probably during late-glacial time in the Lake Simcoe basin.

### 5.3 Purple Sequence

Purple Sequence sediments are widespread in Lake Simcoe and are shallowly buried, or outcrop on the lake floor, in eastern and northern Lake Simcoe (Fig. 13e). Prominent lake floor outcrops of Purple Sequence sediments up to 10 m in height occur throughout the lake (e.g. Fig. 12a, e, j). The steep cross-sectional shape of these mounds suggests that they may be drumlins related to the northeast-southwest oriented drumlin fields mapped by previous workers on land around Lake Simcoe (Barnett *et al.*, 1991). Within Kempenfelt Bay, the top of the Purple Sequence reaches depths of about 50 m in places, though the base of the sequence is not seismically detectable due to gas masking (Fig. 12y).

The distribution of the Purple Sequence, its reflection configuration and its drumlinized, unconformable surface suggests that it is analagous to the Newmarket Till mapped south of Lake Simcoe (Barnett *et al.*, 1998, Pugin, Pullan and Sharpe, 1999; Pugin *et al.*, 1999; Sharpe *et al.*, in prep.).

### 5.4 Red and Brown Sequences

Red Sequence sediments occur in many places in Lake Simcoe (Fig. 13g). These sediments were not detected in Cook's Bay but were observed at depth in Kempenfelt Bay. Red Sequence sediments rarely outcrop on the lakefloor, with the exception of Line 93-15a in the area of Snake and Fox Islands (Fig. 12x) in southwestern Lake Simcoe.

Brown Sequence sediments (Fig. 13h) were detected only on lines 92-1, 92-4, 92-5 and 93-5 (Figs. 12a, d, e, k). These sediments are interpreted as the oldest till within Lake Simcoe detected in the Seistec profiles.

### 5.5 Discussion

The regional seismostratigraphy of the Lake Simcoe basin described in this report is in accord with the depositional model developed for the Oak Ridges Moraine (Barnett *et al.*, 1998). Tunnel channels (e.g. Cook's Bay) were eroded into Newmarket Till by subglacial meltwater flood events. The streamlined upland surface (i.e. drumlins) were also eroded by subglacial meltwater. As the margin of the Late Wisconsinan ice retreated, sediments were shed into ice-marginal lakes or from beneath a floating ice shelf. Glaciolacustrine sand, silt and clay (Green Sequence) were deposited in the Lake Simcoe Basin at this time. Kempenfelt Bay, the northeast-southwest trending bay in western Lake Simcoe, was submerged during Lake Algonquin time (12,000 to 10,000 B.P.) (Fitzgerald, 1985). A regional unconformity marks the top of the Green Sequence sediments and may be the result of a post-Algonquin lowstand. The overlying Blue Sequence muds reflect open water deposition, distal to the retreating ice front, and merging with modern lake sedimentation.

Based on seismic profiles on the Oak Ridges Moraine (Pugin, Pullan and Sharpe, 1999), the assumption of a velocity of 1500 $ms^{-1}$ applies to the Blue Sequence Holocene muds and the Green Sequence Late Wisconsinan glaciolacustrine fine sand, silt and clay. However, for the Purple Sequence Newmarket Till, a velocity of more than 2000 $ms^{-1}$ is more appropriate. Therefore, using 1500 $ms^{-1}$ for the seismic profiles illustrated in this report (Figs. 12 a-z) underestimates the thicknesses of the Newmarket Till.

## 6. FUTURE WORK

Lake Simcoe studies are ongoing. To advance our lithostratigraphic understanding, a suite of sediment cores was obtained in 1997 and 1998 at strategic sites in the lake. These cores have been described geologically and pollen analysis is underway; the results will be published in a Geological Survey of Canada Open File report (Todd *et al*., in prep.).

Recently, the Ontario Geological Survey has made available to the Geological Survey of Canada the Lake Simcoe region of their Geographic Information System (ESRI ArcView 8) compilation of the surficial geology of southern Ontario(Ontario Geological Survey, in prep.). Based on this information, the Geological Survey of Canada has developed a Lake Simcoe GIS project, including the seismostratigraphic mapping reported in this Open File. In the future, the two organizations plan to release a joint Open File report on the onshore-offshore surficial geology correlation.

## 7. ACKNOWLEDGEMENTS

The marine geophysical survey was conducted in cooperation with Environment Canada Parks Service. We would like to thank John E. Lewis, Superintendent, Jim Norris and Frank Burrows of the Trent-Severn Waterway headquarters, Peterborough, for their advice, assistance and encouragement. The survey was successful as a result of cooperation between two divisions of the Geological Survey of Canada: the Terrain Sciences Division (TSD) in Ottawa and the Atlantic Geoscience Centre (AGC, now the Geological Survey of Canada Atlantic) in Dartmouth. Navigational, seismic and magnetic survey equipment was provided by AGC and we thank Keith Manchester, Mike Gorveatt and Bosko Loncarevic for their help in organizing this material. Anthony Atkinson and Brian Nichols of AGC provided technical advice during outfitting and surveying. Bill Shilts (TSD) provided the EG&G sidescan sonar system. Unflagging assistance on board during the survey was provided by Paul White and Steve Grant. We thank Mark Jones for diving to recover the sidescan towfish. L. Harvey Thorleifson (TSD) joined the survey for a day on Friday June 11, 1993, to observe operations and discuss the applications of the geophysical techniques to Lake Winnipeg; the outcome of that visit kept us busy for years. John Stewart and Steve Hart of McGregor Geosciences in Halifax digitized the interpreted Seistec records and worked with the authors to ensure the accuracy of the process. We thank Jennifer Adams for digitizing and preparing the Lake Simcoe base map and Gary Grant and Phil O'Regan, GSCA Electronic Publishing, for assistance with Figures 10 and 11. Photographs for Appendix C were contributed by Brian Todd, Ron Good and Marten Douma and digitally enhanced by Gary Grant. Maps for this report were produced using software developed by the Ocean Mapping Group at GSCA; Robert Courtney and Russell Parrott helped prepare the data for map production and provided valuable assistance and advice during the process. We thank Robert O. Miller (GSCA), and L. Harvey Thorleifson (TSD) for insightful reviews of this Open File report. David R. Sharpe (TSD) has been particularly supportive of this work for the past decade and has shared his ideas and provided helpful discussion of Lake Simcoe geology; his review of this Open File greatly improved its content and clarity.

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## LIST OF TABLES

## LIST OF FIGURES

Table 1. Deployment of survey instruments in 1992.

| Date | Day of the Year | Line No. | Instruments deployed | | | |
|---|---|---|---|---|---|---|
| | | | Seistec | Seismic | Sidescan | RTT 1000 |
| Sept 15 | 259 | 92-1 | √ | √ | √ | √ |
| Sept 16 | 260 | 92-2 | √ | √ | √ | √ |
| Sept 17 | 261 | 92-3 | √ | √ | √ | √ |
| Sept 17 | 261 | 92-4 | √ | √ | √ | √ |
| Sept 18 | 262 | 92-5 | √ | √ | √ | √ |
| Sept 23 | 267 | 92-6 | — | √ | — | — |
| Sept 24 | 268 | 92-7 | — | √ | — | — |

Table 2. Deployment of survey instruments in 1993.

| Date | Day of the Year | Line No. | Instruments deployed | | | | |
|---|---|---|---|---|---|---|---|
| | | | Seistec | Seismic | Sidescan | Mag | NSRF eel |
| May 26 | 146 | 93-12W | √ | — | √ | √ | — |
| May 27 | 147 | 93-1 | √ | √ | √ | √ | — |
| | | 93-1b | √ | — | — | √ | — |
| May 28 | 148 | 93-13 | √ | √ | — | √ | √ |
| May 29 | 149 | 93-11 | √ | √ | √ | √ | √ |
| May 30 | 150 | 93-3 | √ | √ | √ | √ | √ |
| May 31 | 151 | 93-10 | √ | √ | √ | √ | √ |
| June 1 | 152 | 93-14a | √ | √ | √ | √ | √ |
| June 2 | 153 | 93-2 | √ | √ | √ | √ | √ |
| June 3 | 154 | 93-4 | √ | √ | √ | √ | √ |
| June 4 | 155 | 93-14b | √ | √ | √ | √ | √ |
| June 6 | 157 | 93-9 | √ | √ | √ | √ | √ |
| June 7 | 158 | 93-15b | √ | √ | √ | √ | √ |
| June 8 | 159 | 93-7, 8a, 8b | √ | √ | √ | √ | √ |
| June 9 | 160 | 93-5, 12E | √ | √ | √ | √ | √ |
| June 10 | 161 | 93-15a | √ | √ | √ | √ | √ |
| June 11 | 162 | 93-6 | √ | √ | √ | √ | √ |
| June 12 | 163 | 93-16 | √ | √ | √ | — | √ |

Table 3. Seistec record inventory.

| Line No. | Year | Date | Day of the Year | Record length (s) | Record No. | Start time | End time |
|---|---|---|---|---|---|---|---|
| 92-1 | 1992 | September 15 | 259 | 0.05 | 1 | 1901 (Fix 1) | 2014 (Fix 69) |
| | | | | | 2 | 2022 (Fix 77) | 2126 (Fix 137) |
| | | | | 0.10 | 3 | 1901 (Fix 1) | 2014 (Fix 69) |
| | | | | | 4 | 2022 (Fix 77) | 2126 (Fix 137) |
| 92-2 | 1992 | September 16 | 260 | 0.05 | 5 | 1400 (Fix 138) | 2115 (Fix 572) |
| | | | | 0.10 | 6 | | |
| 92-3 | 1992 | September 17 | 261 | 0.05 | 7 | 1406 (Fix 573) | 1713 (Fix 761) |
| | | | | 0.10 | 8 | | |
| 92-4 | 1992 | September 17 | 261 | 0.05 | 9 | 1847 (Fix 762) | 2100 (Fix 894) |
| | | | | 0.10 | 10 | | |
| 92-5 | 1992 | September 18 | 262 | 0.05 | 11 | 1330 (Fix 1001) | 1614 (Fix 1165) |
| | | | | 0.10 | 12 | | |
| 93-1a | 1993 | May 27 | 147 | 0.05 | 13 | 1557 | 1844 |
| | | | | 0.10 | 14 | | |
| 93-1b | 1993 | May 27 | 147 | 0.05 | 15 | 1903 | 2000 |
| | | | | 0.10 | 16 | | |

| Line No. | Year | Date | Day of the Year | Record length (s) | Record No. | Start time | End time |
|---|---|---|---|---|---|---|---|
| 93-2 | 1993 | June 2 | 153 | 0.05 | 17 | 1555 | 1935 |
| | | | | 0.10 | 18 | | |
| 93-3 | 1993 | May 30 | 150 | 0.05 | 19 | 1453 | 1910 |
| | | | | 0.10 | 20 | | |
| 93-4 | 1993 | June 3 | 154 | 0.05 | 21 | 1414 | 1845 |
| | | | | 0.10 | 22 | | |
| 93-5 | 1993 | June 9 | 160 | 0.05 | 23 | 1506 | 1738 |
| | | | | 0.05 | 24 | 1741 | 1823 |
| | | | | 0.10 | 25 | 1505 | 1823 |
| 93-6 | 1993 | June 11 | 162 | 0.05 | 26 | 1451 | 1815 |
| | | | | 0.10 | 27 | | |
| 93-7 | 1993 | June 8 | 159 | 0.05 | 28 | 1901 | 1946 |
| | | | | 0.10 | 29 | | |
| 93-8a, b | 1993 | June 8 | 159 | 0.05 | 30 | 1530 | 1901 |
| | | | | 0.10 | 31 | | |
| 93-9 | 1993 | June 6 | 157 | 0.05 | 32 | 1456 | 1822 |
| | | | | 0.10 | 33 | | |
| 93-10 | 1993 | May 31 | 151 | 0.05 | 34 | 1538 | 2029 |
| | | | | 0.10 | 35 | | |

| Line No. | Year | Date | Day of the Year | Record length (s) | Record No. | Start time | End time |
|---|---|---|---|---|---|---|---|
| 93-11 | 1993 | May 29 | 149 | 0.05 | 36 | 1732 | 2023 |
| | | | | 0.10 | 37 | | |
| 93-12E | 1993 | June 9 | 160 | 0.05 | 38 | 1824 | 1917 |
| | | | | 0.10 | 39 | | |
| 93-12W | 1993 | May 26 | 146 | 0.05 | 40 | 1646 | 2102 |
| | | | | 0.10 | 41 | | |
| 93-13 | 1993 | May 28 | 148 | 0.05 | 42 | 1705 | 2000 |
| | | | | 0.10 | 43 | | |
| 93-14a | 1993 | June 1 | 152 | 0.05 | 44 | 1423 | 1726 |
| | | | | 0.10 | 45 | | |
| 93-14b | 1993 | June 4 | 155 | 0.05 | 46 | 1330 | 1830 |
| | | | | 0.10 | 47 | | |
| 93-15a | 1993 | June 10 | 161 | 0.05 | 48 | 1404 | 1824 |
| | | | | 0.10 | 49 | | |
| 93-15b | 1993 | June 7 | 158 | 0.05 | 50 | 1405 | 1832 |
| | | | | 0.10 | 51 | | |
| 93-16 | 1993 | June 12 | 163 | 0.05 | 52 | 1350 | 1800 |
| | | | | 0.10 | 53 | | |

Table 4. 1993 seismic NSRF eel record inventory.

| Line No. | Year | Date | Day of the Year | Record No. | Start time | End time |
|---|---|---|---|---|---|---|
| 93-2 | 1993 | June 2 | 153 | 1 | 1555 | 1935 |
| 93-3 | 1993 | May 30 | 150 | 2 | 1453 | 1910 |
| 93-4 | 1993 | June 3 | 154 | 3 | 1414 | 1845 |
| 93-5 | 1993 | June 9 | 160 | 4 | 1506 | 1738 |
| 93-6 | 1993 | June 11 | 162 | 5 | 1451 | 1815 |
| 93-7 | 1993 | June 8 | 159 | 6 | 1901 | 1946 |
| 93-8a, b | 1993 | June 8 | 159 | 7 | 1530 | 1901 |
| 93-9 | 1993 | June 6 | 157 | 8 | 1456 | 1822 |
| 93-10 | 1993 | May 31 | 151 | 9 | 1538 | 2029 |
| 93-11 | 1993 | May 29 | 149 | 10 | 1732 | 2023 |
| 93-12E | 1993 | June 9 | 160 | 11 | 1824 | 1917 |
| 93-13 | 1993 | May 28 | 148 | 12 | 1705 | 2000 |
| 93-14a | 1993 | June 1 | 152 | 13 | 1423 | 1726 |
| 93-14b | 1993 | June 4 | 155 | 14 | 1330 | 1830 |
| 93-15a | 1993 | June 10 | 161 | 15 | 1404 | 1824 |
| 93-15b | 1993 | June 7 | 158 | 16 | 1405 | 1832 |
| 93-16 | 1993 | June 12 | 163 | 17 | 1350 | 1800 |

Table 5. 1992 RTT 1000 record inventory.

| Line No. | Date | Day of the Year | Record No. | Start time | End time |
|---|---|---|---|---|---|
| 92-1 | Sept 15 | 259 | 1 | 1901 (Fix 1) | 2126 (Fix 137) |
| 92-2 | Sept 16 | 260 | 2 | 1400 (Fix 138) | 2115 (Fix 572) |
| 92-3 | Sept 17 | 261 | 3 | 1406 (Fix 573) | 1713 (Fix 761) |
| 92-4 | Sept 17 | 261 | 3 | 1847 (Fix 762) | 2100 (Fix 894) |
| 92-5 | Sept 18 | 262 | 4 | 1330 (Fix 1001) | 1614 (Fix 1165) |
| 92-6 | Sept 23 | 267 | 5 | 1452 (Fix 2005) | 1822 (Fix 2757) |
| 92-7 | Sept 24 | 268 | 6 | 1454 (Fix 5) | 1927 (Fix 999) |

Table 6. Sidescan sonar record inventory.

| Line No. | Year | Date | Day of the Year | Record No. | Start fix/time | End fix/time |
|---|---|---|---|---|---|---|
| 92-1 | 1992 | September 15 | 259 | 1a | 1 | 69 |
| | | | | 1b | 77 | 137 |
| 92-2 | 1992 | September 16 | 260 | 2 | 138 | 571 |
| 92-3 | 1992 | September 17 | 261 | 3 | 573 | 762 |
| 92-4 | 1992 | September 17 | 261 | 4 | 763 | 896 |
| 92-5 | 1992 | September 18 | 262 | 5 | 1001 | 1165 |
| 93-1a | 1993 | May 27 | 147 | 6 | 1557 | 1844 |
| 93-2 | 1993 | June 2 | 153 | 7 | 1427 | 1730 |
| | | | | 8 | 1730 | 1935 |
| 93-3 | 1993 | May 30 | 150 | 9 | 1508 | 1730 |
| | | | | 10 | 1734 | 1913 |
| 93-4 | 1993 | June 3 | 154 | 11 | 1414 | 1845 |
| 93-5 | 1993 | June 9 | 160 | 12 | 1505 | 1823 |
| 93-6 | 1993 | June 11 | 162 | 13 | 1451 | 1815 |
| 93-7 | 1993 | June 8 | 159 | 14 | 1901 | 1946 |
| 93-8a, b | 1993 | June 8 | 159 | 15 | 1530 | 1901 |
| 93-9 | 1993 | June 6 | 157 | 16 | 1456 | 1822 |
| 93-10 | 1993 | May 31 | 151 | 17 | 1538 | 2111 |
| 93-11 | 1993 | May 29 | 149 | 18 | 1732 | 2023 |
| 93-12E | 1993 | June 9 | 160 | 19 | 1824 | 1917 |
| 93-12W | 1993 | May 26 | 146 | 20 | 1646 | 2102 |
| 93-14a | 1993 | June 1 | 152 | 21 | 1423 | 1726 |
| 93-14b | 1993 | June 4 | 155 | 22 | 1330 | 1830 |
| 93-15a | 1993 | June 10 | 161 | 23 | 1404 | 1824 |
| 93-15b | 1993 | June 7 | 158 | 24 | 1405 | 1832 |
| 93-16 | 1993 | June 12 | 163 | 25 | 1350 | 1800 |

Table 7. Line intersections of 1992 survey lines.

| 1992 survey line | | | | Tie lines | | | |
|---|---|---|---|---|---|---|---|
| Line | Day of the year | Time (hr min) | Fix | Line | Day of the year | Time (hr min sec) | Fix |
| 92-1 | 259 | 21 05 | 119 | 93-4 | 154 | 16 13 00 | — |
| | | 20 25 | 80 | 93-10 | 151 | 17 16 22 | — |
| | | 20 15 | 70 | 93-5 | 160 | 16 55 22 | — |
| | | 19 25 | 20 | 93-6 | 162 | 16 03 22 | — |
| 92-2 | 260 | 21 05 43 | 562 | 93-14b | 155 | 17 26 40 | — |
| | | 21 03 07 | 559 | 93-16 | 163 | 14 55 22 | — |
| | | 20 45 37 | 541 | 93-16 | 163 | 14 19 52 | — |
| | | 20 42 55 | 539 | 93-16 | 163 | 15 55 40 | — |
| | | 20 42 25 | 539 | 93-14b | 163 | 18 17 40 | — |
| | | 20 38 36 | 535 | 93-14b | 155 | 16 53 40 | — |
| | | 20 19 37 | 513 | 93-16 | 163 | 16 23 16 | — |
| | | 20 17 31 | 510 | 93-14b | 155 | 16 22 52 | — |
| | | 20 04 07 | 497 | 93-16 | 163 | 16 32 34 | — |
| | | 19 53 12 | 486 | 93-14b | 155 | 15 43 10 | — |
| | | 19 42 37 | 475 | 93-16 | 163 | 16 59 10 | — |
| | | 19 28 06 | 460 | 93-14b | 155 | 15 16 32 | — |
| | | 19 26 36 | 458 | 93-16 | 163 | 17 13 22 | — |
| | | 19 03 36 | 435 | 93-14b | 155 | 14 40 58 | — |
| | | 18 35 44 | 408 | 93-14b | 155 | 1411 22 | — |
| | | 18 15 06 | 391 | 93-14a | 152 | 17 02 52 | — |
| | | 18 05 06 | 381 | 93-11 | 149 | 19 59 52 | — |
| | | 17 56 06 | 372 | 93-14a | 152 | 16 17 52 | — |
| | | 17 19 05 | 335 | 93-1a | 147 | 18 06 52 | — |
| | | 16 59 07 | 315 | 92-4 | 261 | 20 31 10 | 865 |
| | | 16 19 11 | 277 | 93-2 | 153 | 17 37 52 | — |

| 1992 survey line | | | | Tie lines | | | |
|---|---|---|---|---|---|---|---|
| Line | Day of the year | Time (hr min) | Fix | Line | Day of the year | Time (hr min sec) | Fix |
| | | 15 15 07 | 213 | 93-3 | 150 | 17 15 52 | — |
| | | 14 17 05 | 155 | 93-4 | 154 | 16 13 22 | — |
| 92-3 | 261 | 17 05 06 | 752 | 93-15b | 158 | 14 22 52 | — |
| | | 16 56 35 | 744 | 93-15b | 158 | 14 41 22 | — |
| | | 16 40 04 | 727 | 93-15b | 158 | 15 22 52 | — |
| | | 16 29 04 | 716 | 93-15b | 158 | 15 40 22 | — |
| | | 16 19 35 | 706 | 93-15b | 158 | 15 56 22 | — |
| | | 16 09 05 | 696 | 93-15b | 158 | 16 20 52 | — |
| | | 15 35 18 | 662 | 93-15b | 158 | 17 08 52 | — |
| | | 15 15 38 | 642 | 93-15b | 158 | 17 48 52 | — |
| | | 14 50 05 | 617 | 93-13 | 148 | 17 26 22 | — |
| | | 14 29 10 | 596 | 93-15a | 161 | 17 11 52 | — |
| | | 14 26 40 | 594 | 92-4 | 261 | 18 49 06 | 764 |
| 92-4 | 261 | 18 49 06 | 764 | 92-3 | 261 | 14 26 40 | 594 |
| | | 19 49 05 | 824 | 93-14a | 152 | 15 46 52 | — |
| | | 19 57 05 | 832 | 93-1a | 147 | 17 48 52 | — |
| | | 20 12 05 | 847 | 93-11 | 149 | 19 23 22 | — |
| | | 20 31 10 | 865 | 92-2 | 260 | 16 59 07 | 315 |
| | | 20 56 35 | 890 | 93-1b | 147 | 19 43 52 | — |
| 92-5 | 262 | 13 46 35 | 1018 | 93-10 | 151 | 19 38 52 | — |
| | | 14 01 37 | 1032 | 93-2 | 153 | 17 04 52 | — |
| | | 14 29 06 | 1060 | 93-9 | 157 | 17 37 22 | — |
| | | 15 13 36 | 1104 | 93-8 | 159 | 17 55 52 | — |
| | | 15 51 36 | 1142 | 93-7 | 159 | 19 17 52 | — |

Table 8. Line intersections of 1993 survey lines.

| 1993 survey line | | | Tie lines | | | |
|---|---|---|---|---|---|---|
| **Line** | **Day of the year** | **Time (hr min)** | **Line** | **Day of the year** | **Time (hr min sec)** | **Fix** |
| 93-1a | 147 | 18 31 30 | 93-10 | 151 | 20 07 52 | — |
| | | 18 06 52 | 92-2 | 260 | 17 19 05 | 335 |
| | | 17 56 52 | 93-11 | 149 | 19 28 52 | — |
| | | 17 48 52 | 92-4 | 261 | 19 57 05 | 832 |
| | | 17 39 52 | 93-14a | 152 | 15 39 22 | — |
| | | 17 23 22 | 93-12W | 146 | 17 52 22 | — |
| | | 17 04 22 | 93-15a | 161 | 17 38 22 | — |
| | | 16 46 22 | 93-13 | 148 | 18 00 22 | — |
| | | 16 41 52 | 93-15a | 161 | 15 58 52 | — |
| 93-1b | 147 | 18 31 30 | 93-10 | 151 | 19 51 22 | — |
| | | 19 43 52 | 92-4 | 261 | 20 56 35 | 890 |
| 93-2 | 153 | 16 41 22 | 93-9 | 157 | 17 52 52 | — |
| | | 17 04 52 | 92-5 | 262 | 14 01 37 | 1032 |
| | | 17 18 30 | 93-10 | 151 | 19 29 22 | — |
| | | 17 37 52 | 92-2 | 260 | 16 19 11 | 277 |
| | | 17 54 22 | 93-11 | 149 | 18 50 52 | — |
| | | 18 28 22 | 93-12W | 146 | 18 25 22 | — |
| | | 18 45 52 | 93-15a | 161 | 18 13 22 | — |
| | | 19 04 22 | 93-13 | 148 | 18 41 22 | — |
| | | 19 26 52 | 93-15a | 161 | 15 03 22 | — |
| 93-3 | 150 | 15 44 22 | 93-8a | 159 | 17 47 22 | — |
| | | 16 23 52 | 93-9 | 157 | 17 10 22 | — |
| | | 17 01 52 | 93-10 | 151 | 18 45 52 | — |
| | | 17 15 52 | 92-2 | 260 | 15 15 07 | 213 |
| | | 17 39 52 | 93-11 | 149 | 18 09 00 | — |

| 1993 survey line | | | Tie lines | | | |
|---|---|---|---|---|---|---|
| Line | Day of the year | Time (hr min) | Line | Day of the year | Time (hr min sec) | Fix |
| | | 18 15 52 | 93-12W | 146 | 19 06 22 | — |
| | | 18 52 52 | 93-12 | 148 | 19 19 22 | — |
| 93-4 | 154 | 14 46 52 | 93-8a | 159 | 17 05 00 | — |
| | | 15 26 22 | 93-9 | 157 | 16 26 52 | — |
| | | 16 07 22 | 93-10 | 151 | 17 55 52 | — |
| | | 16 13 22 | 92-1 | 259 | 21 03 00 | 117 |
| | | 16 13 22 | 92-2 | 260 | 14 17 05 | 155 |
| | | 16 48 22 | 93-11 | 149 | 17 27 52 | — |
| | | 18 22 22 | 93-13 | 148 | 19 32 52 | — |
| 93-5 | 160 | 15 35 52 | 93-8a | 159 | 16 26 00 | — |
| | | 16 17 52 | 93-9 | 157 | 15 41 22 | — |
| | | 16 55 22 | 92-1 | 259 | 20 15 08 | 70 |
| | | 16 57 22 | 93-10 | 151 | 17 10 52 | — |
| | | 17 40 52 | 93-11 | 149 | 16 46 52 | — |
| 93-6 | 162 | 15 33 52 | 93-9 | 157 | 15 02 22 | — |
| | | 16 03 22 | 92-1 | 259 | 19 25 04 | 20 |
| | | 16 12 22 | 93-10 | 151 | 16 36 22 | — |
| | | 16 55 52 | 93-11 | 149 | 16 06 52 | — |
| | | 17 37 52 | 93-12E | 160 | 18 59 52 | — |
| 93-7 | 159 | 19 17 52 | 92-5 | 262 | 15 51 36 | 1142 |
| 93-8a | 159 | 17 55 52 | 92-5 | 262 | 15 13 36 | 1104 |
| | | 17 47 22 | 93-3 | 150 | 15 44 22 | — |
| | | 17 05 00 | 93-4 | 154 | 14 46 52 | — |
| | | 16 26 00 | 93-5 | 160 | 15 35 52 | — |
| 93-9 | 157 | 17 52 52 | 93-2 | 153 | 16 41 22 | — |
| | | 17 37 22 | 92-5 | 262 | 14 29 06 | 1060 |
| | | 17 10 22 | 93-3 | 150 | 16 23 52 | — |

| 1993 survey line | | | Tie lines | | | |
|---|---|---|---|---|---|---|
| Line | Day of the year | Time (hr min) | Line | Day of the year | Time (hr min sec) | Fix |
| | | 16 26 52 | 93-4 | 154 | 15 26 22 | — |
| | | 15 41 22 | 93-5 | 160 | 16 17 52 | — |
| | | 15 02 22 | 93-6 | 162 | 15 33 52 | — |
| 93-10 | 151 | 20 07 52 | 93-1a | 147 | 18 31 30 | — |
| | | 19 51 22 | 93-1b | 147 | 19 32 22 | — |
| | | 19 38 52 | 92-5 | 262 | 13 46 35 | 1018 |
| | | 19 29 22 | 93-2 | 153 | 17 18 30 | — |
| | | 18 45 52 | 93-3 | 150 | 17 01 52 | — |
| | | 17 55 52 | 93-4 | 154 | 16 07 22 | — |
| | | 17 16 22 | 92-1 | 259 | 20 25 06 | 80 |
| | | 17 10 52 | 93-5 | 160 | 16 57 22 | — |
| | | 16 36 22 | 93-6 | 162 | 16 12 22 | — |
| 93-11 | 149 | 20 05 22 | 93-14a | 152 | 16 59 52 | — |
| | | 19 59 52 | 92-2 | 260 | 18 0506 | 381 |
| | | 19 50 52 | 93-14a | 152 | 16 13 52 | — |
| | | 19 28 52 | 93-1a | 147 | 17 56 52 | — |
| | | 19 23 22 | 92-4 | 261 | 20 12 05 | 847 |
| | | 18 50 52 | 93-2 | 153 | 17 54 22 | — |
| | | 18 09 00 | 93-3 | 150 | 17 39 52 | — |
| | | 17 27 52 | 93-4 | 154 | 16 48 22 | — |
| | | 16 46 52 | 93-5 | 160 | 17 40 52 | — |
| | | 16 06 52 | 93-6 | 162 | 16 55 52 | — |
| 93-12E | 160 | 18 59 52 | 93-6 | 162 | 17 37 52 | — |
| 93-12W | 146 | 17 51 22 | 93-1a | 147 | 17 23 52 | — |
| | | 18 10 52 | 93-14a | 152 | 15 05 52 | — |
| | | 18 25 22 | 93-2 | 153 | 18 28 22 | — |
| | | 19 06 22 | 93-3 | 150 | 18 15 52 | — |

| 1993 survey line | | | Tie lines | | | |
|---|---|---|---|---|---|---|
| **Line** | **Day of the year** | **Time (hr min)** | **Line** | **Day of the year** | **Time (hr min sec)** | **Fix** |
| 93-13 | 148 | 17 26 22 | 92-3 | 261 | 14 50 05 | 617 |
| | | 17 49 52 | 93-15a | 161 | 16 09 52 | — |
| | | 18 00 22 | 93-1a | 147 | 16 46 22 | — |
| | | 18 41 22 | 93-2 | 153 | 19 04 22 | — |
| | | 19 19 22 | 93-3 | 150 | 18 52 52 | — |
| | | 19 32 52 | 93-4 | 154 | 18 22 22 | — |
| 93-14a | 152 | 15 05 52 | 93-12W | 146 | 18 10 52 | — |
| | | 15 39 22 | 93-1a | 147 | 17 39 52 | — |
| | | 15 46 52 | 92-4 | 261 | 19 49 05 | 824 |
| | | 16 13 52 | 93-11 | 149 | 19 50 52 | — |
| | | 16 17 52 | 92-2 | 260 | 17 56 06 | 372 |
| | | 16 59 52 | 93-11 | 149 | 20 05 22 | — |
| | | 17 02 52 | 92-2 | 260 | 18 15 06 | 391 |
| | | 17 14 52 | 93-14b | 155 | 13 52 34 | — |
| 93-14b | 155 | 13 52 34 | 93-14a | 152 | 17 14 52 | — |
| | | 14 11 22 | 92-2 | 260 | 18 35 44 | 408 |
| | | 14 26 22 | 93-16 | 163 | 17 57 22 | — |
| | | 14 40 58 | 92-2 | 260 | 19 03 36 | 435 |
| | | 14 58 52 | 93-16 | 163 | 13 25 40 | — |
| | | 15 07 52 | 93-16 | 163 | 13 27 28 | — |
| | | 15 16 22 | 93-16 | 163 | 17 11 22 | — |
| | | 15 16 32 | 92-2 | 260 | 19 28 06 | 460 |
| | | 15 41 34 | 93-16 | 163 | 16 50 04 | — |
| | | 15 43 10 | 92-2 | 260 | 19 53 12 | 486 |
| | | 15 52 58 | 93-16 | 163 | 13 38 22 | — |
| | | 16 21 04 | 93-16 | 163 | 13 45 52 | — |
| | | 16 22 16 | 93-16 | 163 | 16 24 04 | — |

| 1993 survey line | | | Tie lines | | | |
|---|---|---|---|---|---|---|
| Line | Day of the year | Time (hr min) | Line | Day of the year | Time (hr min sec) | Fix |
| | | 16 22 52 | 92-2 | 260 | 20 17 31 | 510 |
| | | 16 46 46 | 93-16 | 163 | 16 19 04 | — |
| | | 16 53 40 | 92-2 | 260 | 20 38 36 | 535 |
| | | 16 54 22 | 93-14b | 155 | 18 20 22 | — |
| | | 16 55 37 | 93-16 | 163 | 14 15 22 | — |
| | | 16 57 04 | 93-16 | 163 | 15 22 52 | — |
| | | 16 57 52 | 93-16 | 163 | 15 53 46 | — |
| | | 17 26 40 | 92-2 | 260 | 21 05 43 | 562 |
| | | 17 26 52 | 93-16 | 163 | 14 52 22 | — |
| | | 17 28 37 | 93-16 | 163 | 14 42 22 | — |
| | | 17 29 22 | 93-14b | 155 | 17 57 52 | — |
| | | 17 57 52 | 93-14b | 155 | 17 29 22 | — |
| | | 18 00 52 | 93-16 | 163 | 14 38 22 | — |
| | | 18 10 22 | 93-16 | 163 | 14 27 22 | — |
| | | 18 17 16 | 93-16 | 163 | 15 55 42 | — |
| | | 18 17 40 | 92-2 | 260 | 20 42 25 | 539 |
| | | 18 20 22 | 93-14b | 155 | 16 54 22 | — |
| 93-15a | 161 | 15 03 22 | 93-2 | 153 | 19 26 52 | — |
| | | 15 58 52 | 93-1a | 147 | 16 41 52 | — |
| | | 16 09 52 | 93-13 | 148 | 17 49 52 | — |
| | | 16 36 22 | 92-3 | 261 | 14 32 05 | 599 |
| | | 17 11 52 | 92-3 | 261 | 14 29 10 | 596 |
| | | 17 38 22 | 93-1a | 147 | 17 04 22 | — |
| | | 18 13 22 | 93-2 | 153 | 18 45 52 | — |
| 93-15b | 158 | 14 22 52 | 92-3 | 261 | 17 05 06 | 752 |
| | | 14 41 22 | 92-3 | 261 | 16 56 35 | 744 |
| | | 16 22 52 | 92-3 | 261 | 16 40 04 | 727 |

| 1993 survey line | | | Tie lines | | | |
|---|---|---|---|---|---|---|
| Line | Day of the year | Time (hr min) | Line | Day of the year | Time (hr min sec) | Fix |
| | | 15 40 22 | 92-3 | 261 | 16 29 04 | 716 |
| | | 15 56 22 | 92-3 | 261 | 16 19 35 | 706 |
| | | 16 20 52 | 92-3 | 261 | 16 09 05 | 696 |
| | | 17 08 52 | 92-3 | 261 | 15 35 18 | 662 |
| | | 17 48 52 | 92-3 | 261 | 15 15 38 | 642 |
| 93-16 | 163 | 13 25 40 | 93-14b | 155 | 14 58 52 | — |
| | | 13 27 28 | 93-14b | 155 | 15 07 52 | — |
| | | 13 38 22 | 93-14b | 155 | 15 52 58 | — |
| | | 13 45 52 | 93-14b | 155 | 16 21 04 | — |
| | | 14 15 22 | 93-14b | 155 | 16 55 37 | — |
| | | 14 17 22 | 93-16 | 163 | 15 55 22 | — |
| | | 14 19 52 | 92-2 | 260 | 20 45 37 | 541 |
| | | 14 27 22 | 93-14b | 155 | 18 10 22 | — |
| | | 14 38 22 | 93-14b | 155 | 18 00 52 | — |
| | | 14 42 22 | 93-14b | 155 | 17 28 37 | — |
| | | 14 52 22 | 93-14b | 155 | 17 26 52 | — |
| | | 14 55 22 | 92-2 | 260 | 21 03 07 | 559 |
| | | 15 21 52 | 93-16 | 163 | 15 54 10 | — |
| | | 15 22 52 | 93-14b | 155 | 16 57 04 | — |
| | | 15 53 46 | 93-14b | 155 | 16 57 52 | — |
| | | 15 54 10 | 93-16 | 163 | 15 21 52 | — |
| | | 15 55 22 | 93-16 | 163 | 14 17 22 | — |
| | | 15 55 40 | 92-2 | 260 | 20 42 55 | 539 |
| | | 15 55 42 | 93-14b | 155 | 18 17 16 | — |
| | | 16 04 52 | 93-16 | 163 | 16 13 04 | — |
| | | 16 13 04 | 93-16 | 163 | 16 04 52 | — |
| | | 16 19 04 | 93-14b | 155 | 16 46 46 | — |

| 1993 survey line | | | Tie lines | | | |
|---|---|---|---|---|---|---|
| Line | Day of the year | Time (hr min) | Line | Day of the year | Time (hr min sec) | Fix |
| | | 16 23 16 | 92-2 | 260 | 20 19 37 | 513 |
| | | 16 24 04 | 93-14b | 155 | 16 22 16 | — |
| | | 16 32 34 | 92-2 | 260 | 20 04 07 | 497 |
| | | 16 50 04 | 93-14b | 155 | 15 41 34 | — |
| | | 16 59 10 | 92-2 | 260 | 19 42 37 | 475 |
| | | 17 11 22 | 93-14b | 155 | 15 16 22 | — |
| | | 17 13 22 | 92-2 | 260 | 19 26 36 | 458 |
| | | 17 57 22 | 93-14b | 155 | 14 26 22 | — |

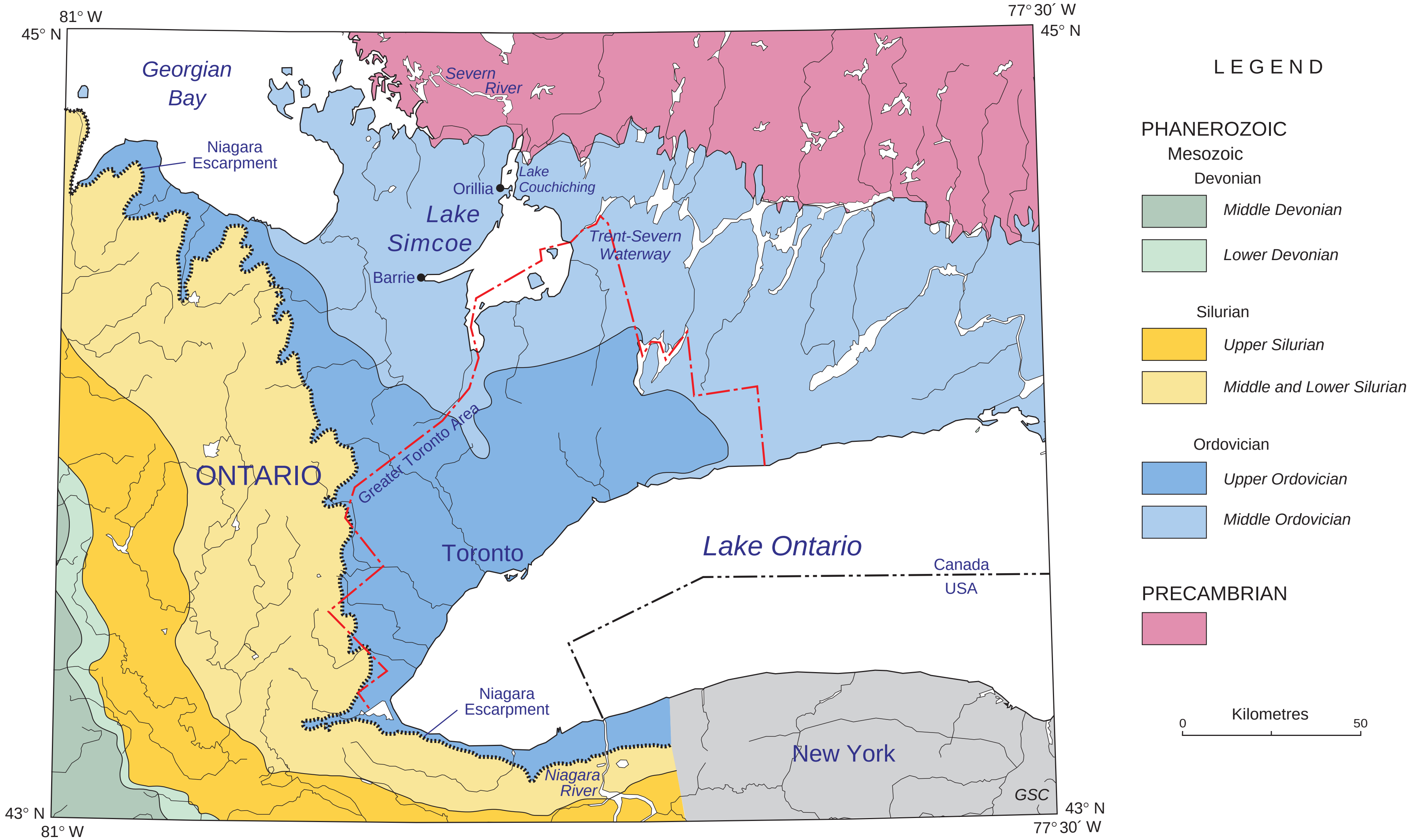



Figure 1. Location map of Lake Simcoe in southern Ontario. Note that the political boundary of the Greater Toronto Area includes southern Lake Simcoe. The Precambrian Grenville Province of the Canadian Shield lies north of the lake. Paleozoic sedimentary rocks overlain by Quaternary sediments occupy southern Ontario.Geological boundaries adapted from Ontario Geological Survey (1991).

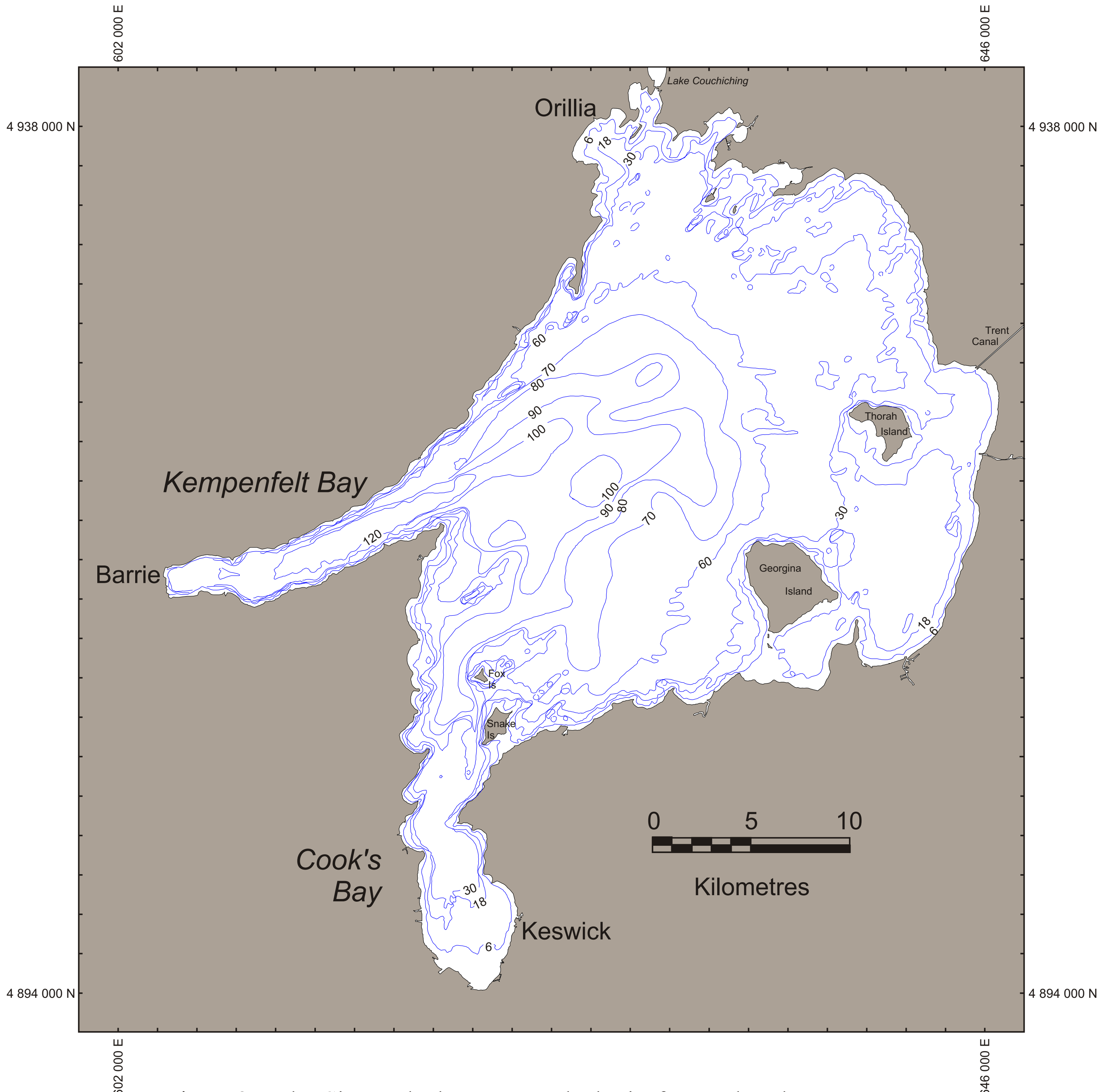



Figure 2. Lake Simcoe bathymetry. Isobaths in feet, reduced to Low Water Datum. Lake elevation is 218.7 m or 717.5 feet. UTM Projection, Zone 17, North American Datum 1927. Digitized and interpolated from Canadian Hydrographic Service Chart 2028, Lake Simcoe, 1987.

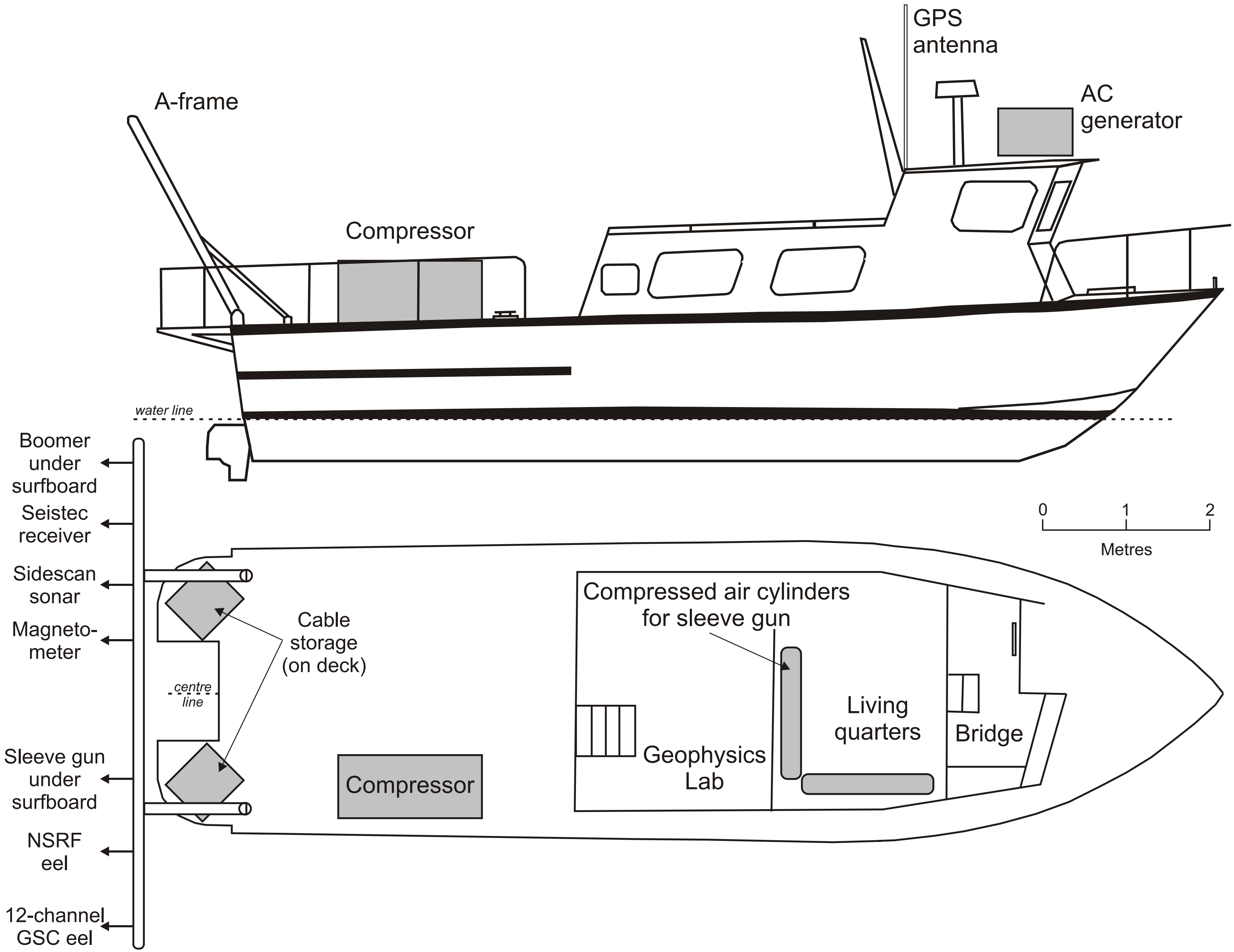



Figure 3. Elevation and plan view of MV *J. Ross Mackay* showing survey equipment layout.


Figure 4. MV *J. Ross Mackay* underway in Lake Simcoe, June, 1993.

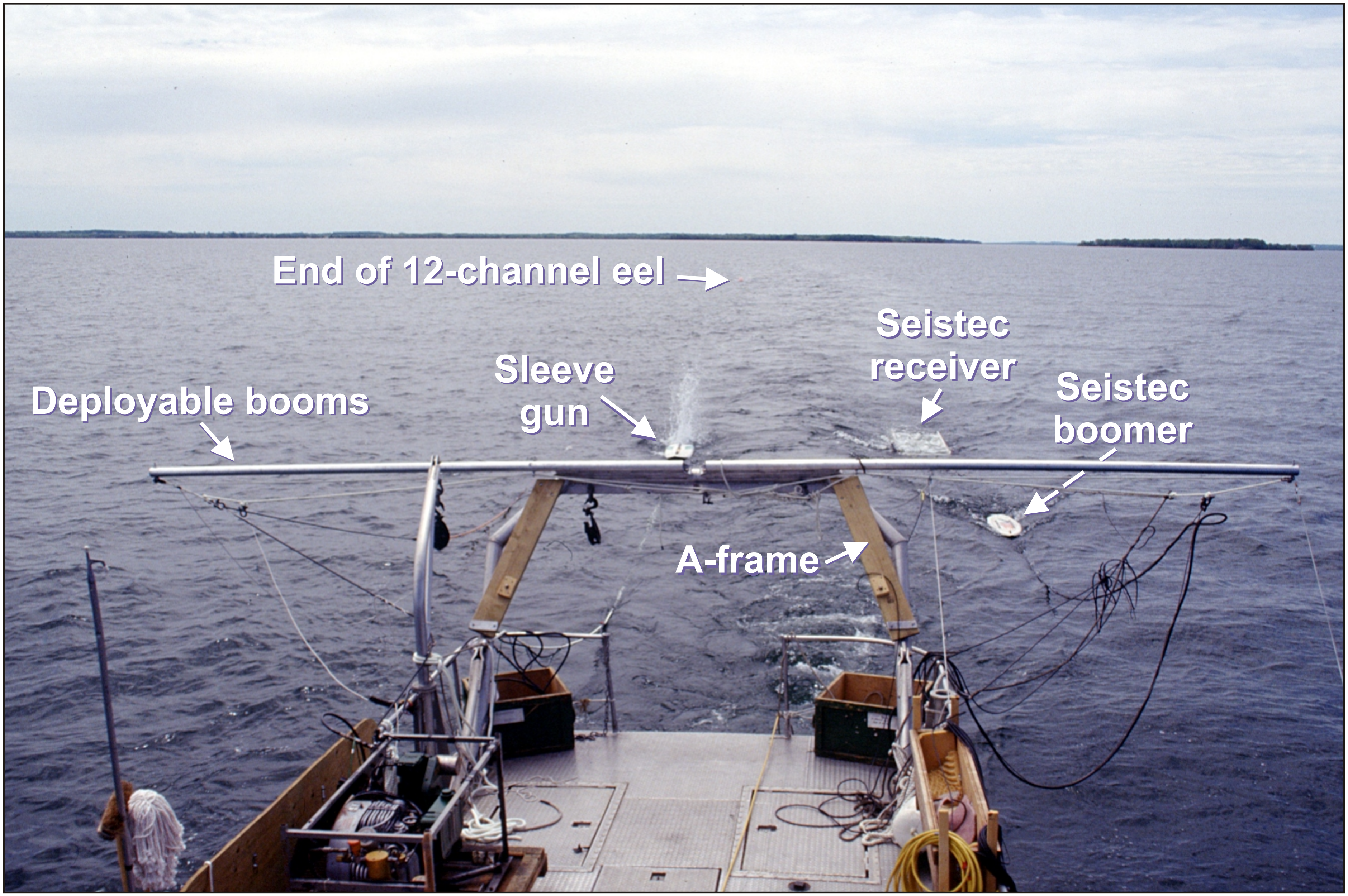



Figure 5. View aft of the MV *J. Ross Mackay* illustrating towing of geophysical instruments from deployable booms.

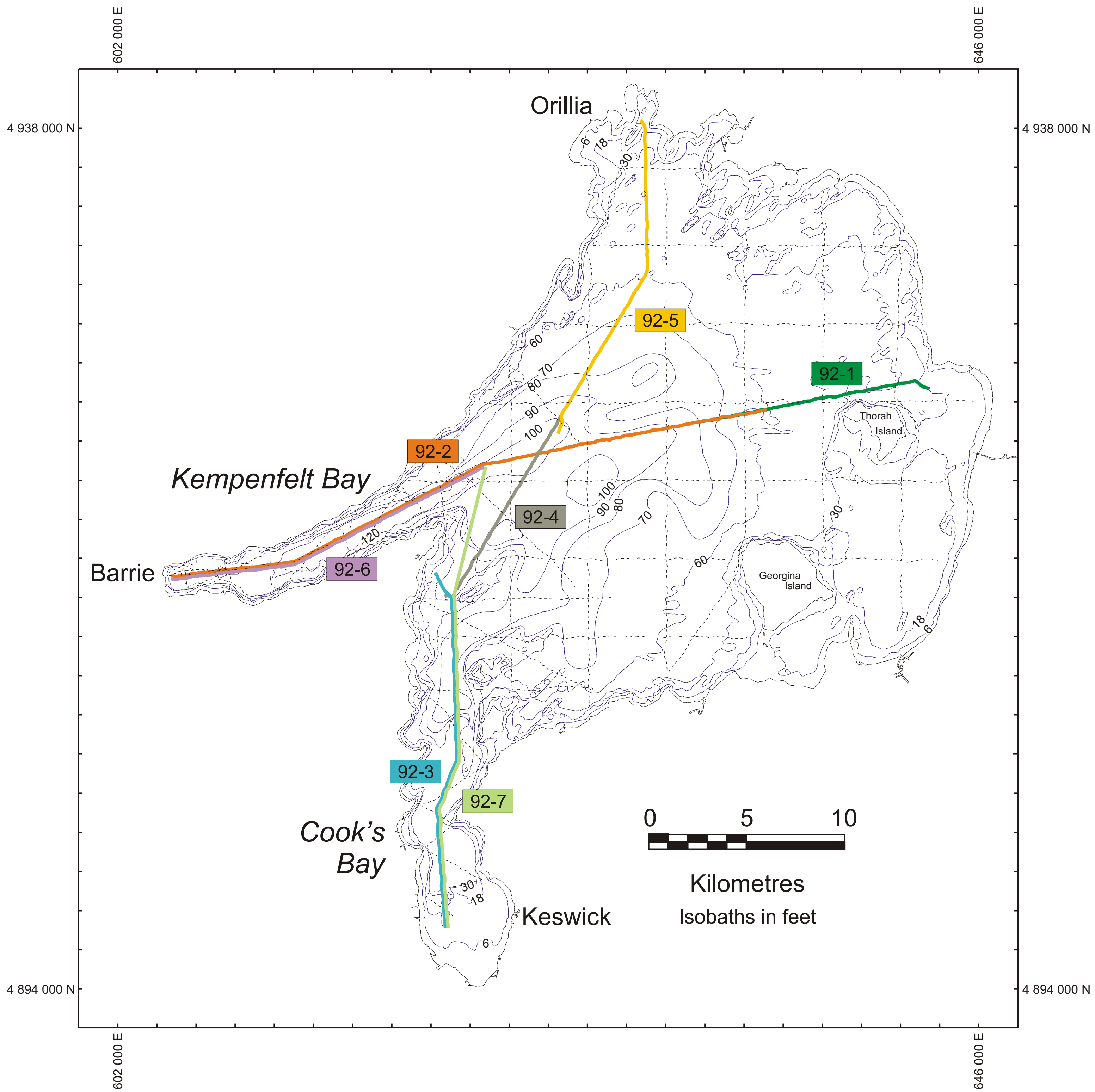



Figure 6. Lake Simcoe 1992 survey lines.

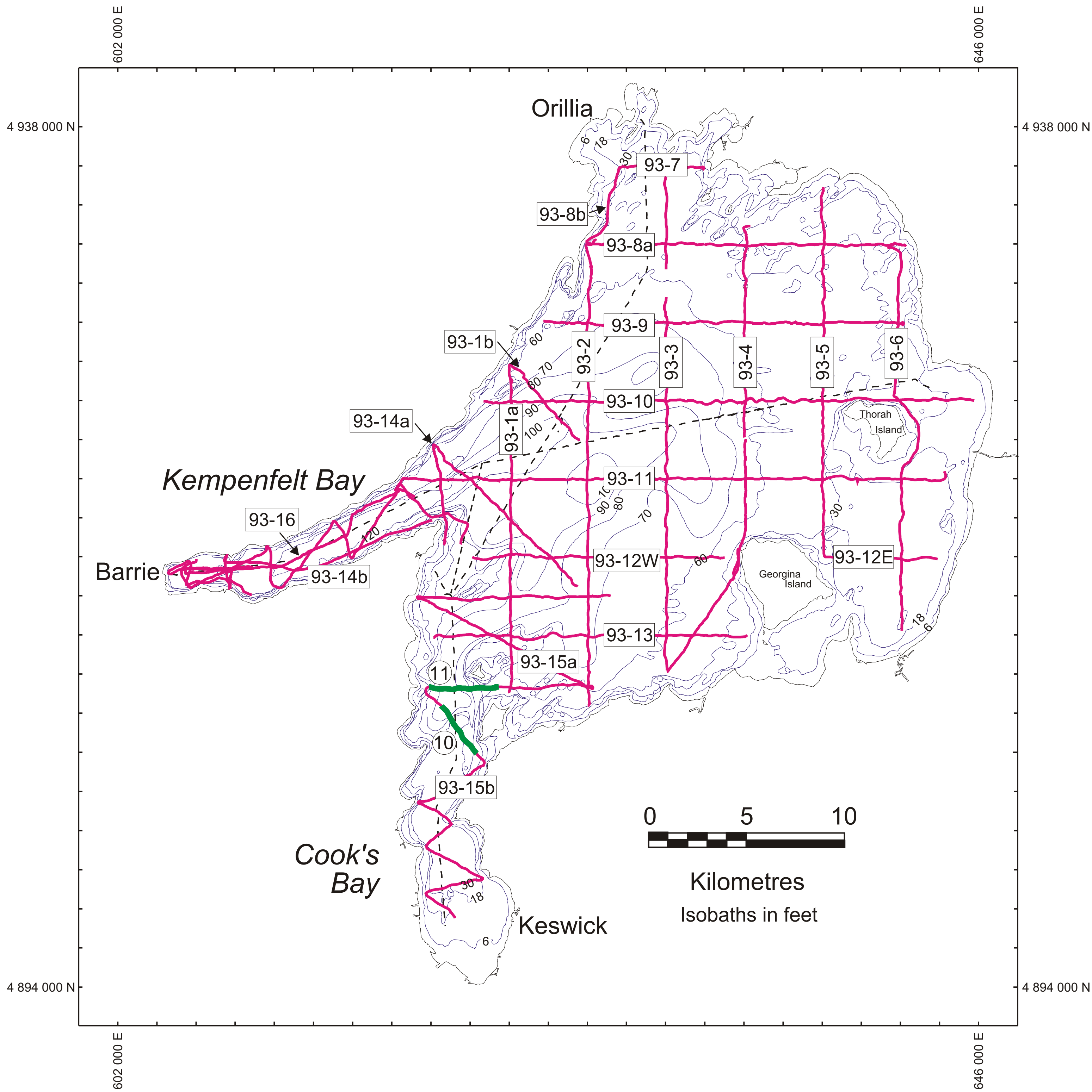



Figure 7. Lake Simcoe 1993 survey lines. The two sections of line 93-15b highlighted in green indicate the locations of the seismic profiles illustrated in Figures 10 and 11.

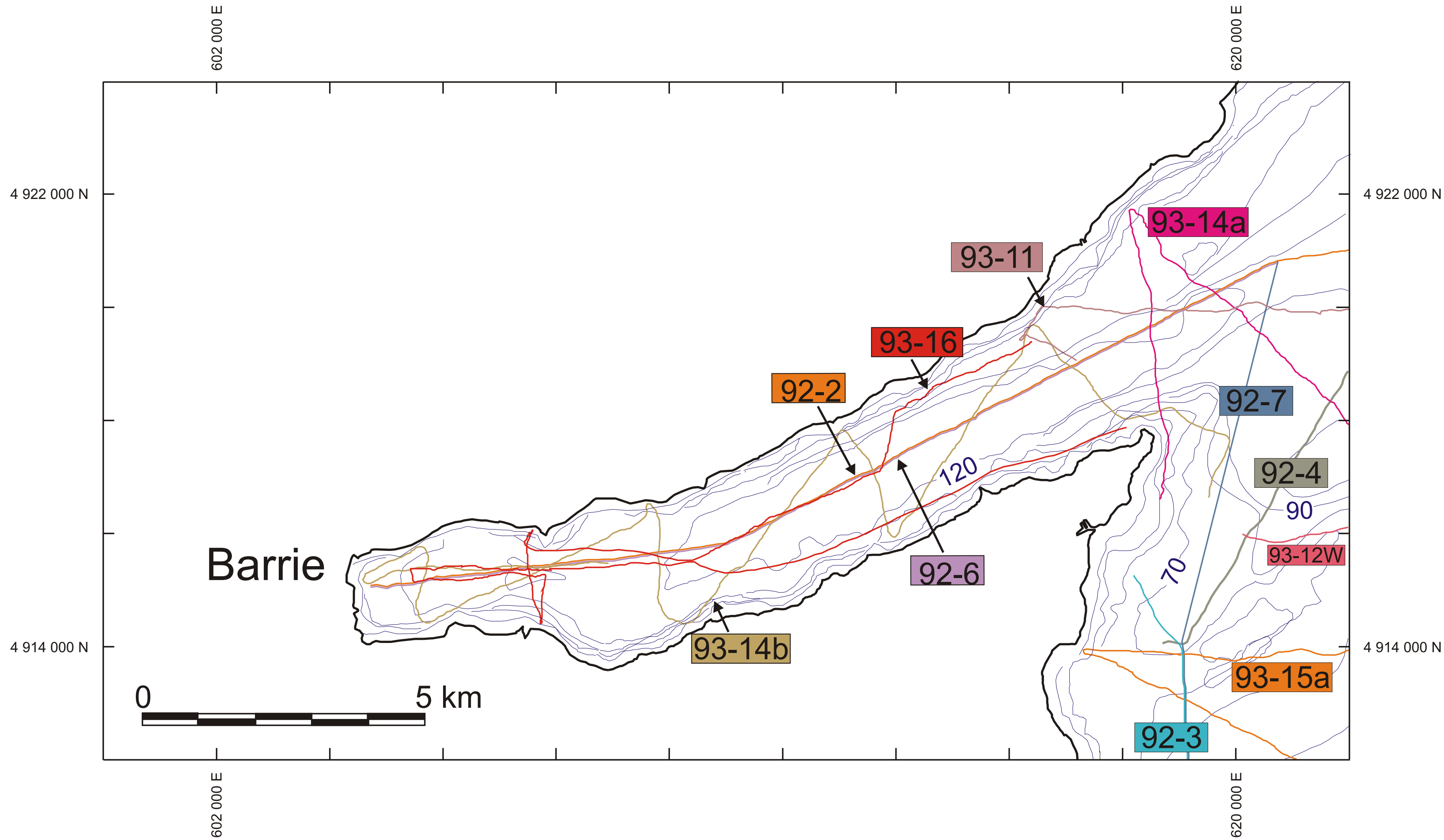



Figure 8. Kempenfelt Bay survey lines, 1992 and 1993.

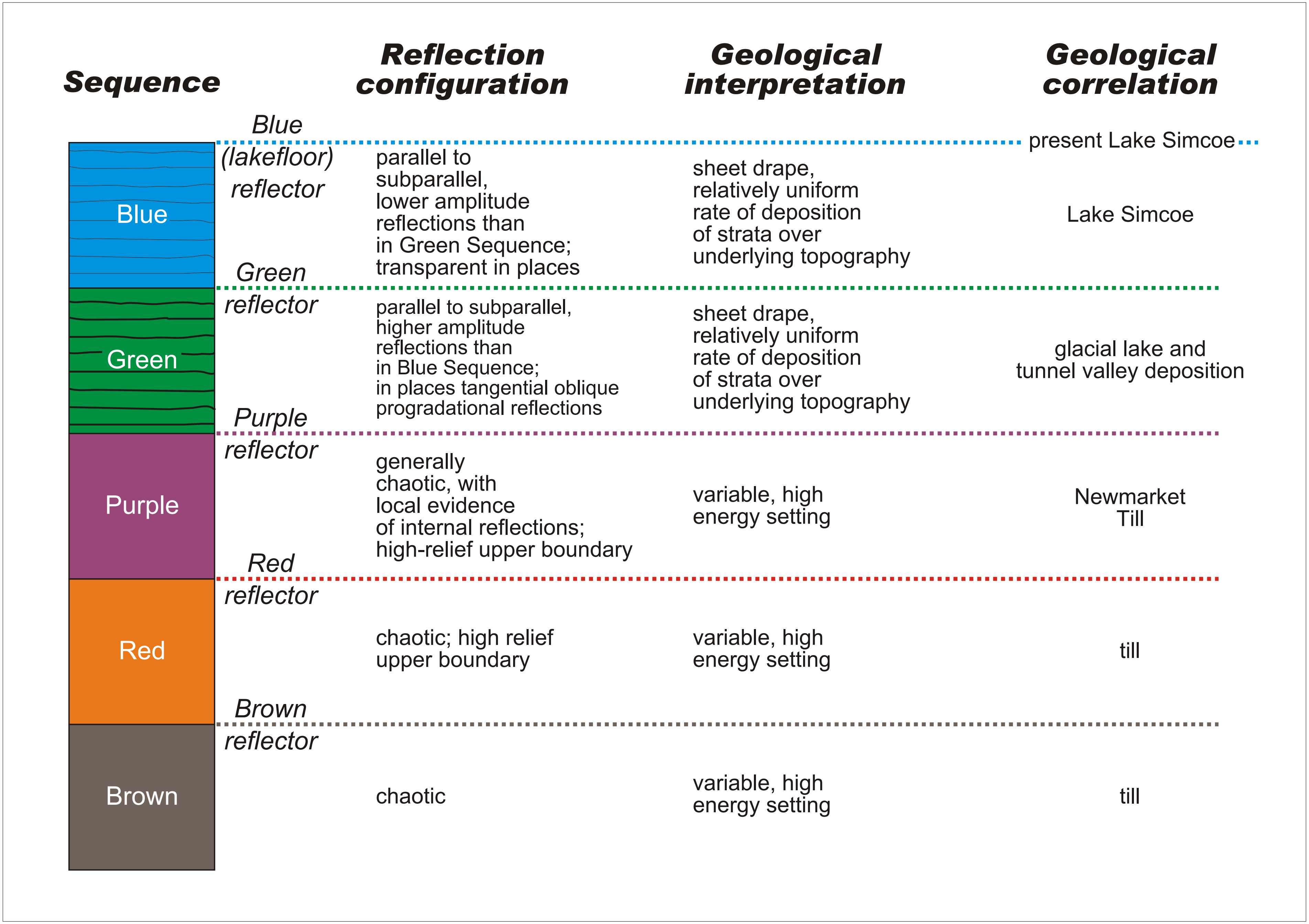



Figure 9. Lake Simcoe seismostratigraphic sequences, reflection configuration, geological interpretation and geological correlation.

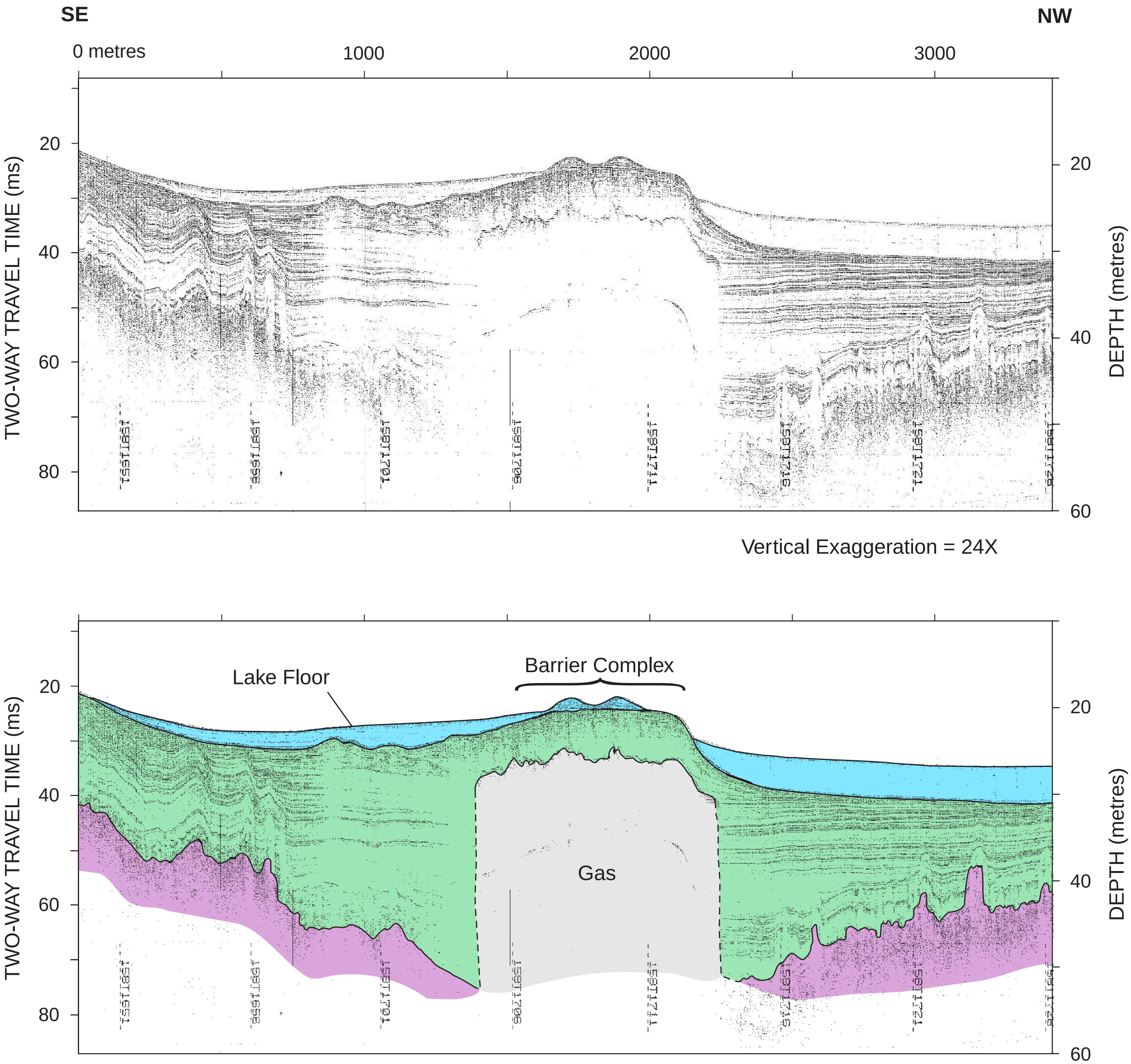



Figure 10. Seistec IKB seismic reflection profile (upper) and interpretive cross section showing stratigraphic relations (lower) across possible drowned barrier complex in Cook's Bay in southern Lake Simcoe. Acoustic basement is Purple Sequence, overlain by Green and Blue Sequences. Reflections beneath the barrier are masked by the presence of gas in the sediments. See Figure 7 for location of profile (Line 93-15b, day 158, 1650-1726).

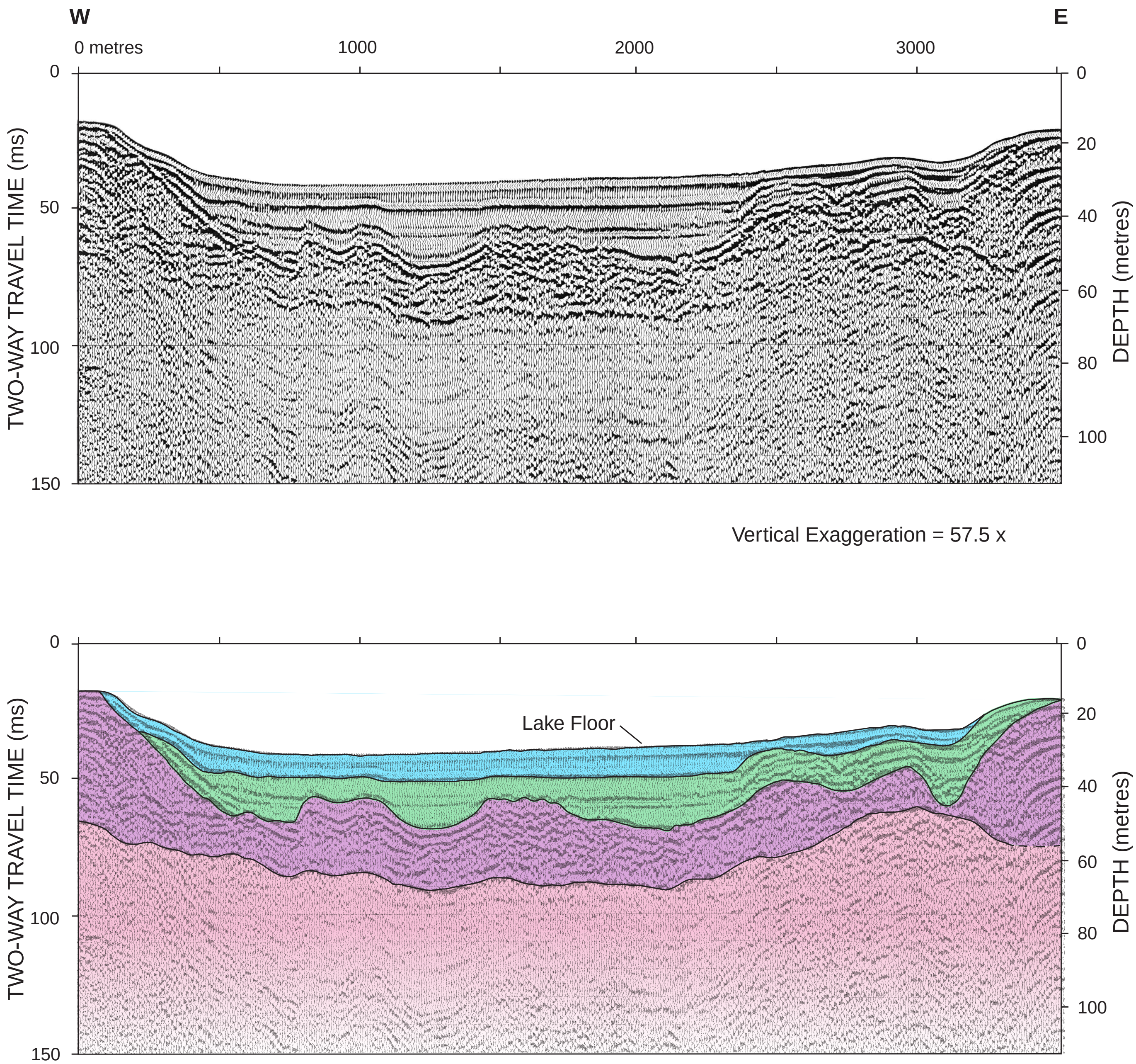



Figure 11. Airgun single-channel seismic reflection profile (upper) and interpretive cross-sectionshowing stratigraphic relations (lower) in Cook's Bay in southern Lake Simcoe. Acousticbasement is Red Sequence, overlain by Purple, Green and Blue Sequences. See Figure 7 for location of profile (Line 93-15b, day 158, 1735-1811).

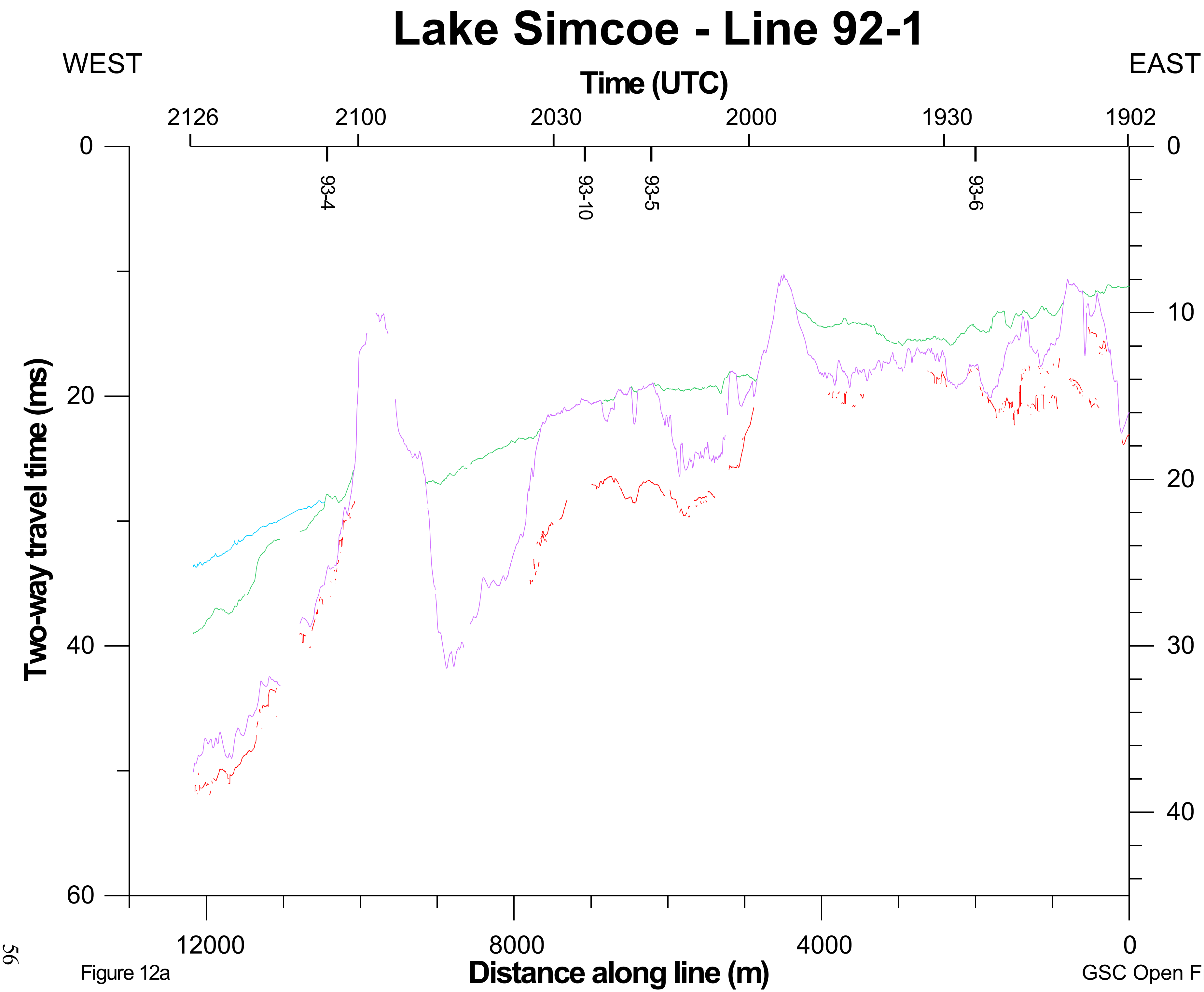



Figure 12a

GSC Open File 3037

# Lake Simcoe - Line 92-2

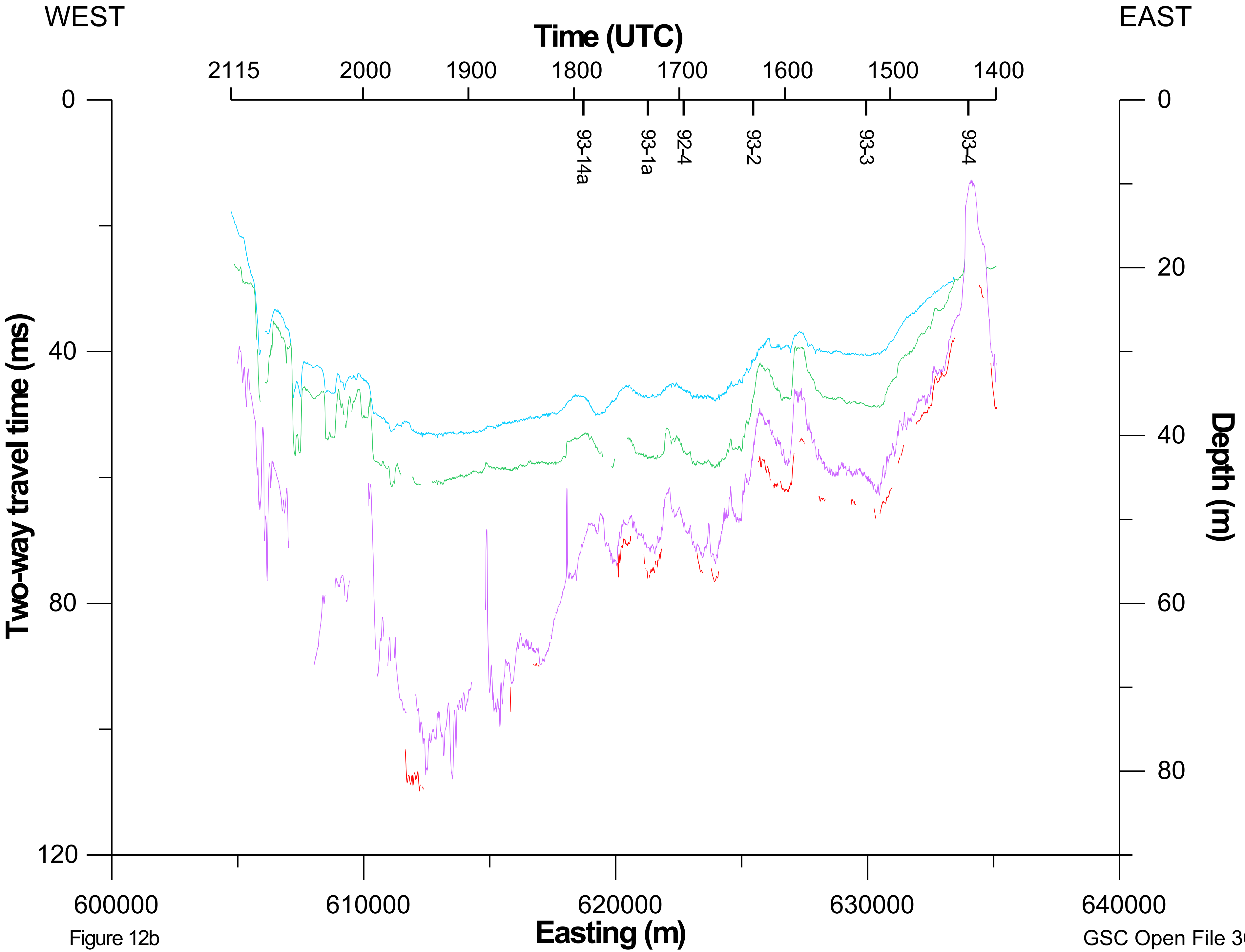



Figure 12b

GSC Open File 3037

# Lake Simcoe - Line 92-3

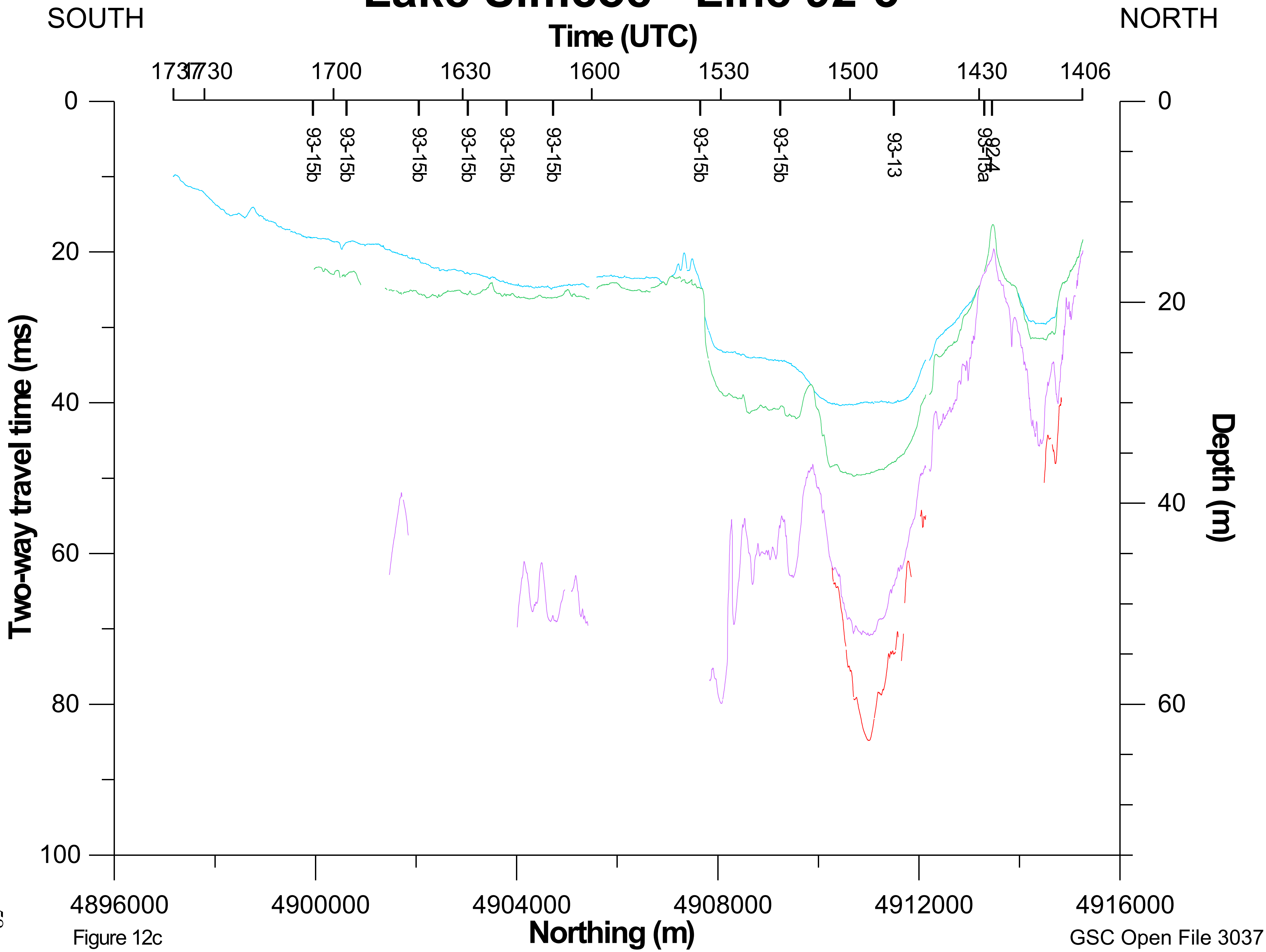



Figure 12c

GSC Open File 3037

# Lake Simcoe - Line 92-4

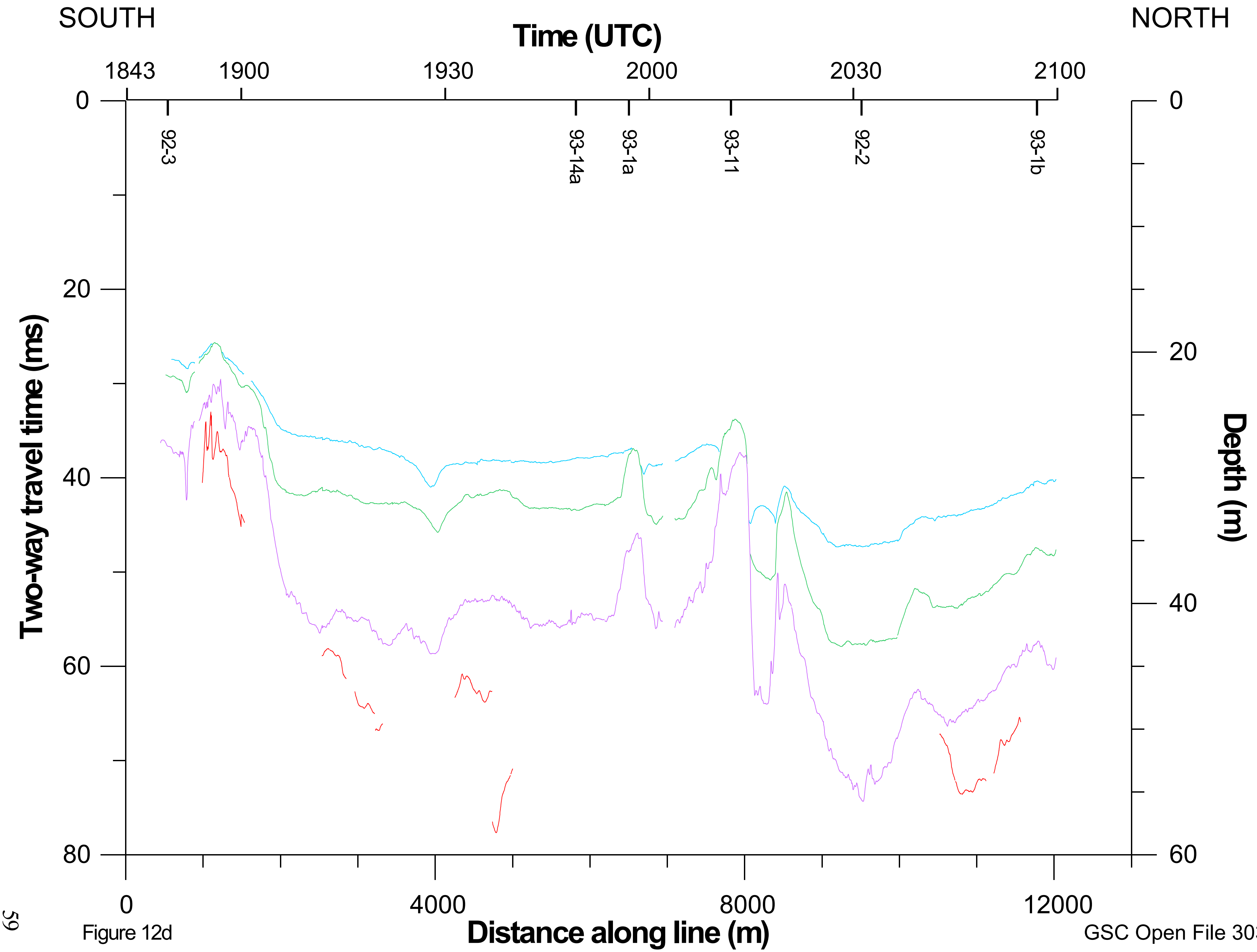



Figure 12d

GSC Open File 3037

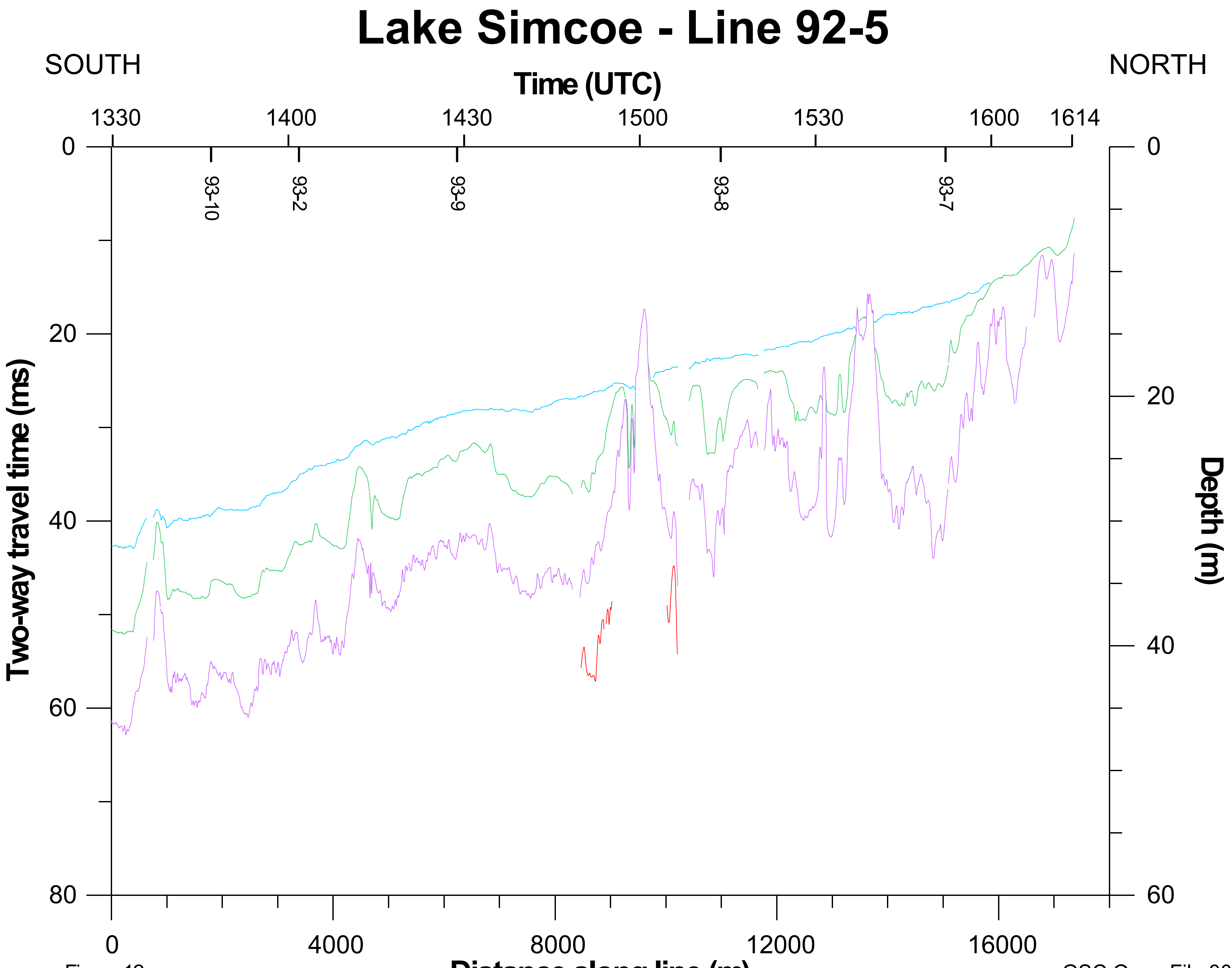



Figure 12e

GSC Open File 3037

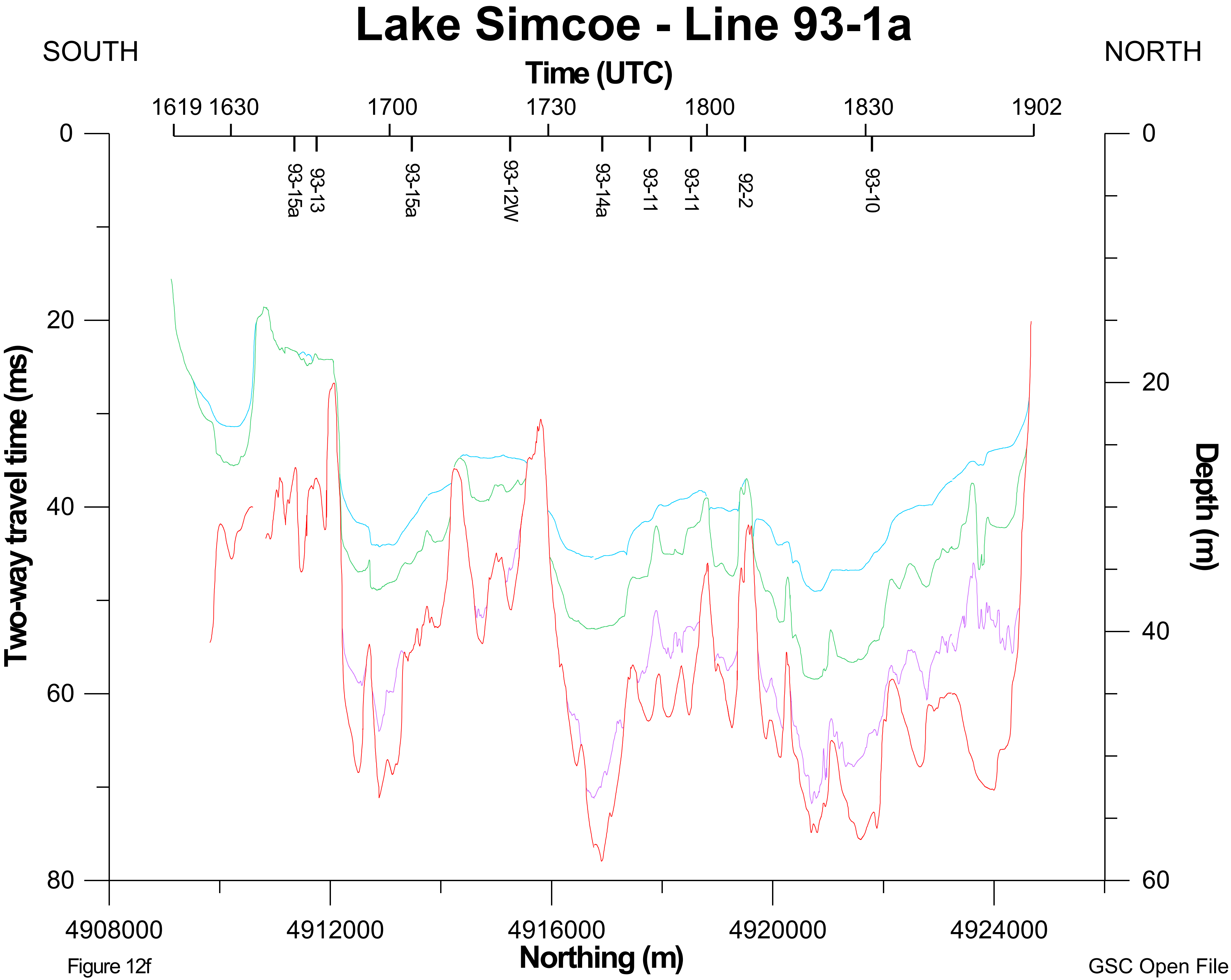



Figure 12f

GSC Open File 3037

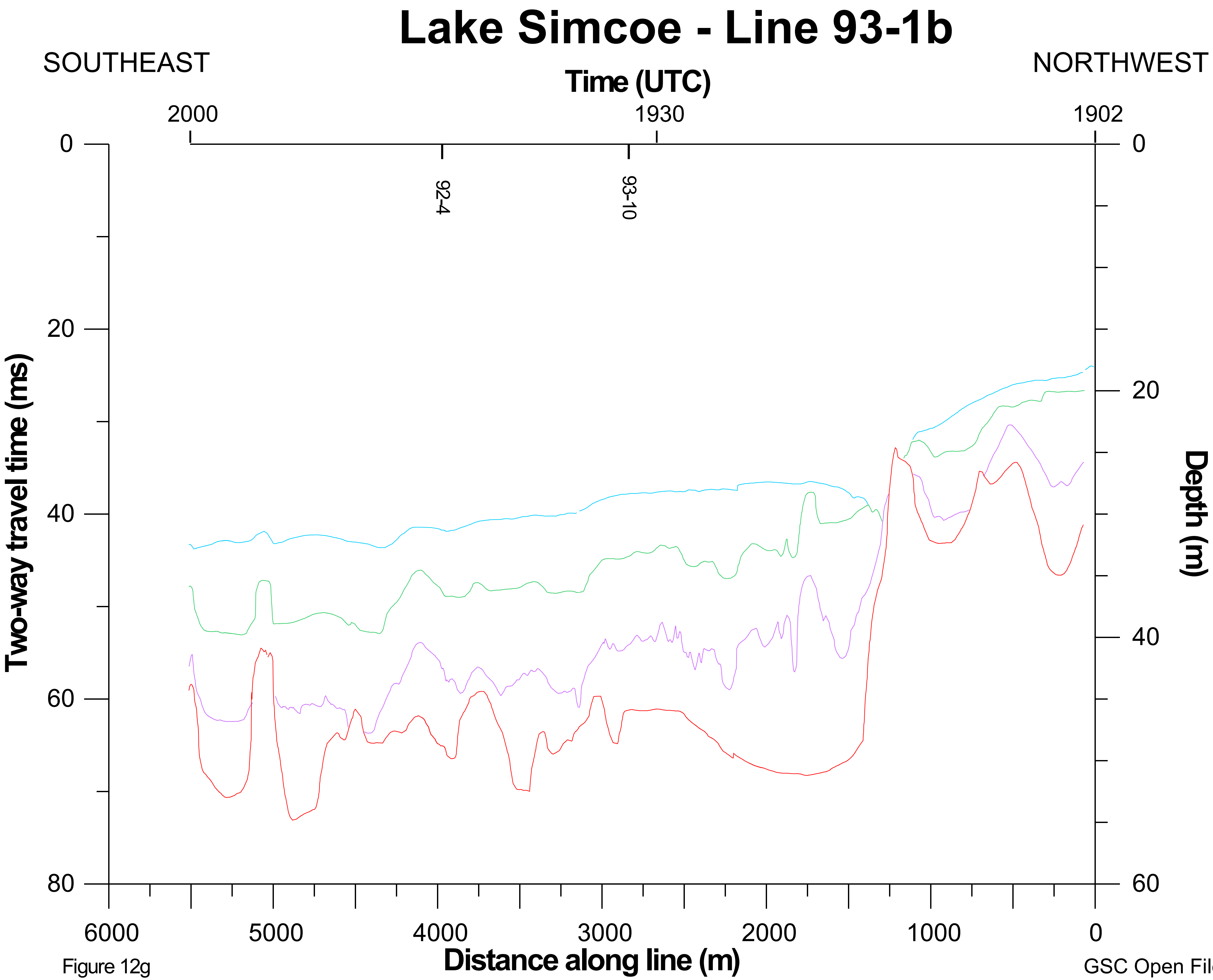





Figure 12g

GSC Open File 3037

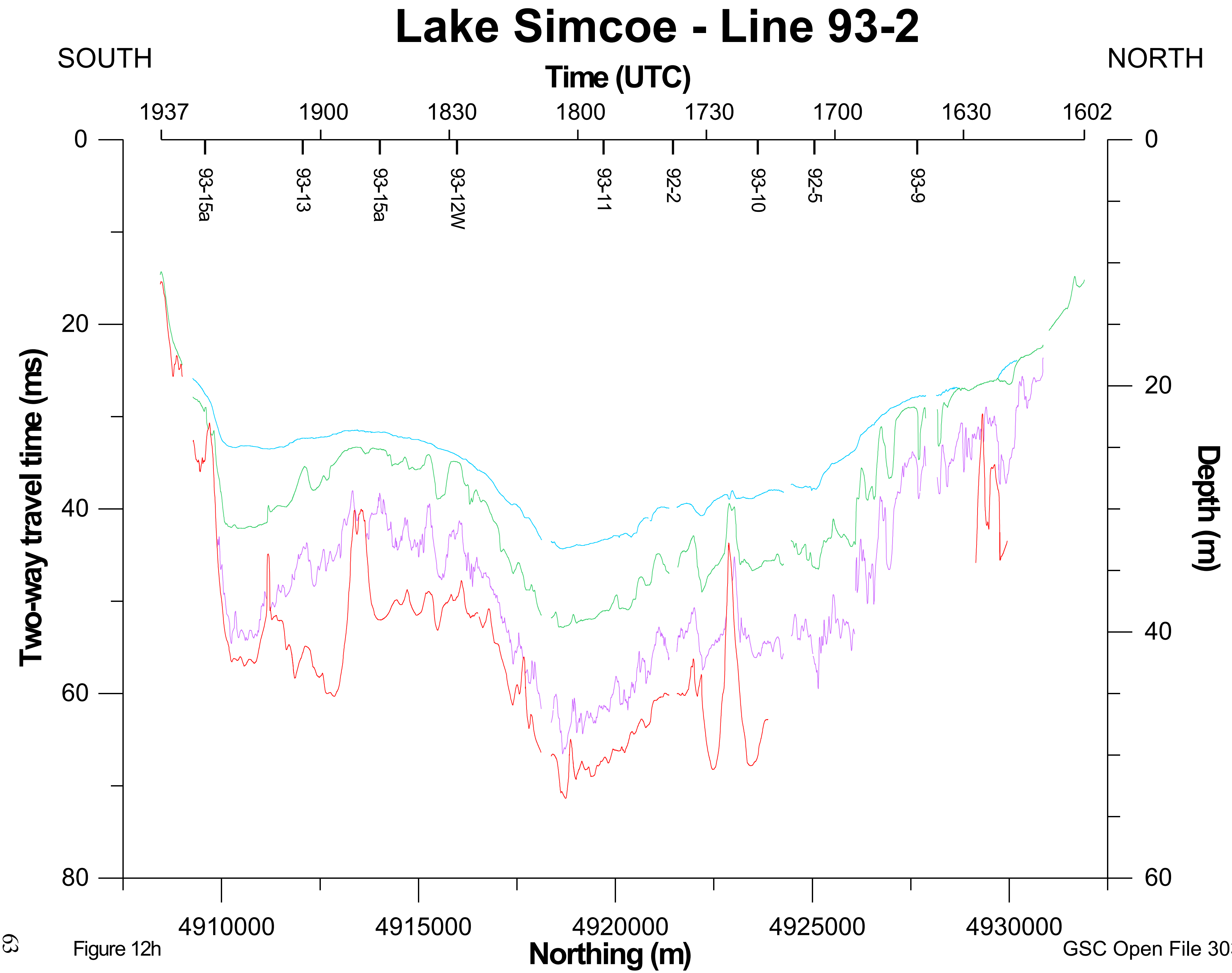

Lake Simcoe - Line 93-2
SOUTH
NORTH
Time (UTC)
1937
1900
1830
1800
1730
1700
1630
1602
93-15a
93-13
93-15a
93-12W
93-11
92-2
93-10
92-5
93-9
Two-way travel time (ms)
0
20
40
60
80
Depth (m)
0
20
40
60
4910000
4915000
4920000
4925000
4930000
Northing (m)

Figure 12h

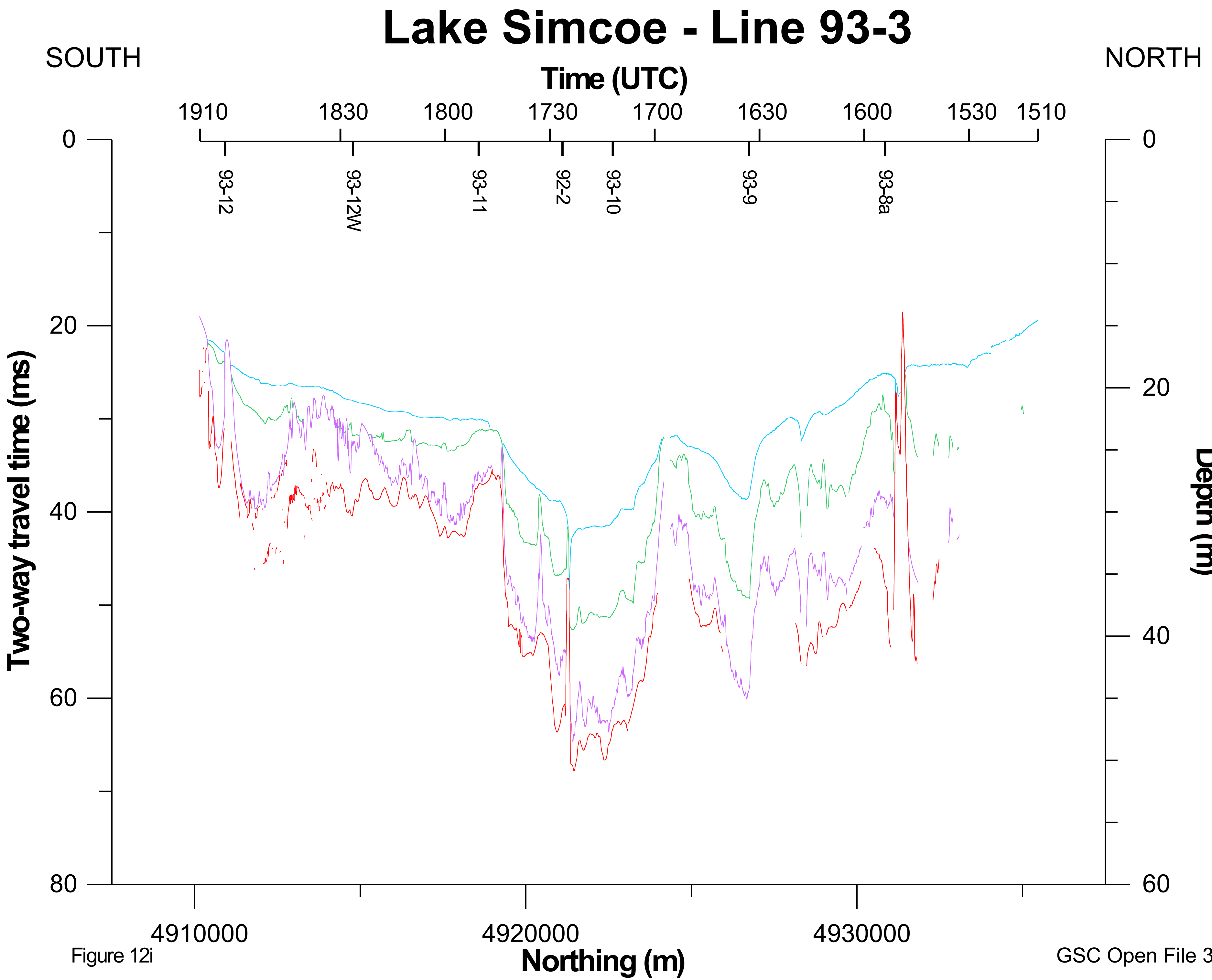



Figure 12i

GSC Open File 3037

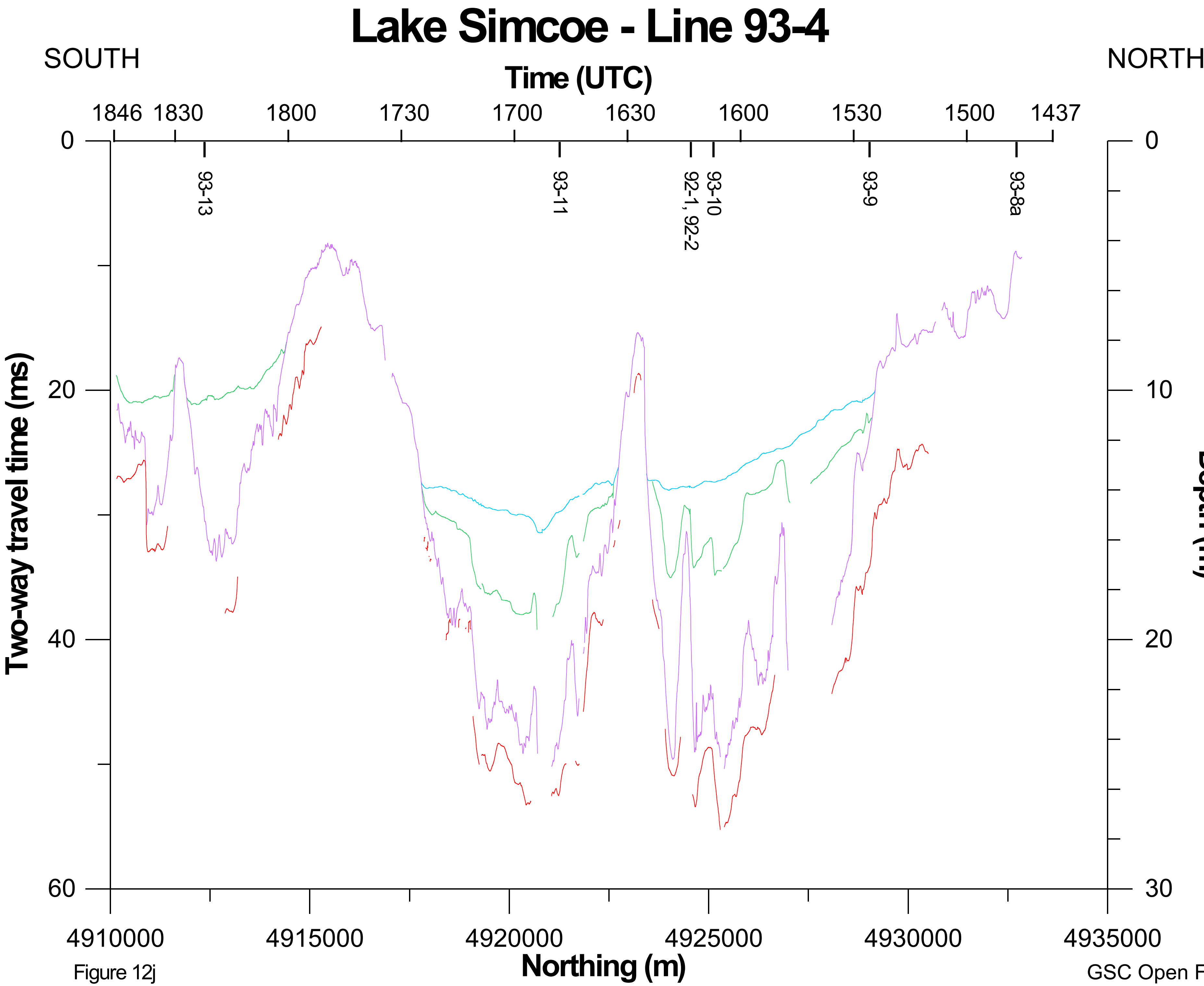



Figure 12j

GSC Open File 3037

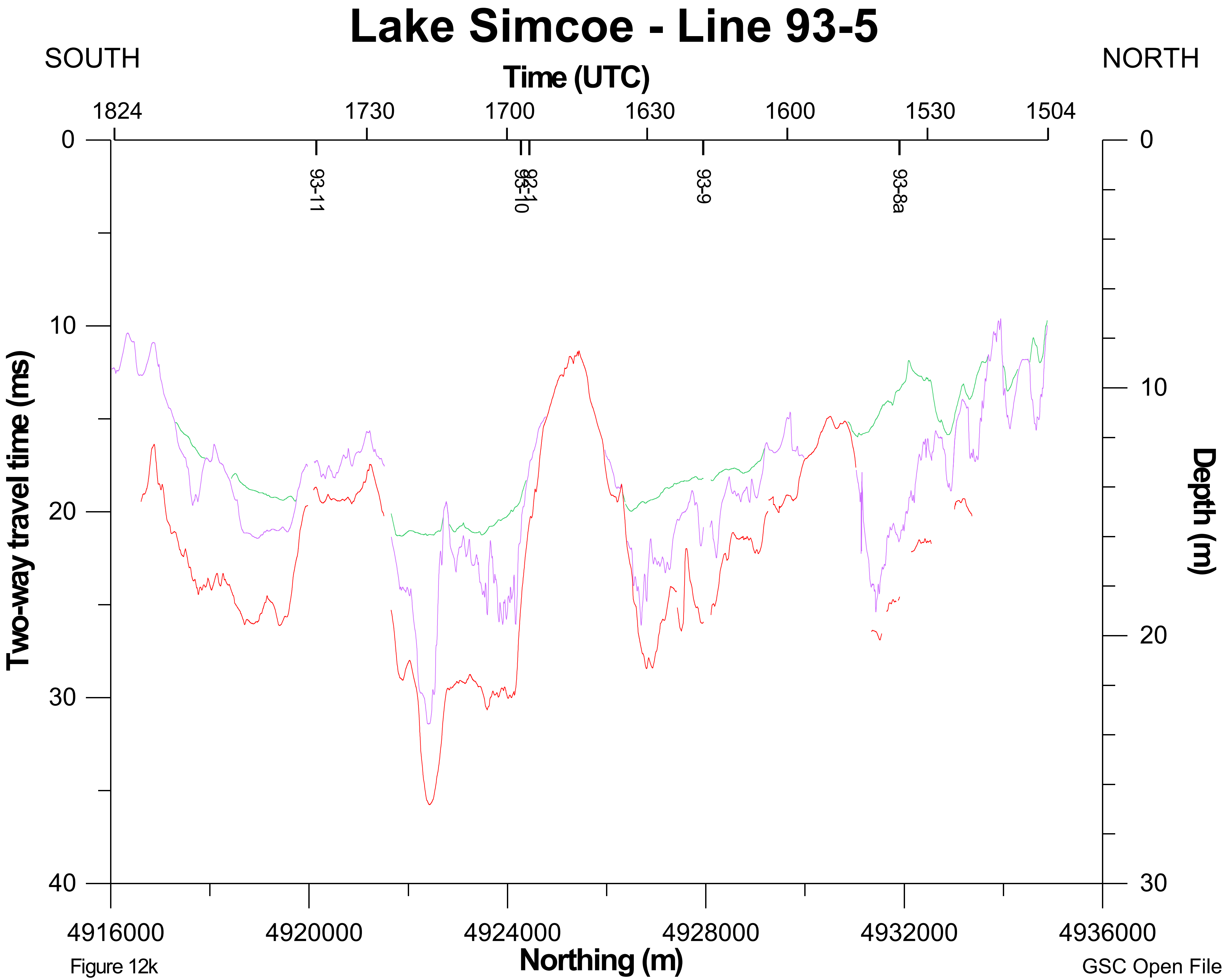
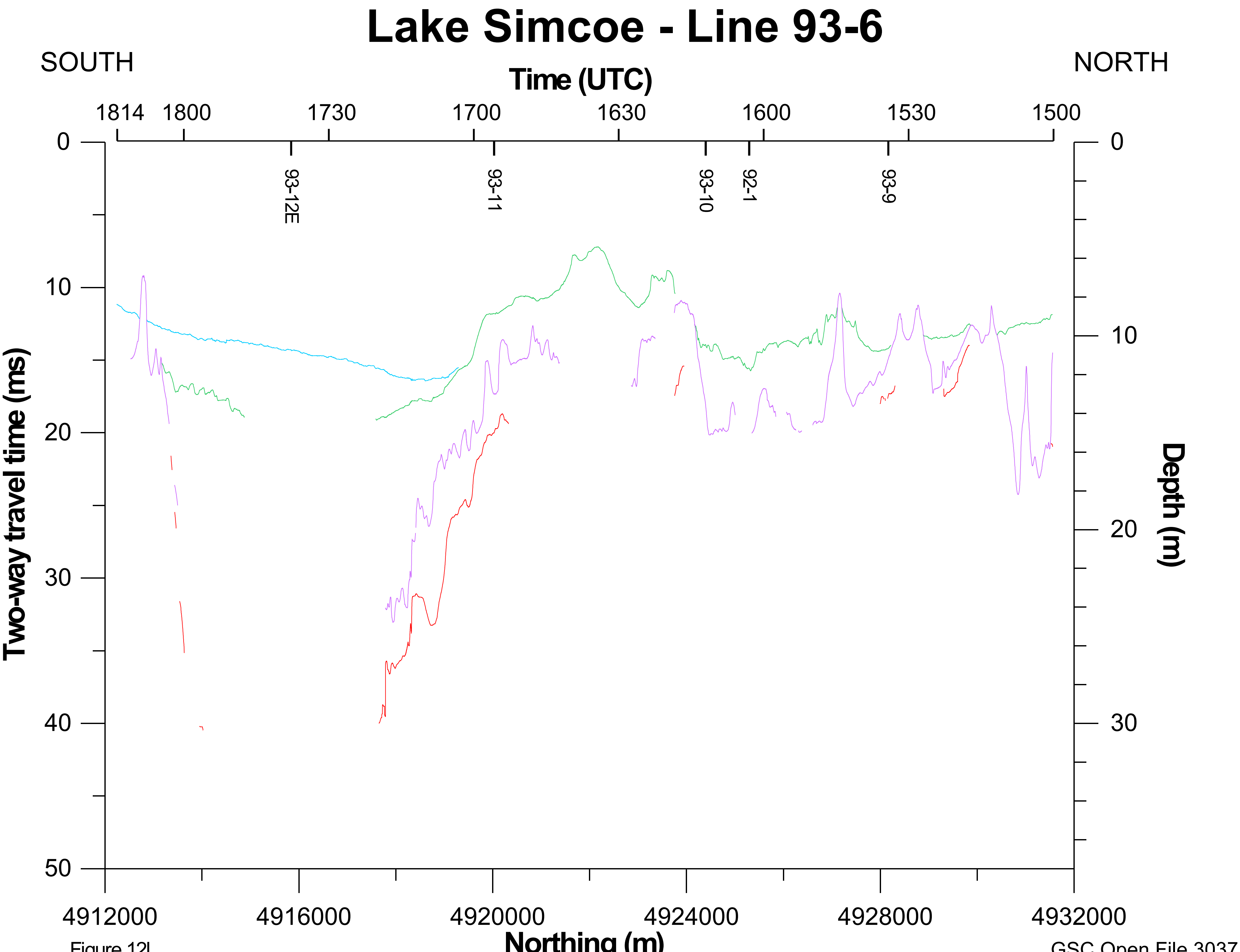



Figure 12k

GSC Open File 3037


Lake Simcoe - Line 93-6
SOUTH
NORTH
Time (UTC)
1814
1800
1730
1700
1630
1600
1530
1500
93-12E
93-11
93-10
92-1
93-9
Two-way travel time (ms)
0
10
20
30
40
50
Depth (m)
0
10
20
30
4912000
4916000
4920000
4924000
4928000
4932000
Northing (m)
Figure 12l

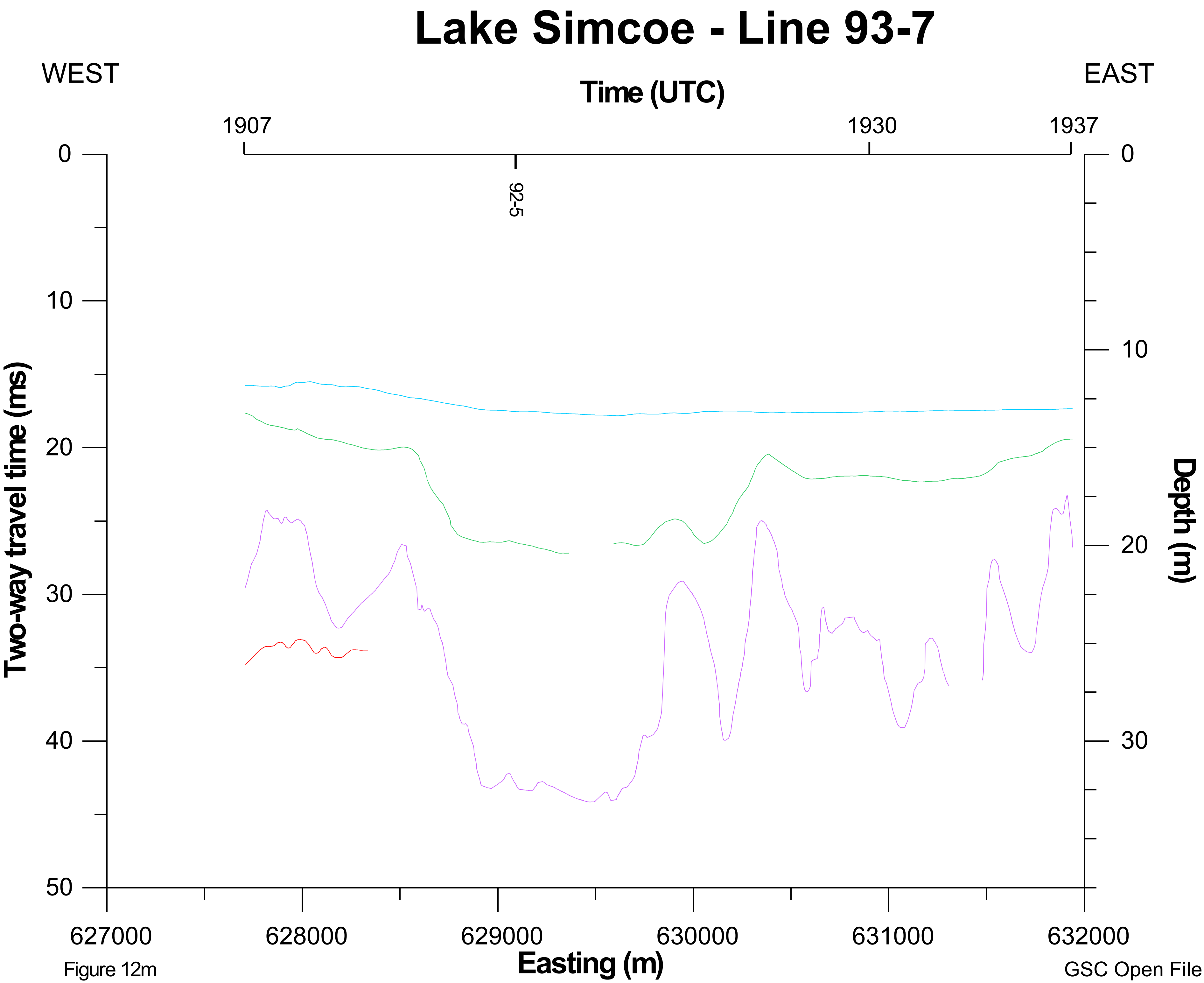



Figure 12m



GSC Open File 3037

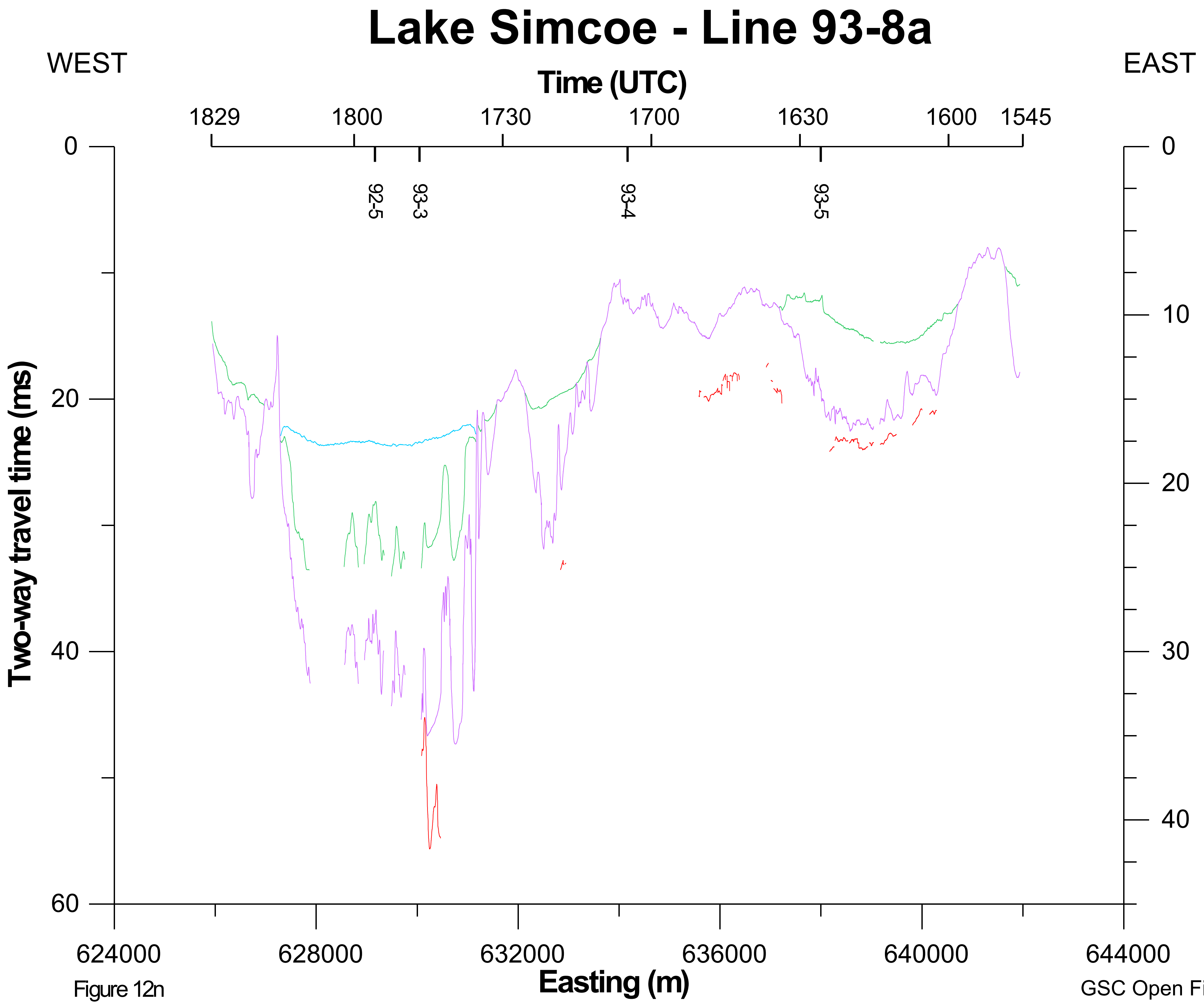
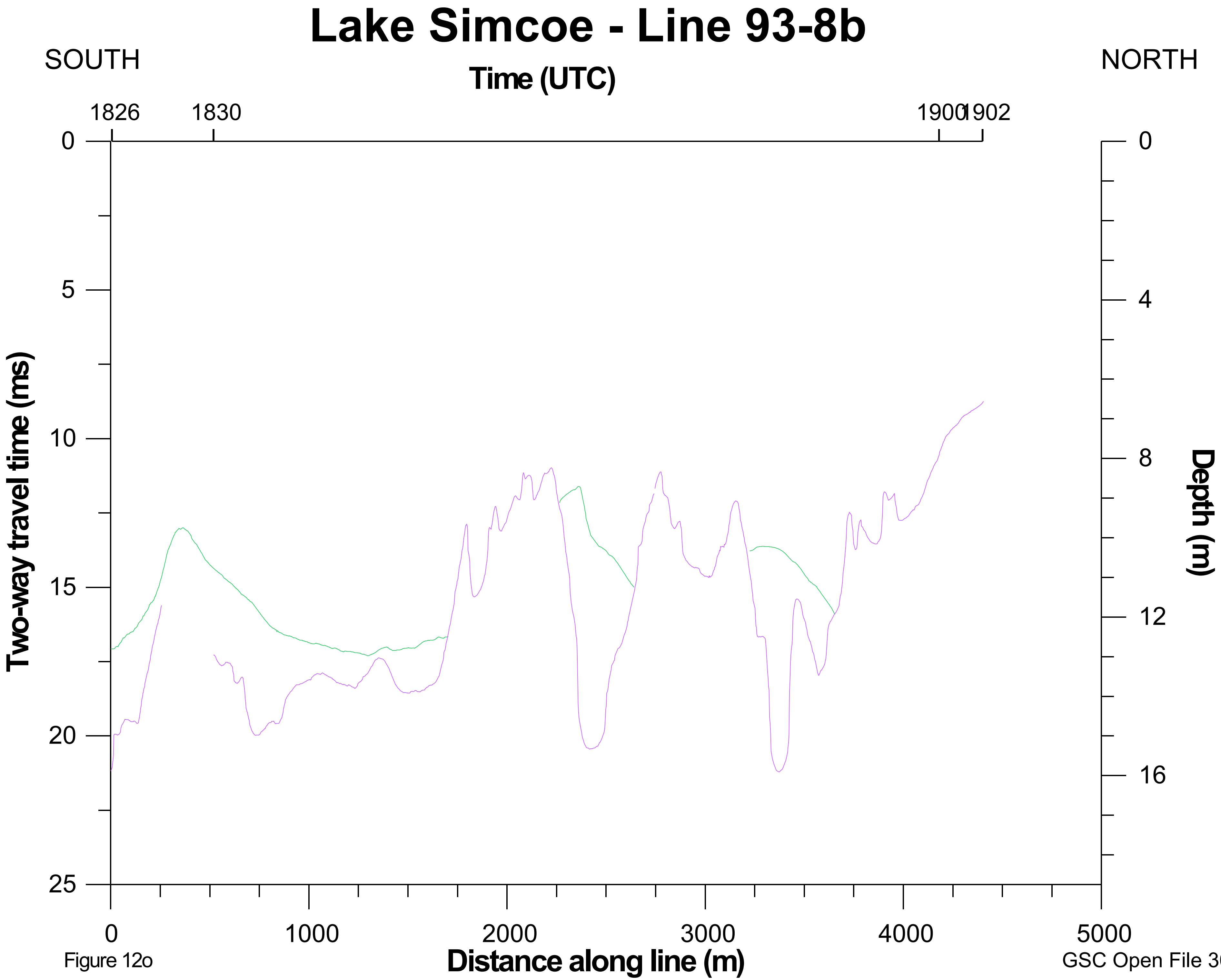





Figure 12n

GSC Open File 3037



Lake Simcoe - Line 93-8b
SOUTH
NORTH
Time (UTC)
1826
1830
1900
1902
Two-way travel time (ms)
0
5
10
15
20
25
Depth (m)
0
4
8
12
16
0
1000
2000
3000
4000
5000
Distance along line (m)


Figure 12o

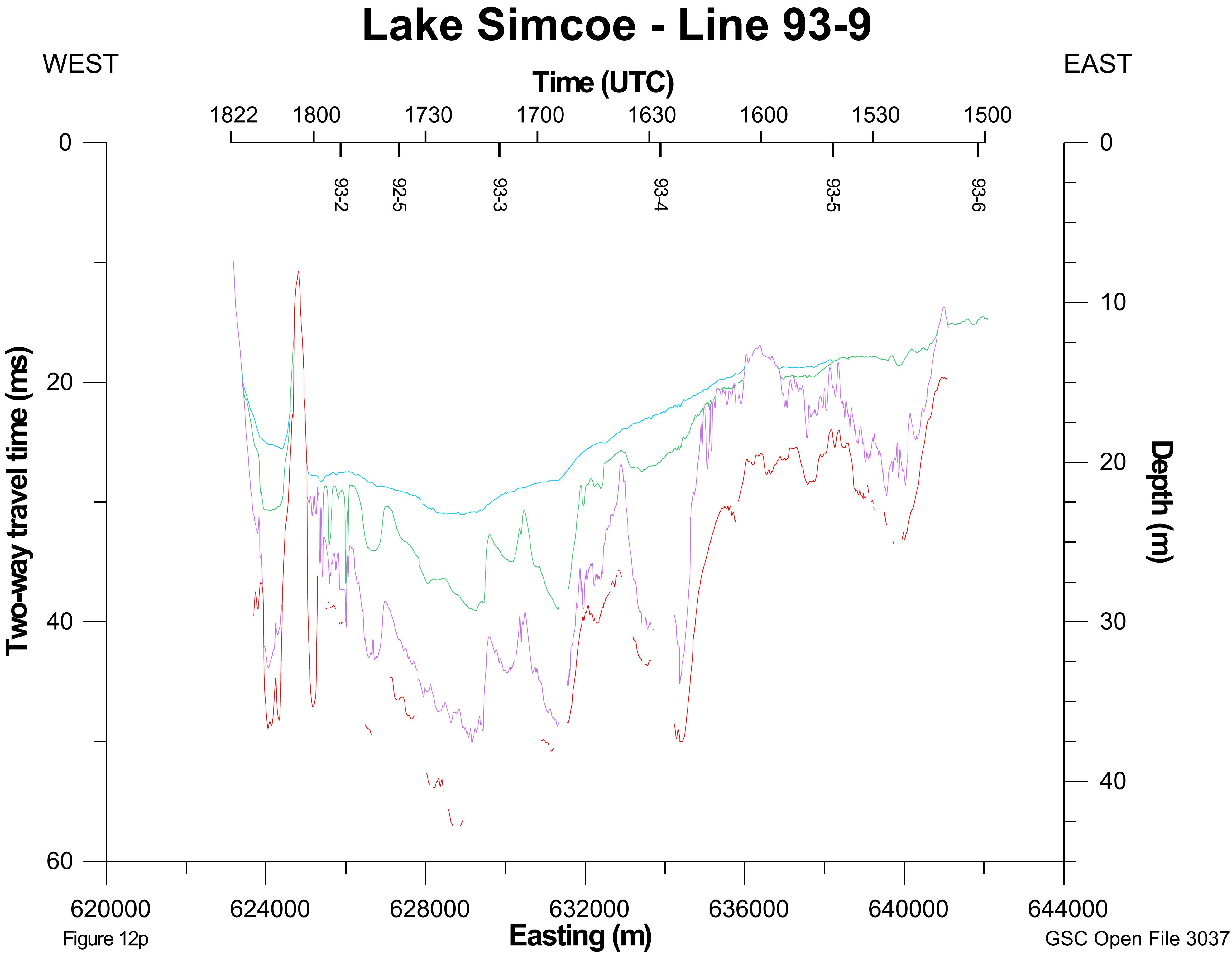



Figure 12p

GSC Open File 3037

# Lake Simcoe - Line 93-10

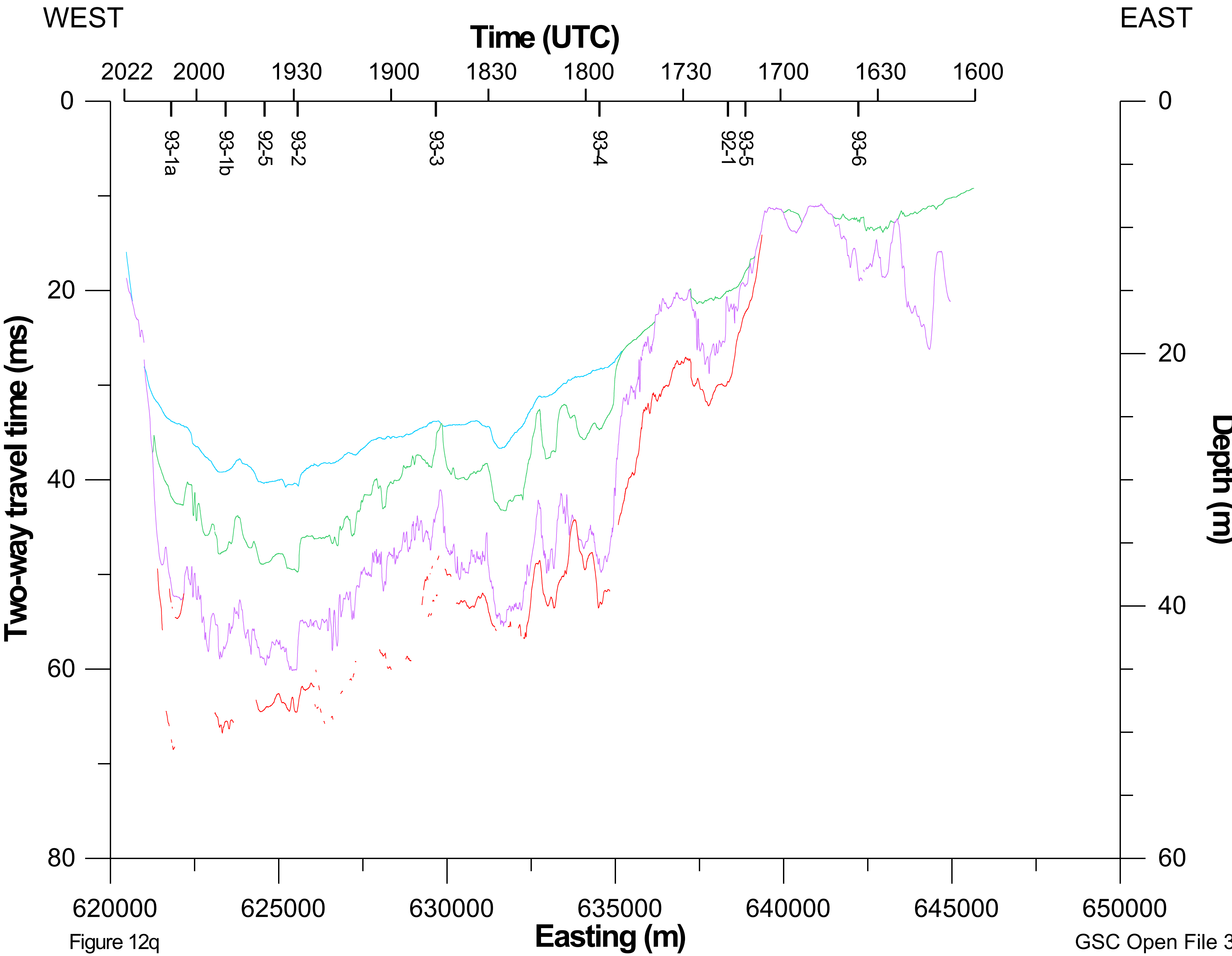



Figure 12q

GSC Open File 3037

# Lake Simcoe - Line 93-11

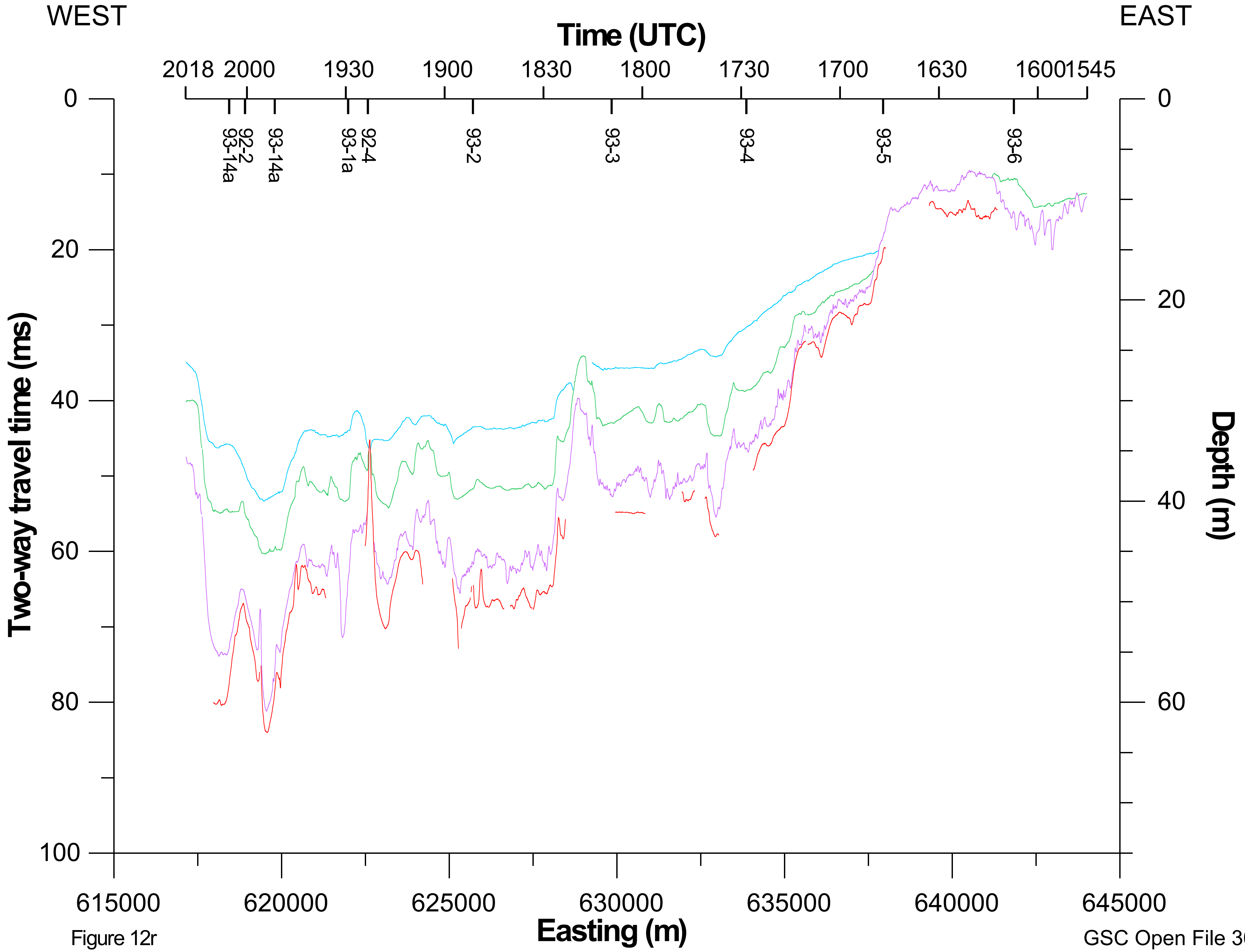



Figure 12r

# Lake Simcoe - Line 93-12W

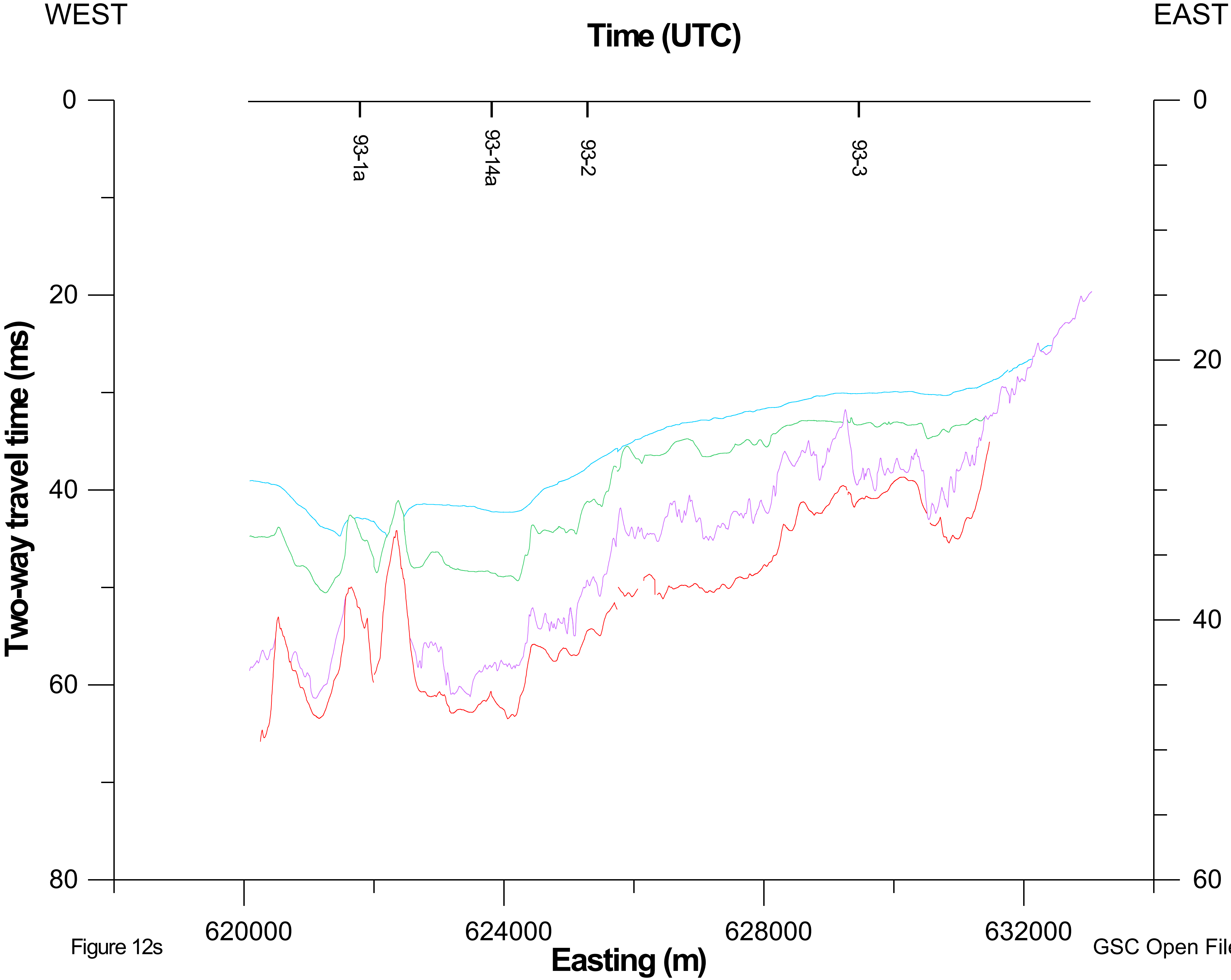



Figure 12s

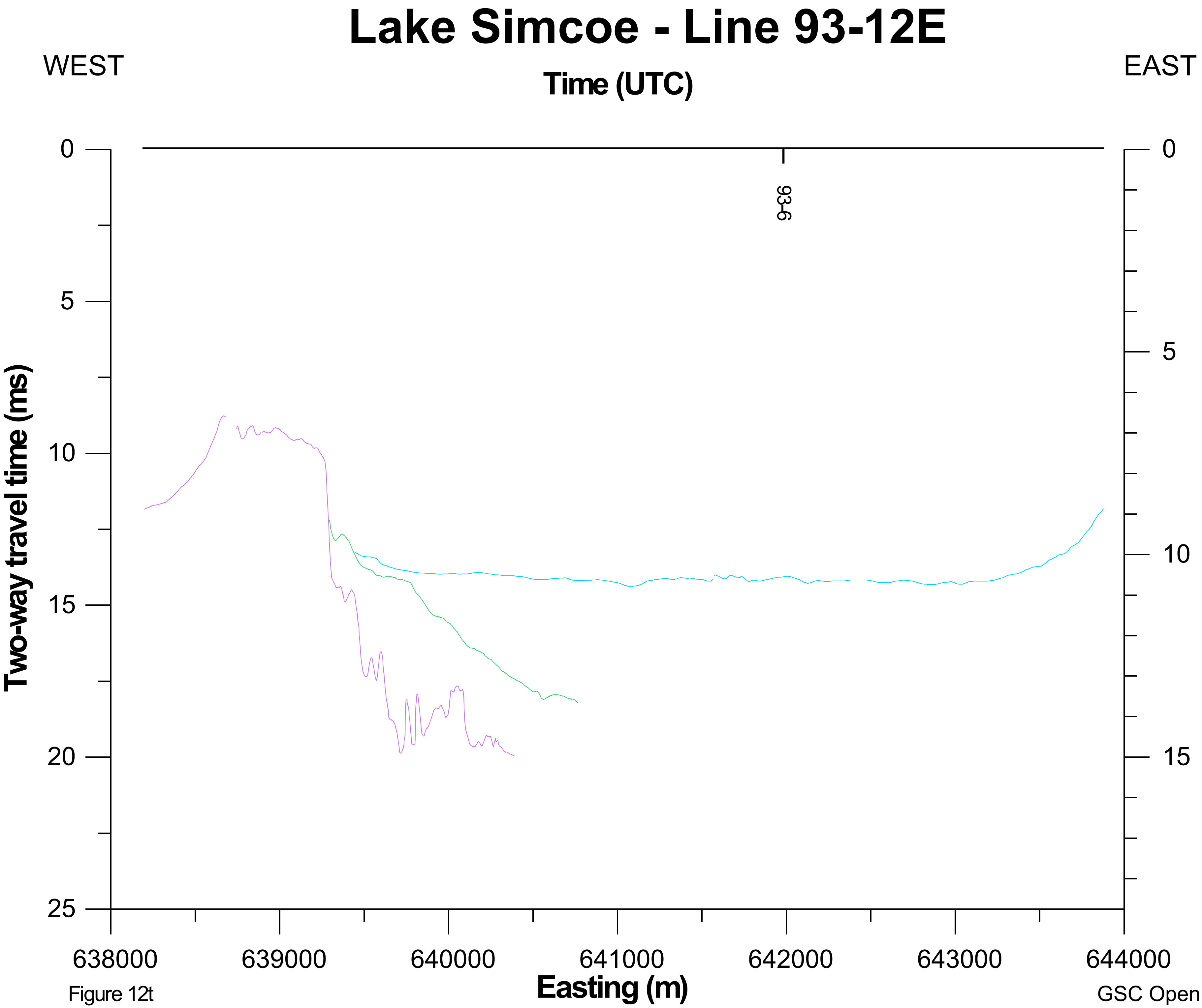

Lake Simcoe - Line 93-12E
WEST
EAST
Time (UTC)
93-6
Two-way travel time (ms)
Depth (m)
0
5
10
15
20
25
638000
639000
640000
641000
642000
643000
644000
Easting (m)



Figure 12t

Lake Simcoe - Line 93-13

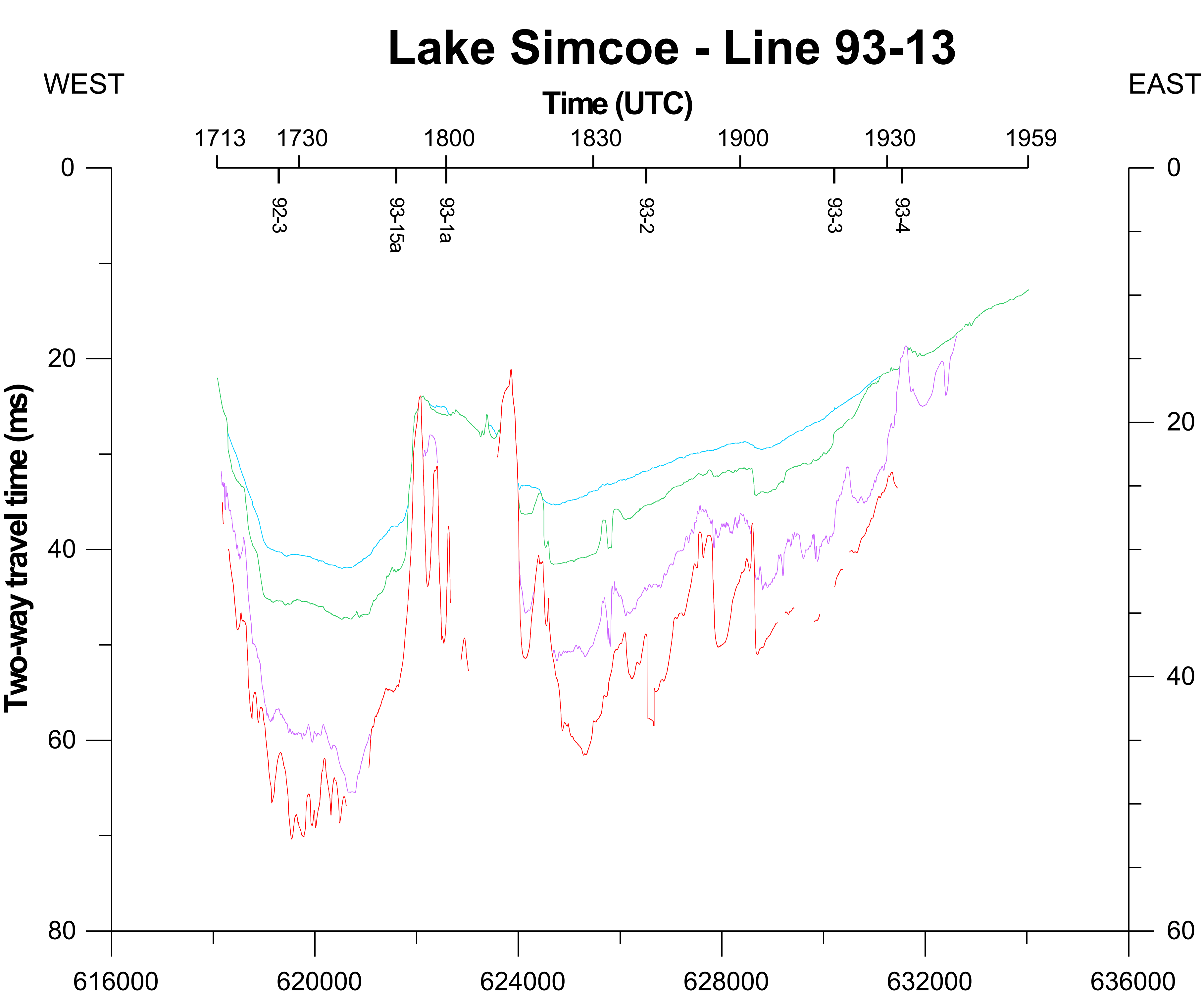



Figure 12u

GSC Open File 3037

# Lake Simcoe - Line 93-14a

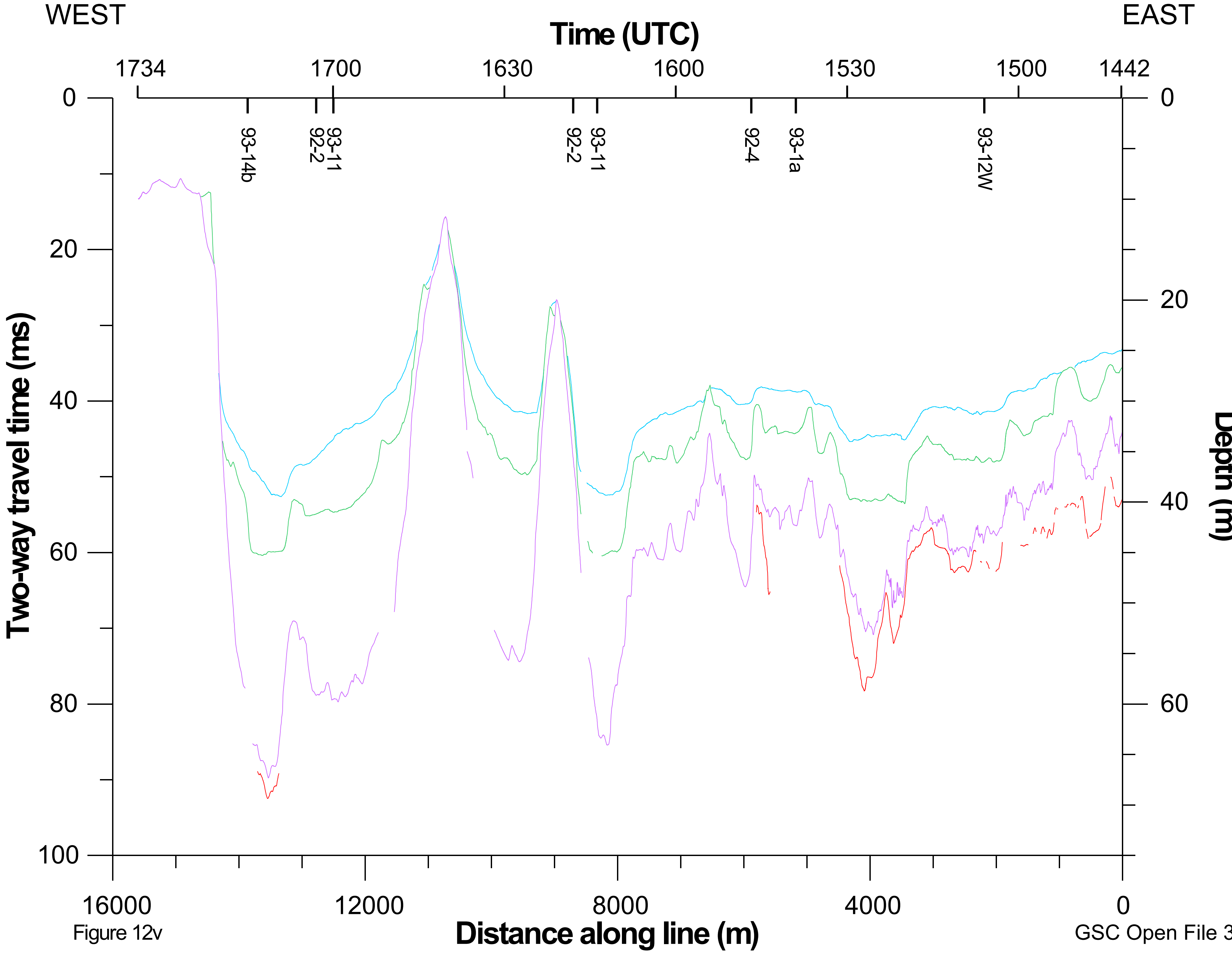



Figure 12v

GSC Open File 3037

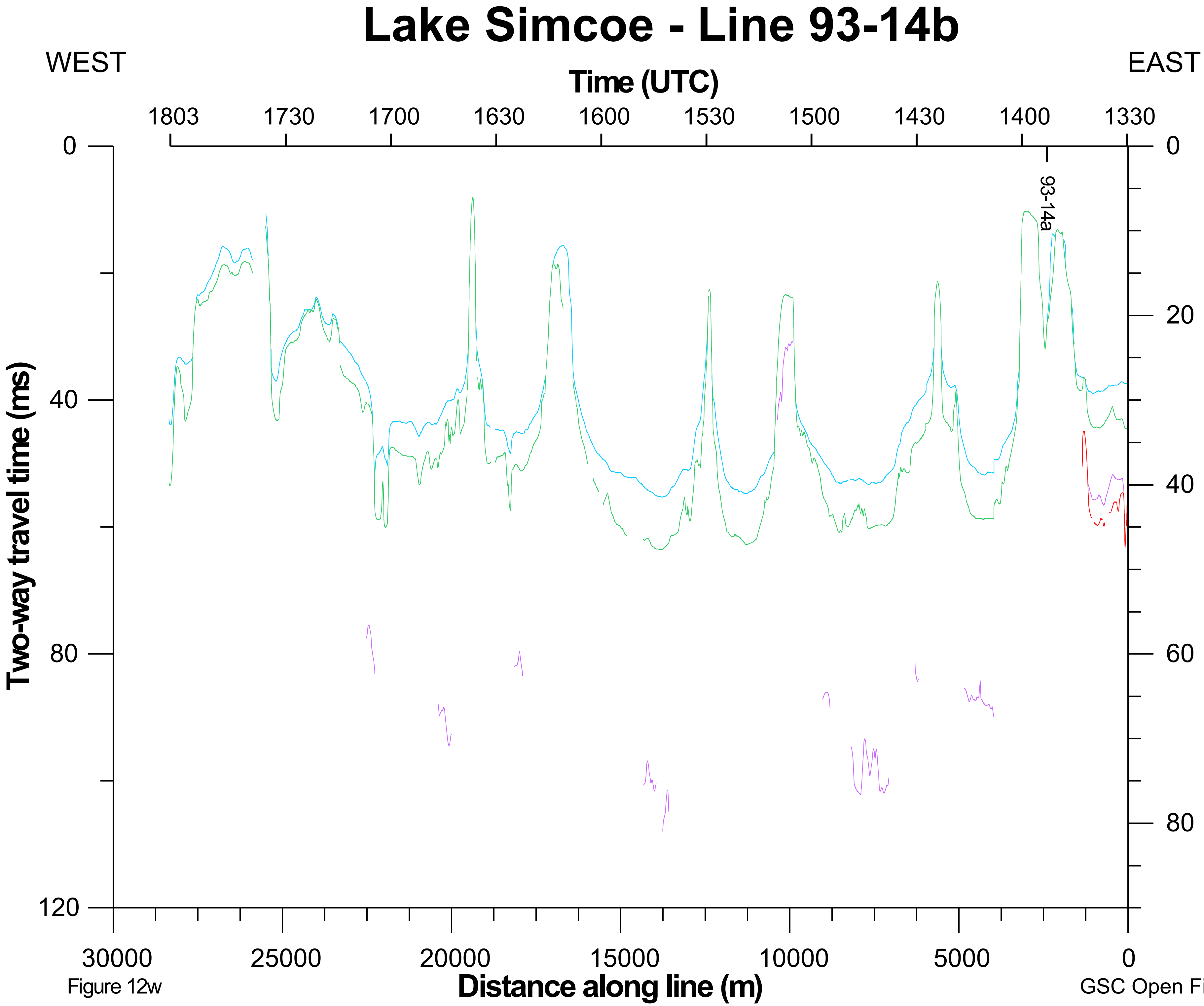



Figure 12w

GSC Open File 3037

# Lake Simcoe - Line 93-15a

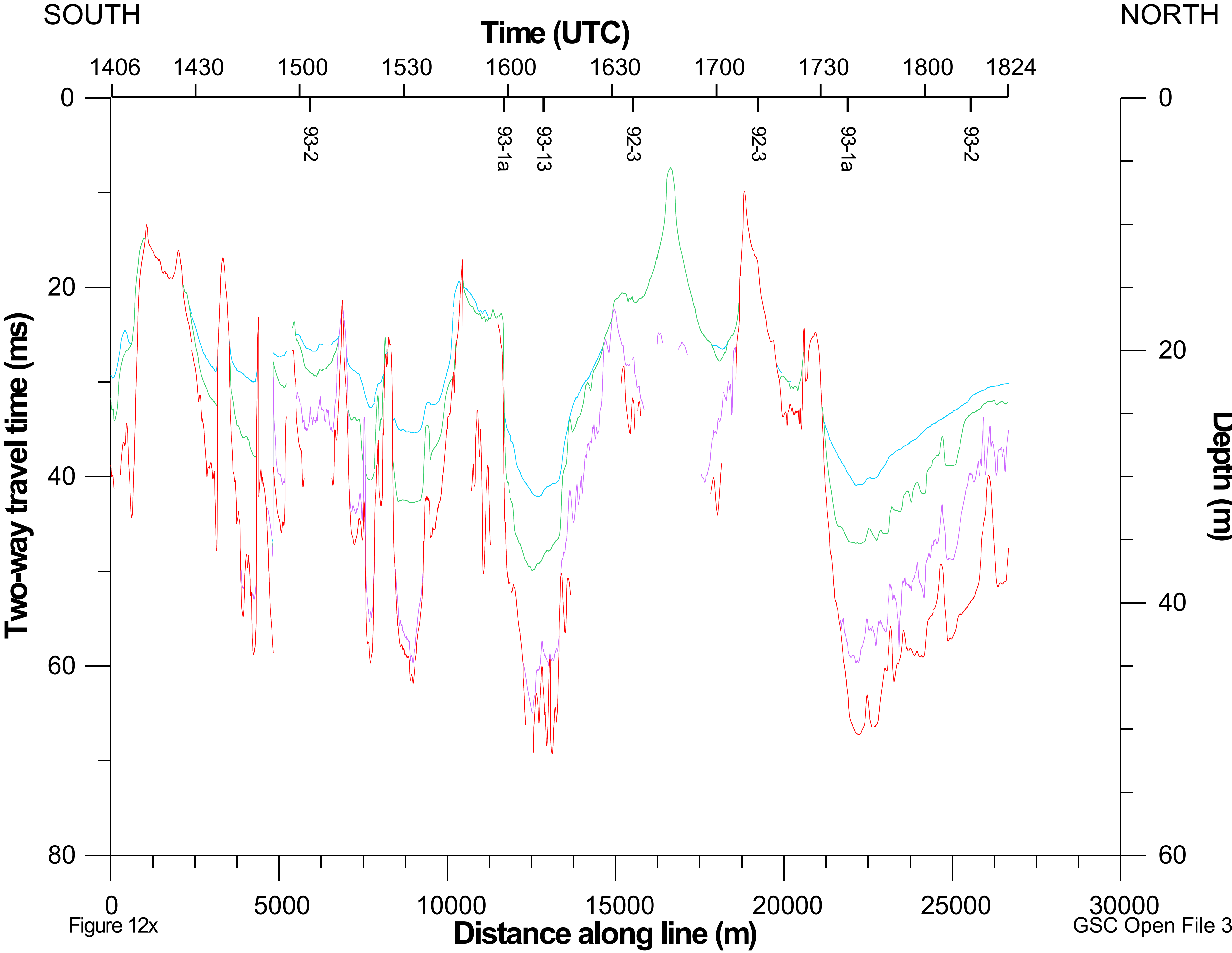
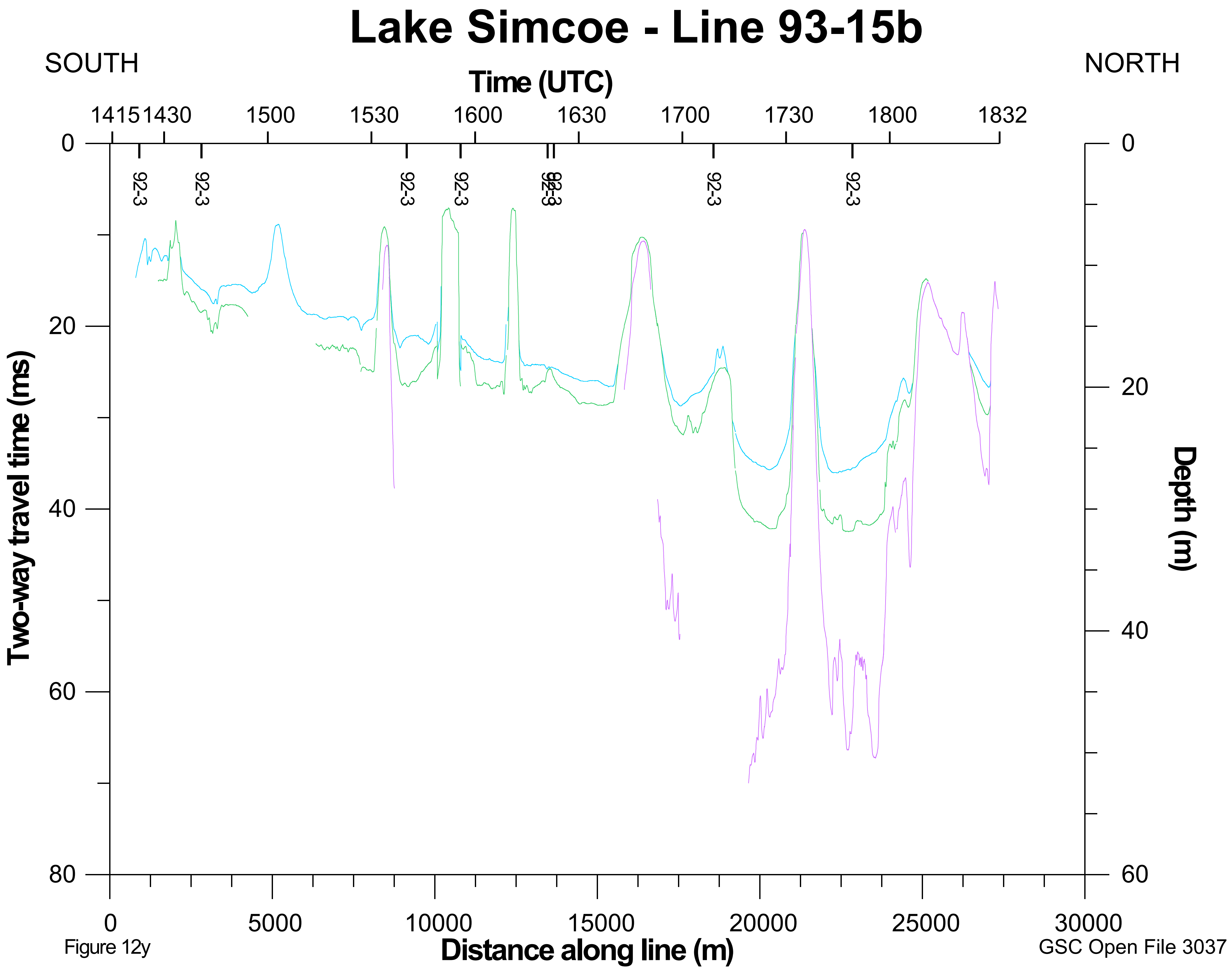



Figure 12x

GSC Open File 3037




80

Figure 12y

GSC Open File 3037

# Lake Simcoe - Line 93-16

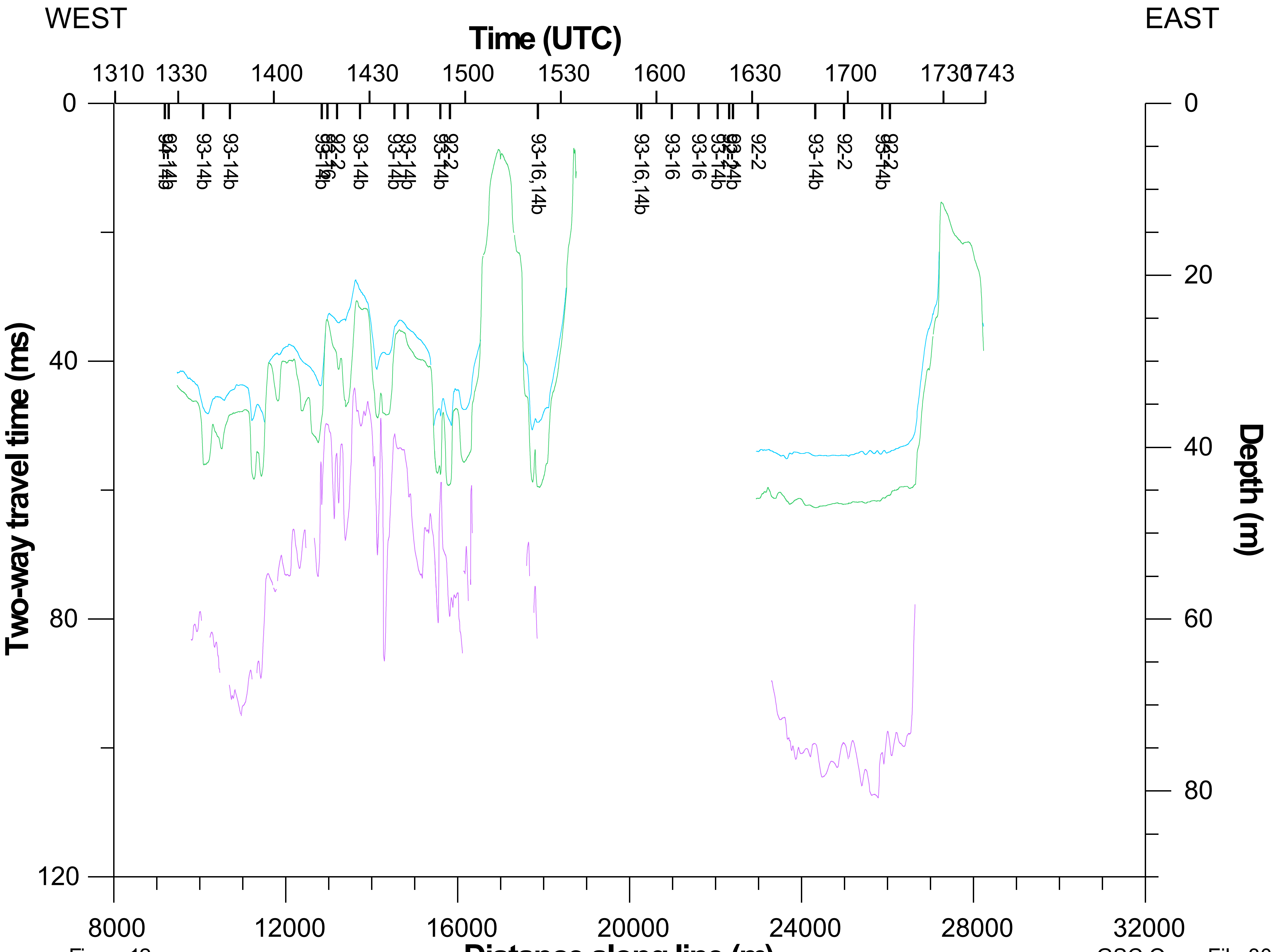



Figure 12z

GSC Open File 3037

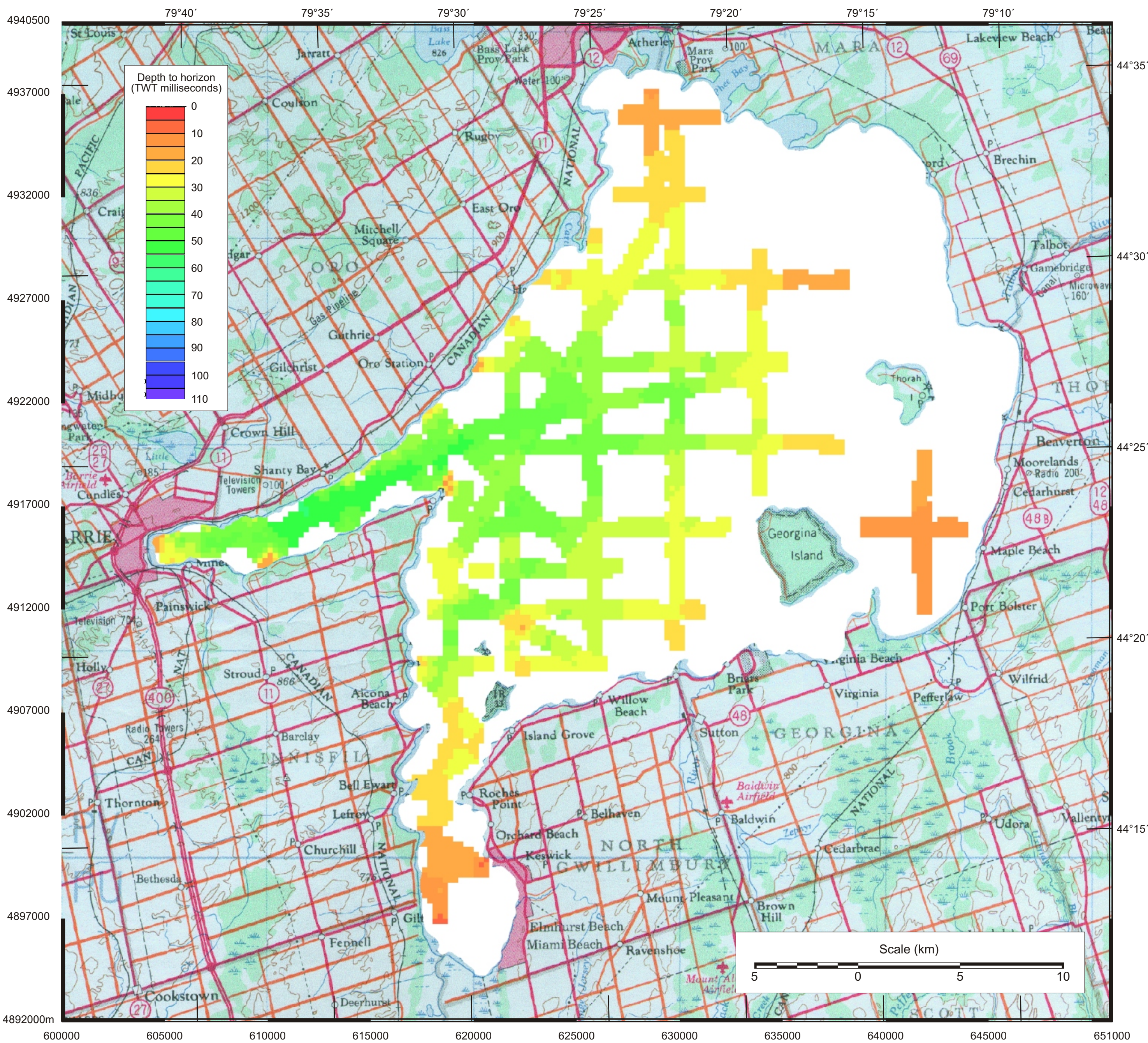



Figure 13a. Extent and depth of Blue Sequence sediments.

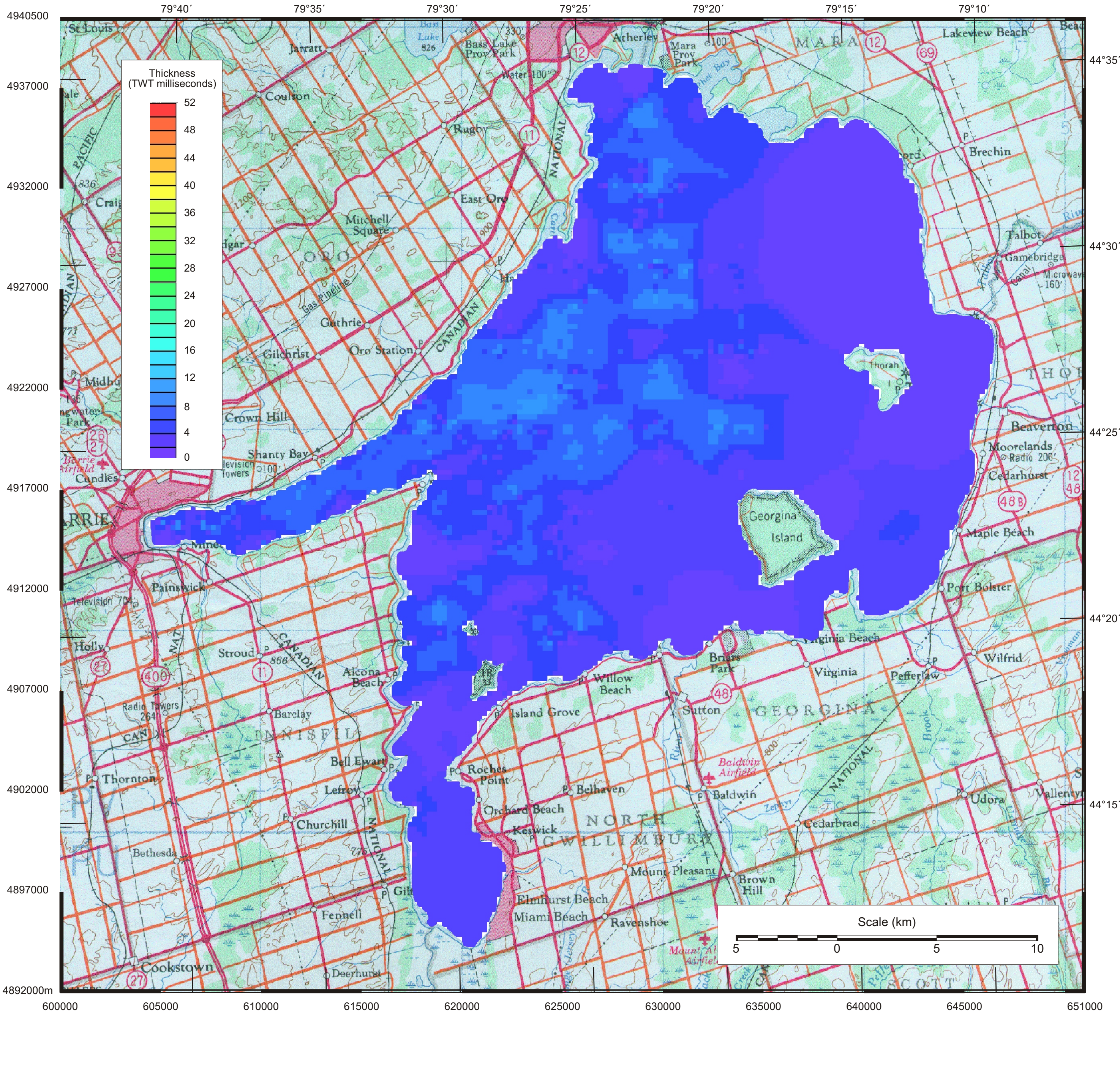



Figure 13b. Isopach of Blue Sequence sediments.

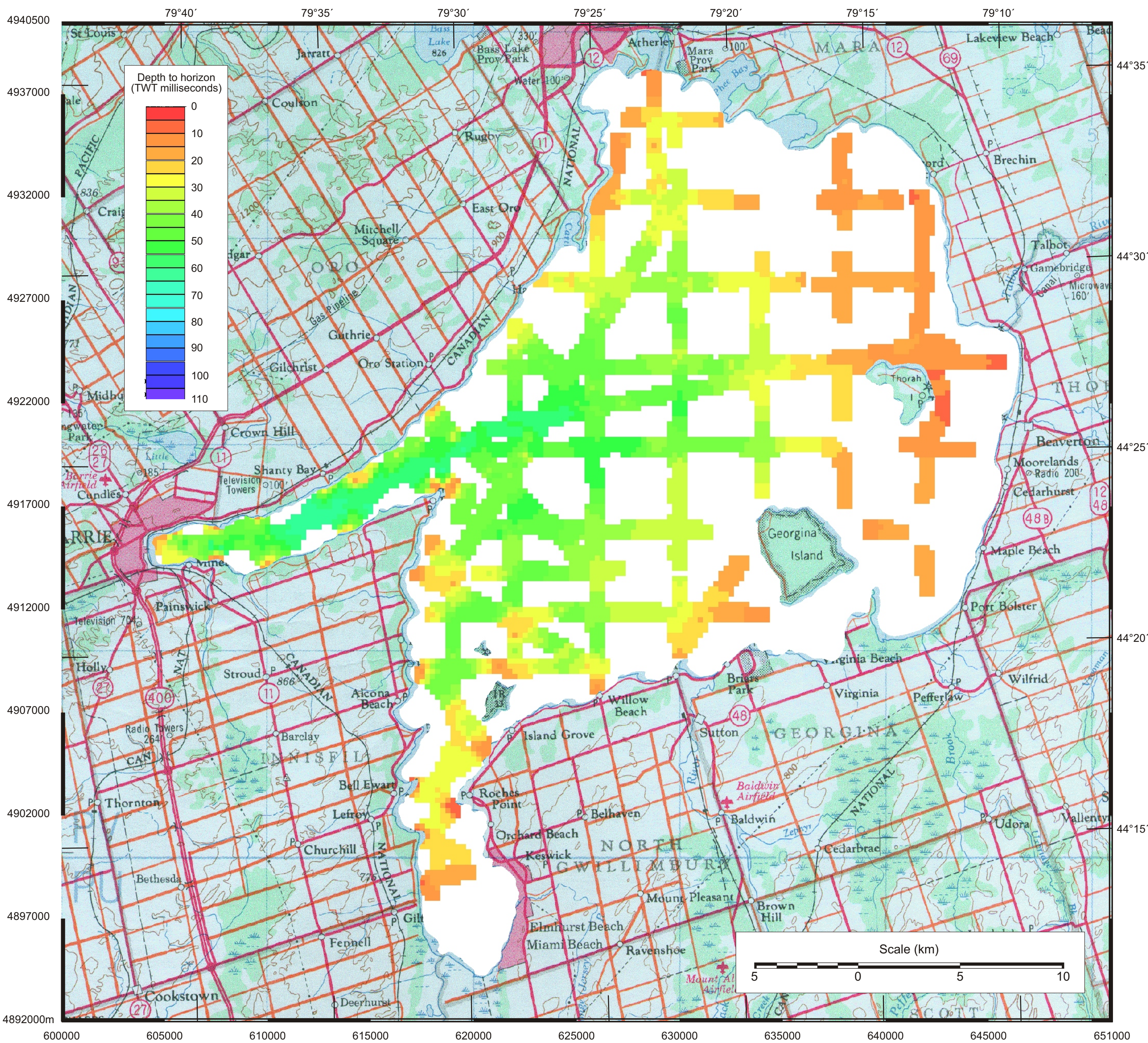



Figure 13c. Extent and depth of Green Sequence sediments.

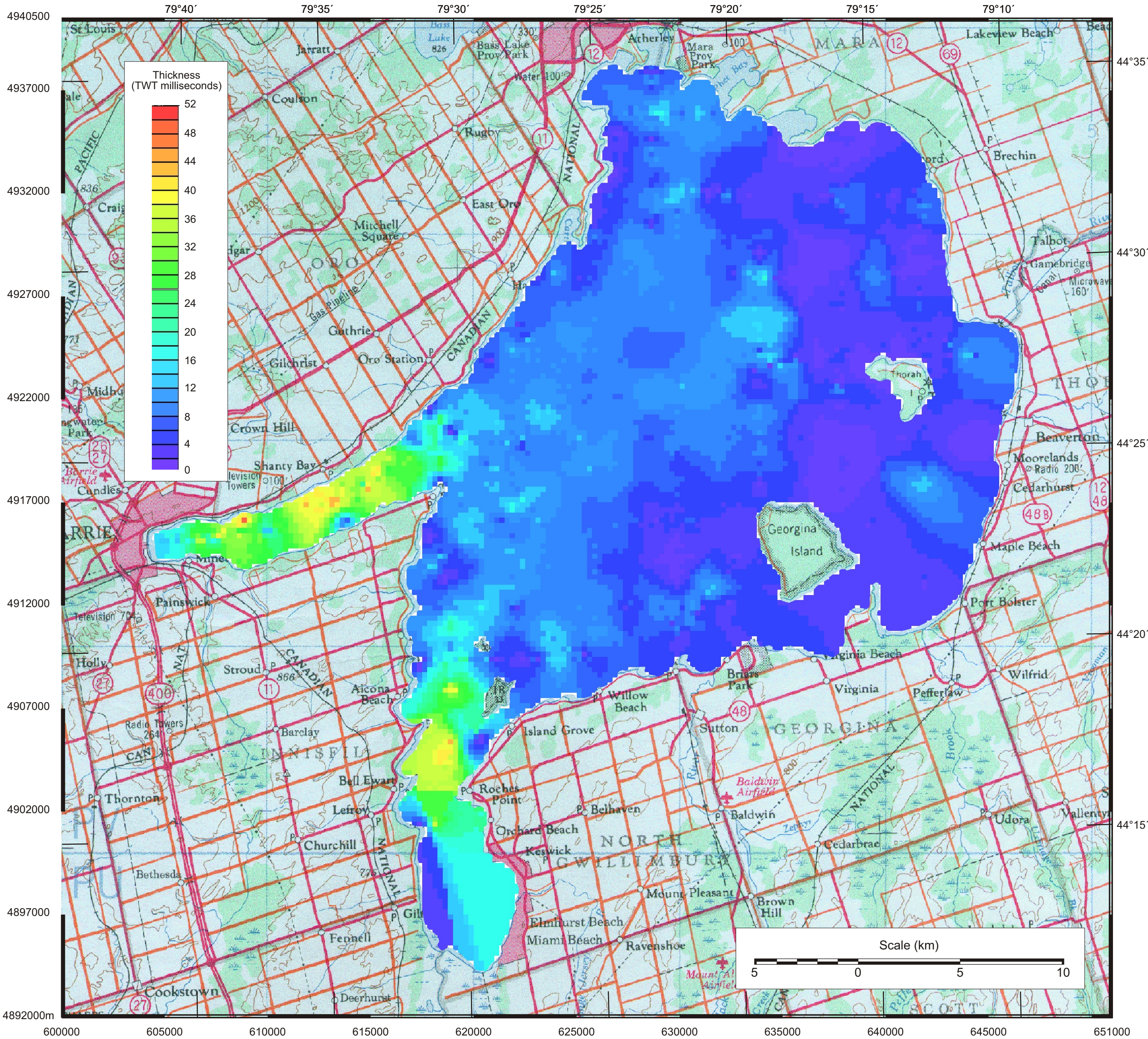



Figure 13d. Isopach of Green Sequence sediments.

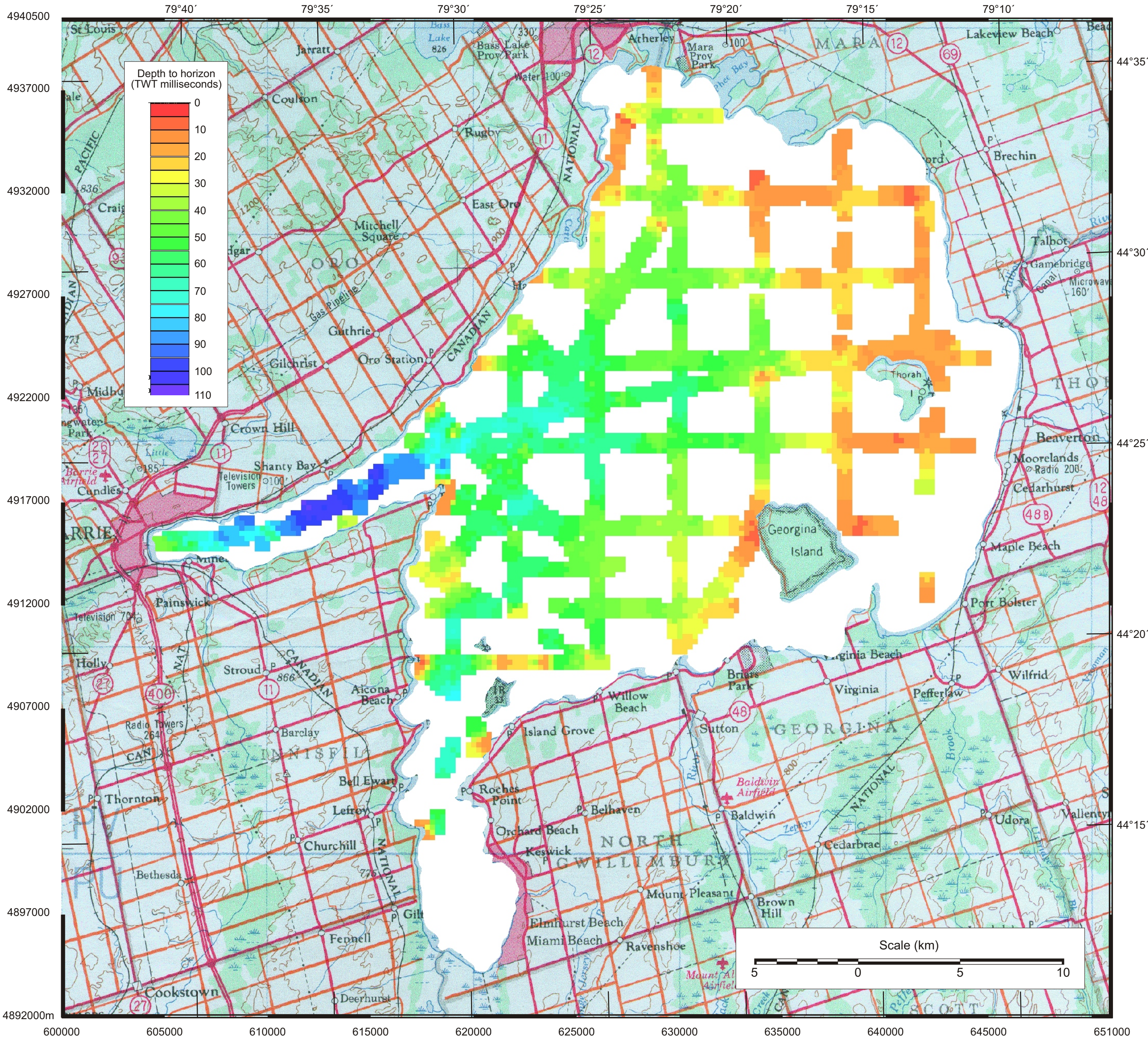



Figure 13e. Extent and depth of Purple Sequence sediments.

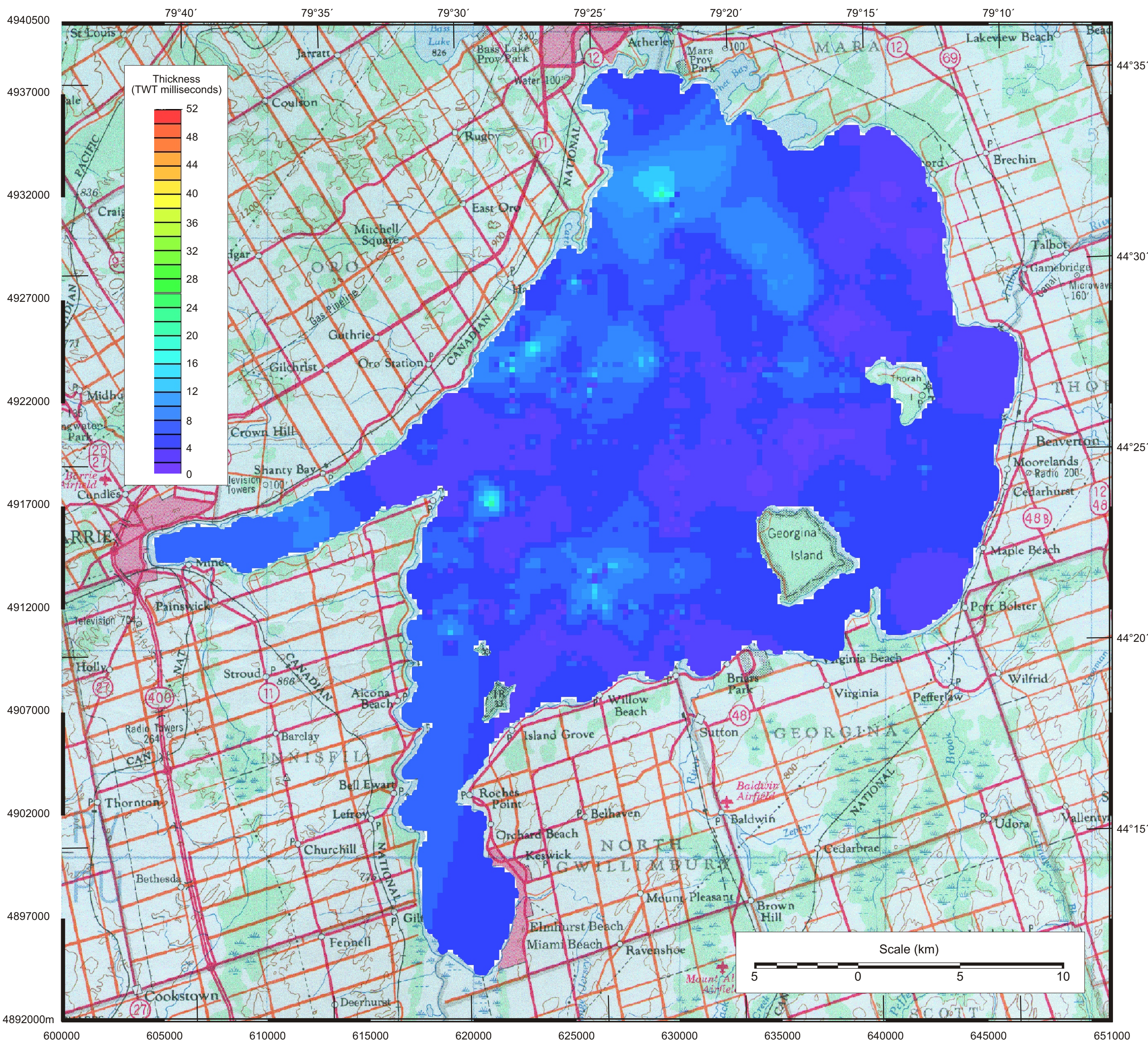



Figure 13f. Isopach of Purple Sequence sediments.

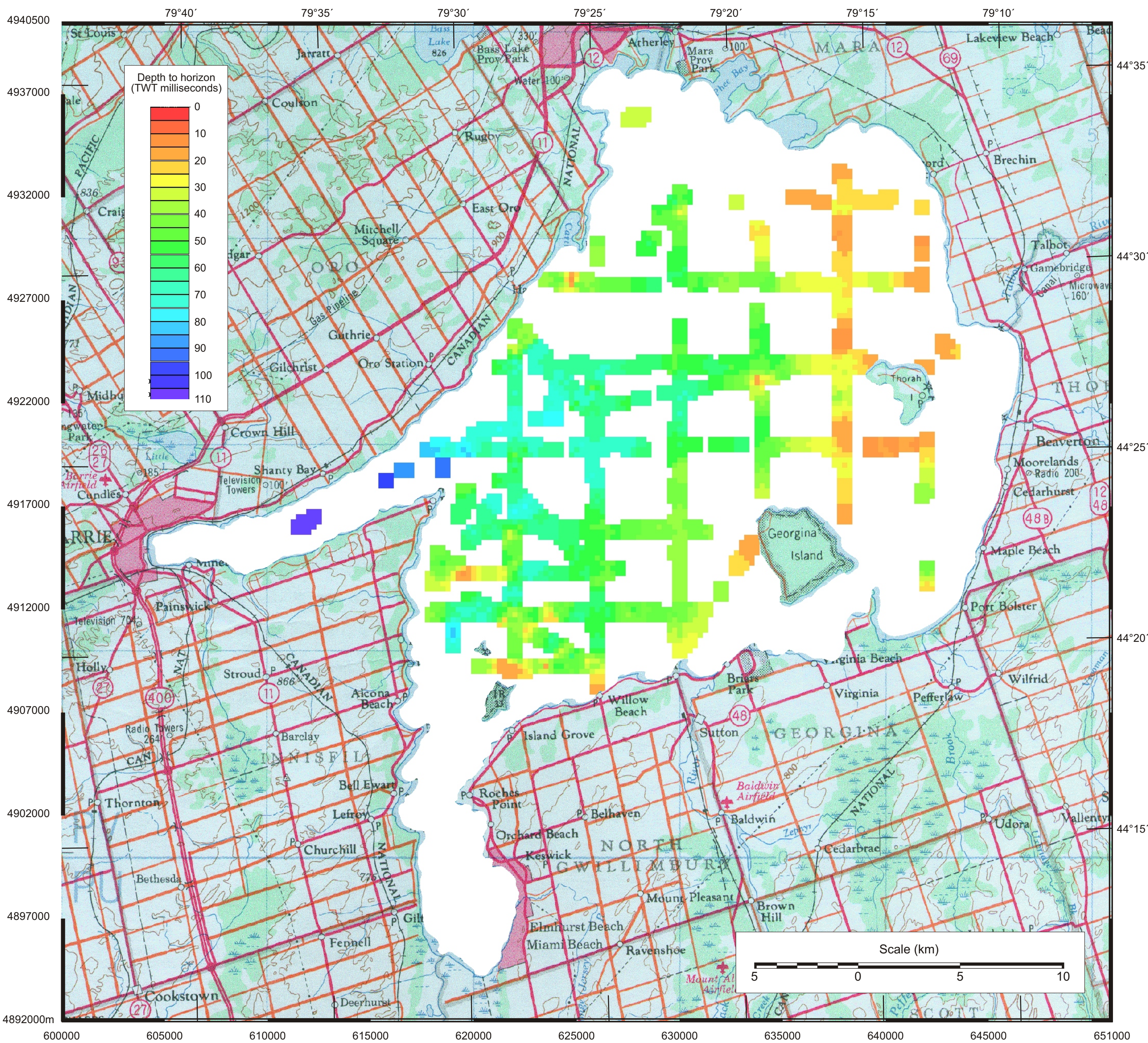



Figure 13g. Extent and depth of Red Sequence sediments.

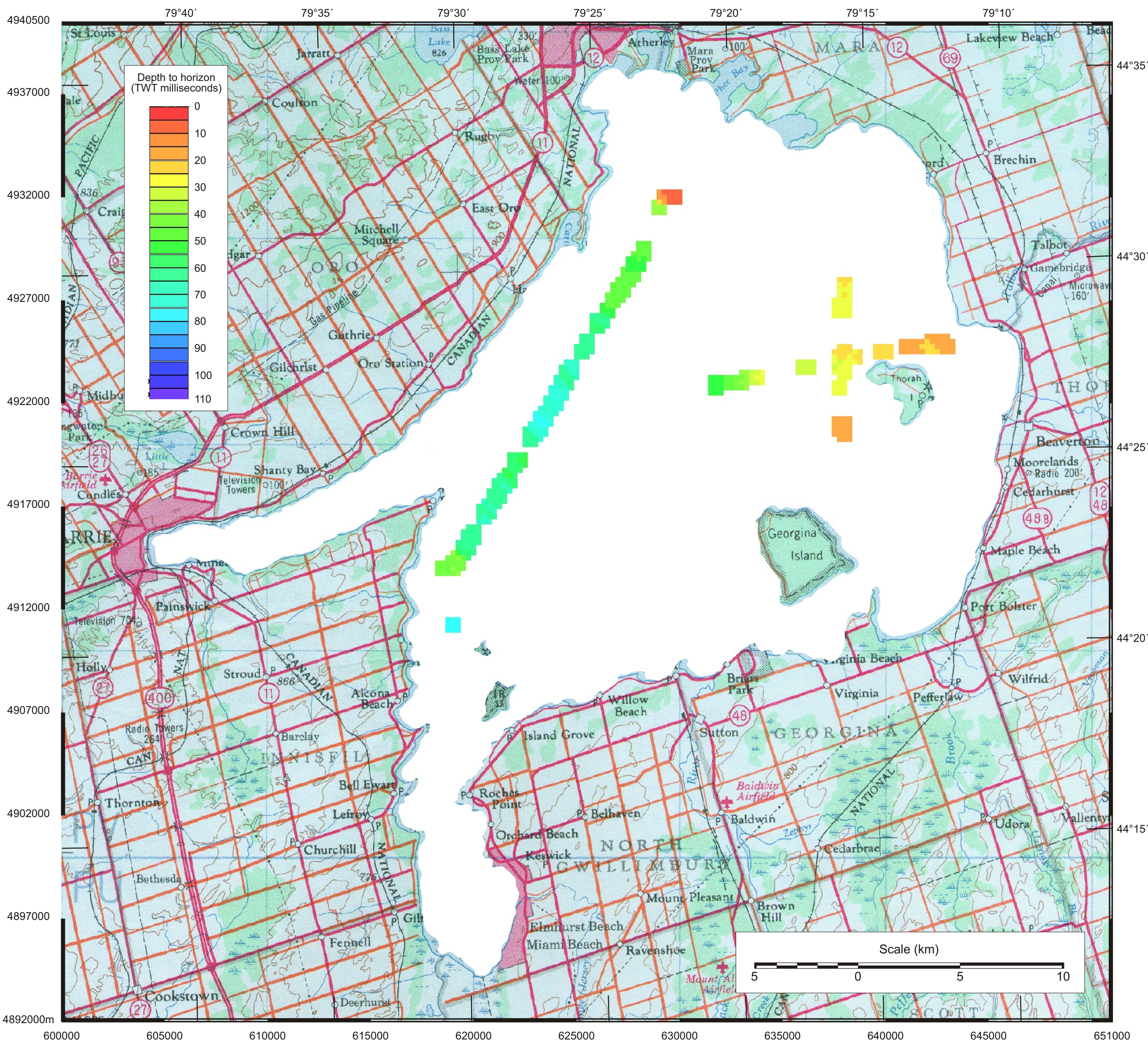



Figure 13h. Extent and depth of Brown Sequence sediments.

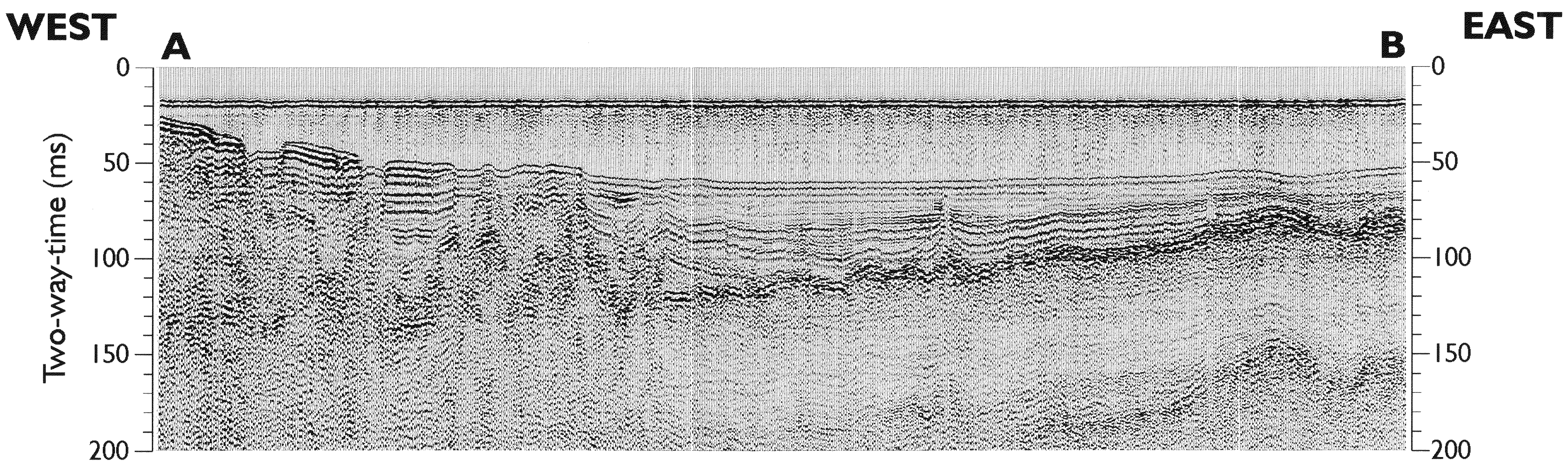
## Appendix A: Airgun seismic profiles

Single-channel - common offset gathers

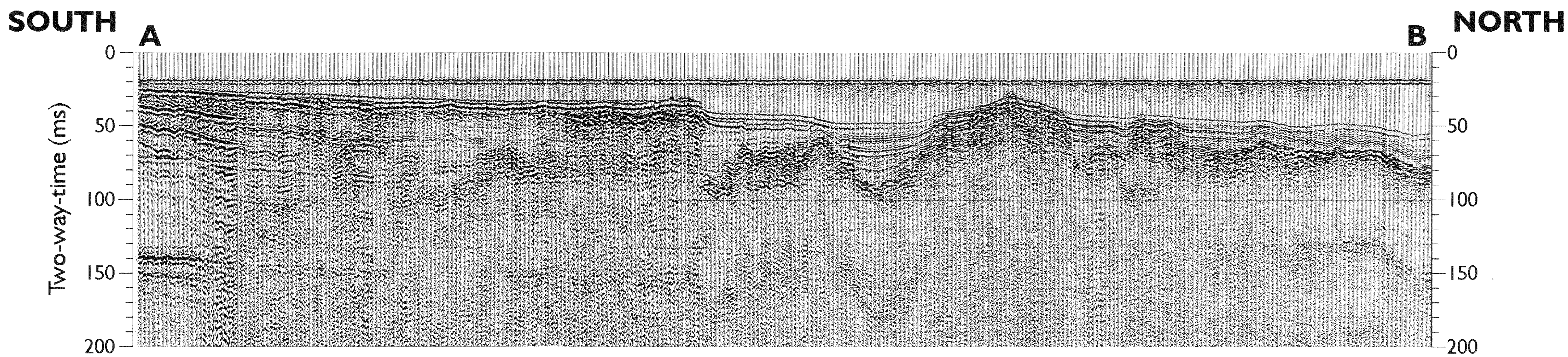
Trace number = 2
Offset from source = 34 m
Automatic gain control with 80 ms window
Digital bandpass filter 100-800 Hz

# LAKE SIMCOE SEISMIC PROFILES

## LINE 92-6




## LINE 92-7




V.E. (@1500 m/s)=11.4X

0 1 2

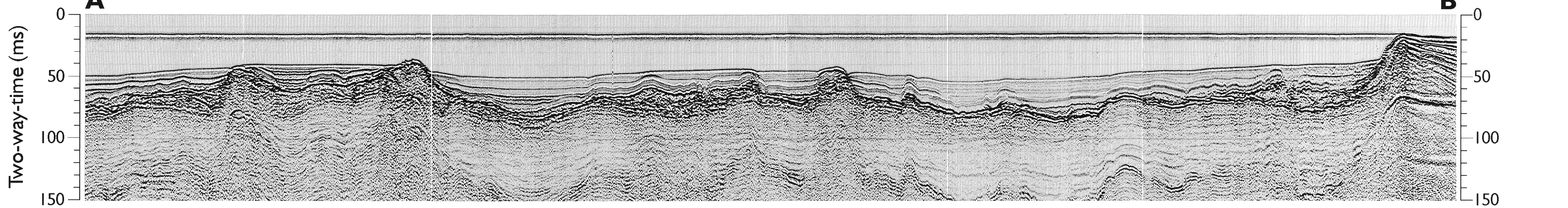
Distance (km)

**To accompany GSC Open File 3037**

# LAKE SIMCOE SEISMIC PROFILES

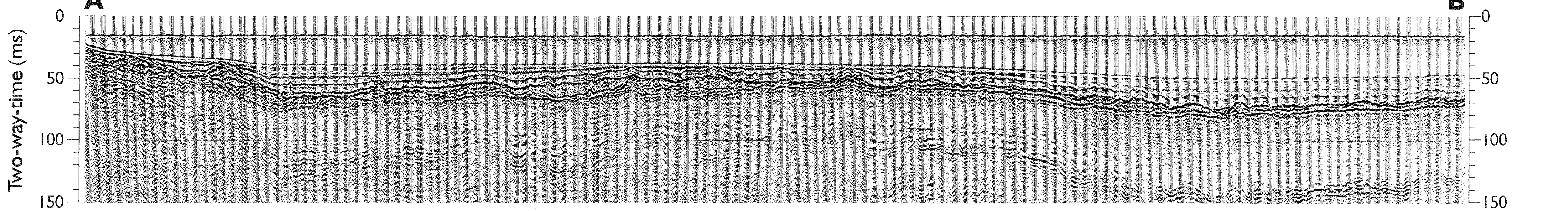
## LINE 93-1

SOUTH A — B NORTH

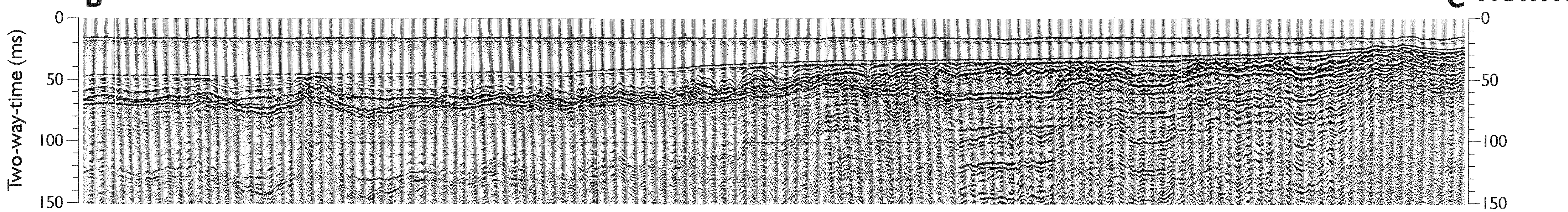



## LINE 93-2

SOUTH A — B




B — C NORTH




V.E. (@1500 m/s)=11.6X

0 1 2

Distance (km)

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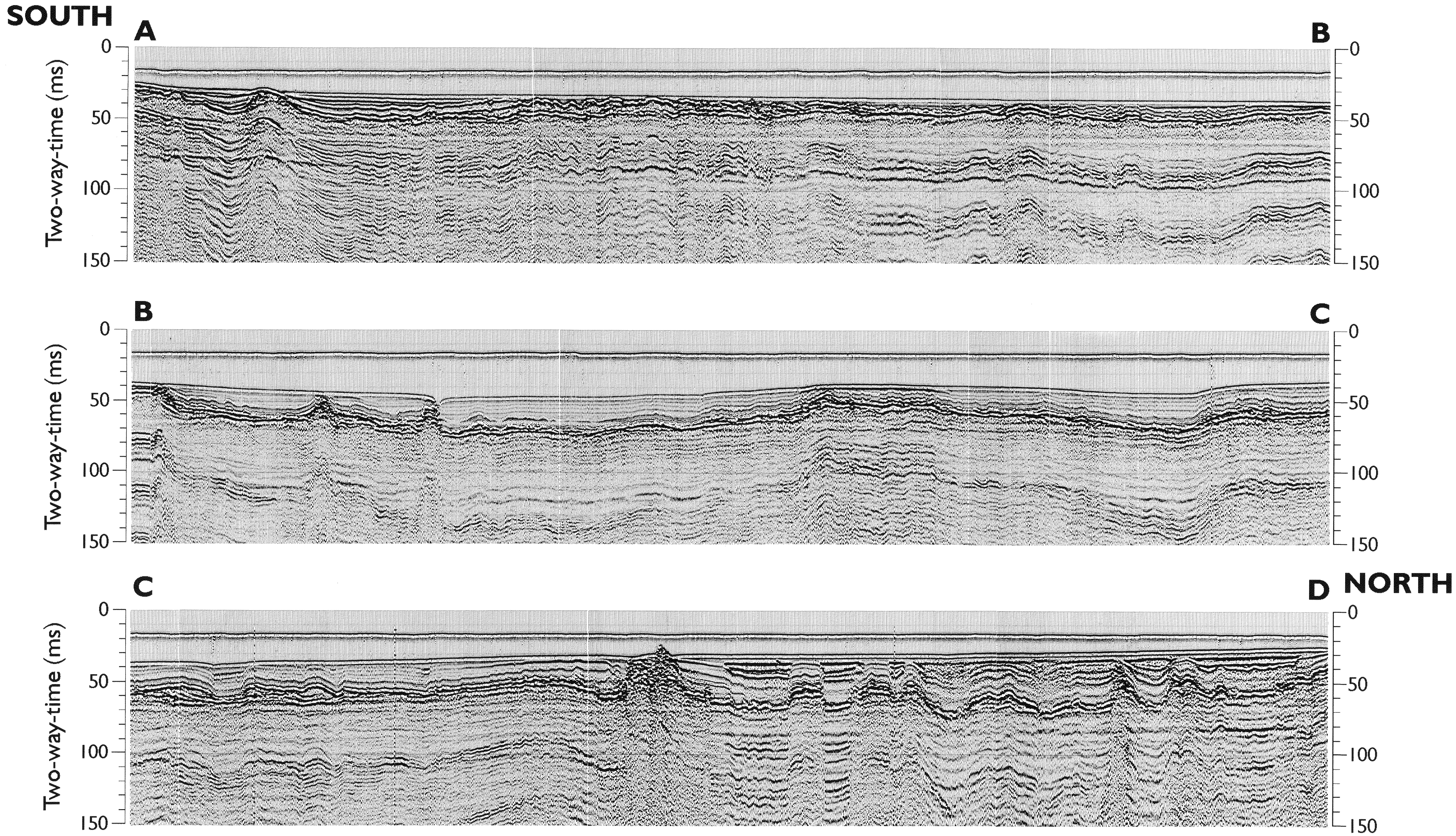
# LAKE SIMCOE SEISMIC PROFILES

## LINE 93-3




V.E. (@1500 m/s)=11.6X

0 1 2

Distance (km)

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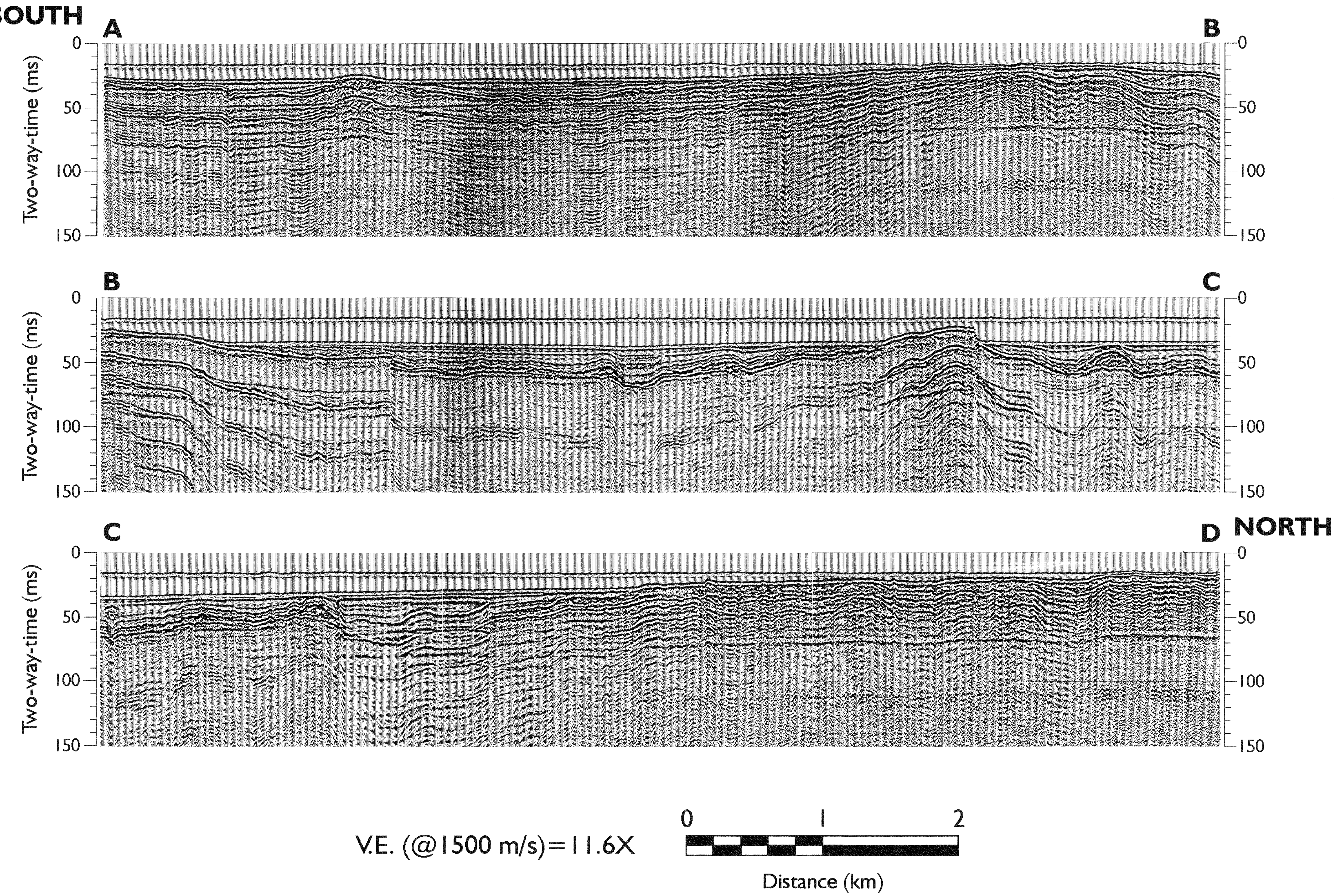
# LAKE SIMCOE SEISMIC PROFILES

## LINE 93-4

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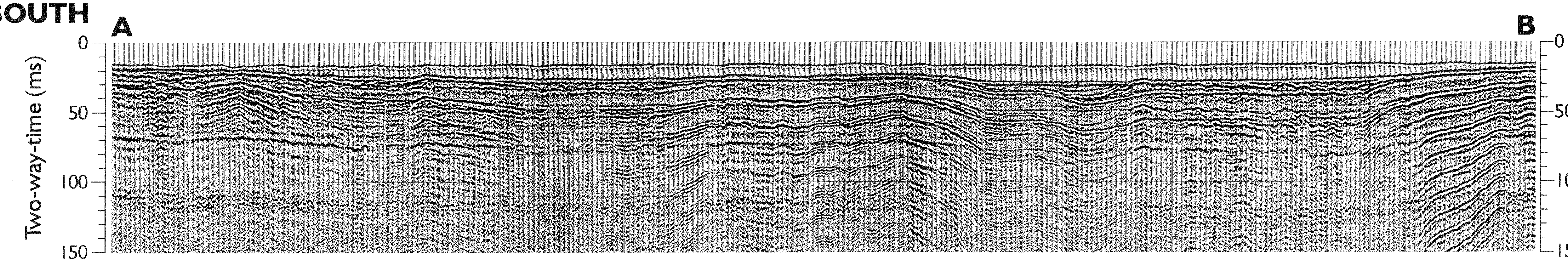
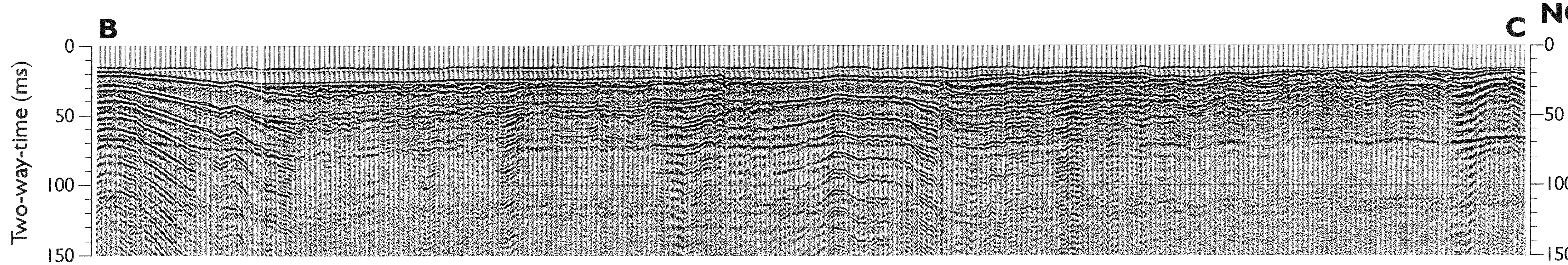
# LAKE SIMCOE SEISMIC PROFILES

## LINE 93-5




V.E. (@1500 m/s)=11.6X

0 1 2

Distance (km)

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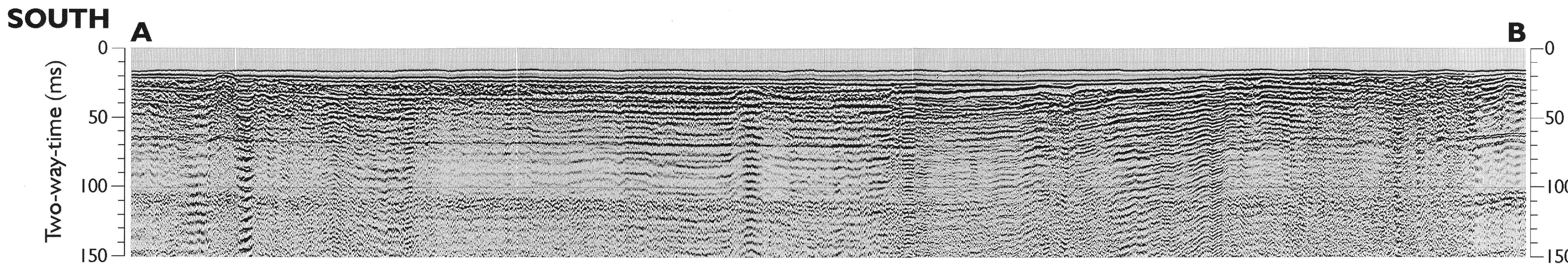
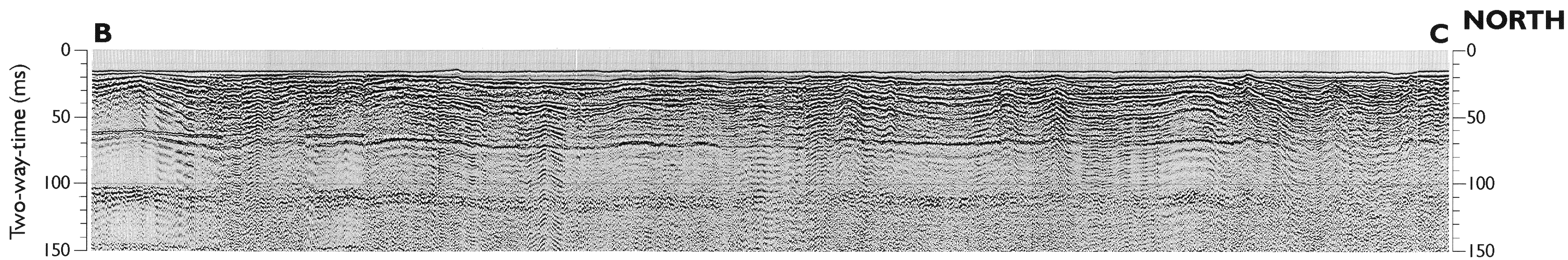
# LAKE SIMCOE SEISMIC PROFILES

## LINE 93-6




V.E. (@1500 m/s)=11.6X

0 1 2

Distance (km)

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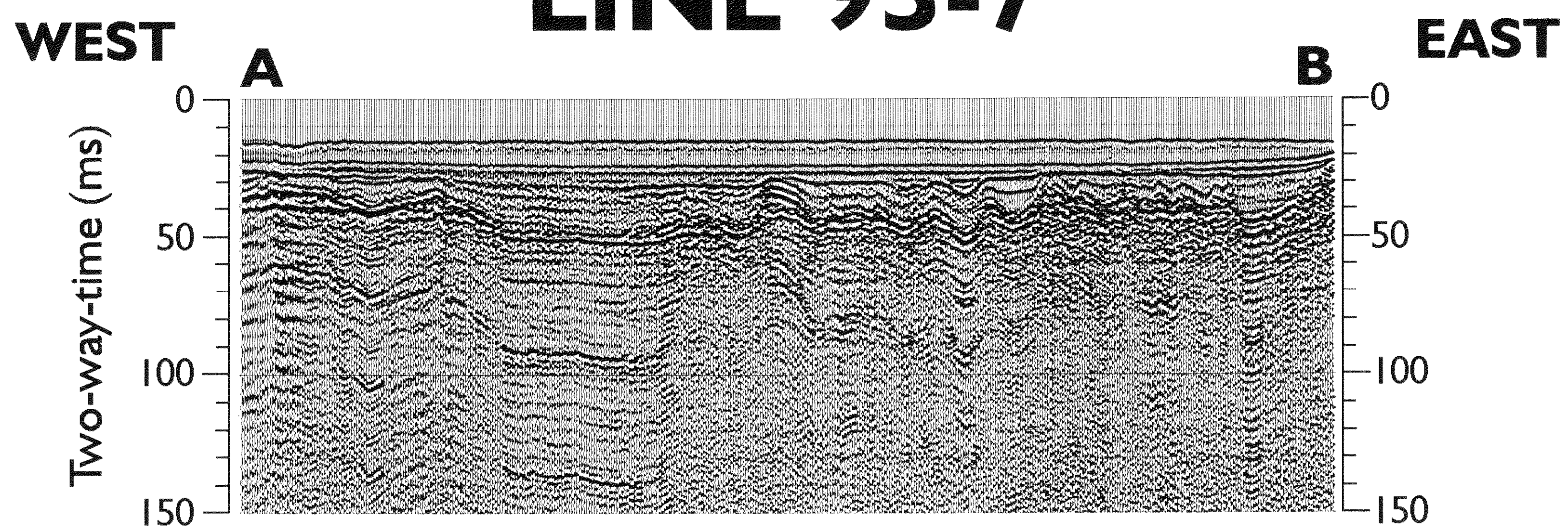
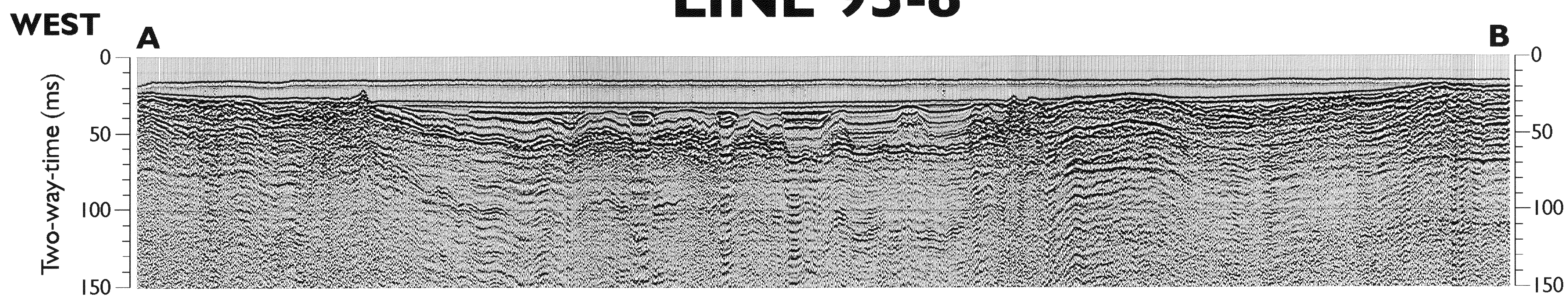
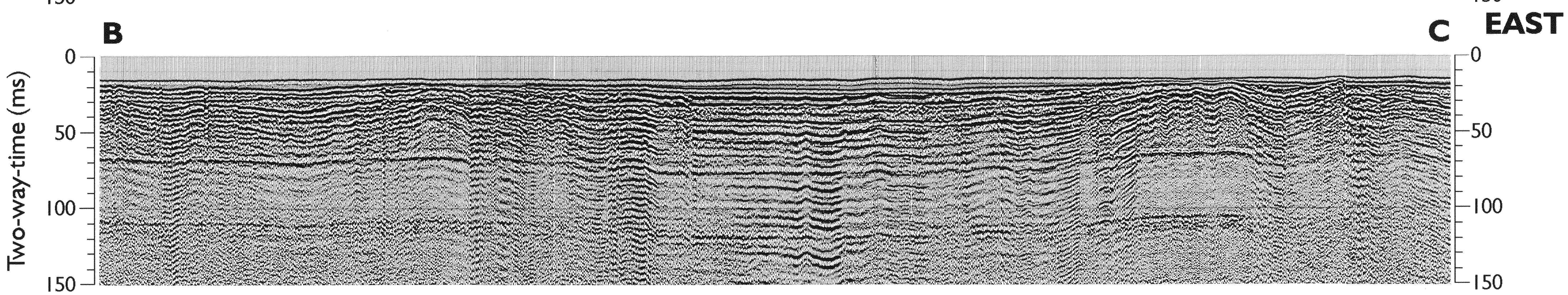
# LAKE SIMCOE SEISMIC PROFILES

## LINE 93-7




## LINE 93-8




V.E. (@1500 m/s)=11.6X

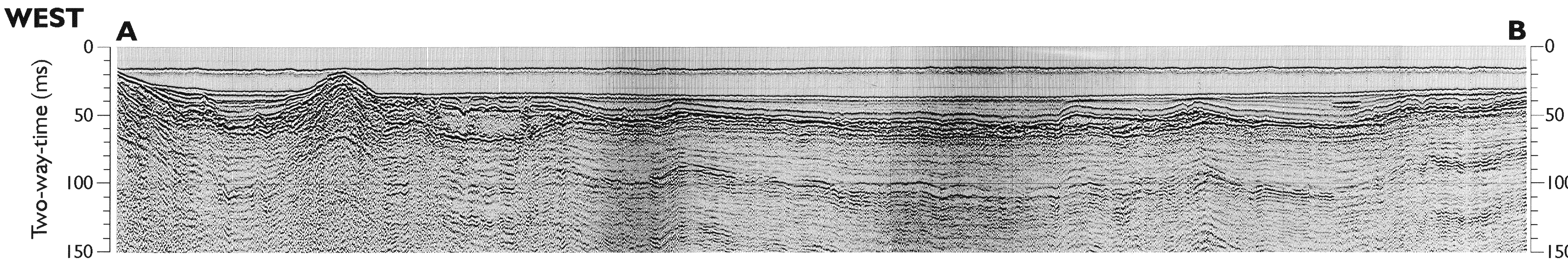
0 1 2

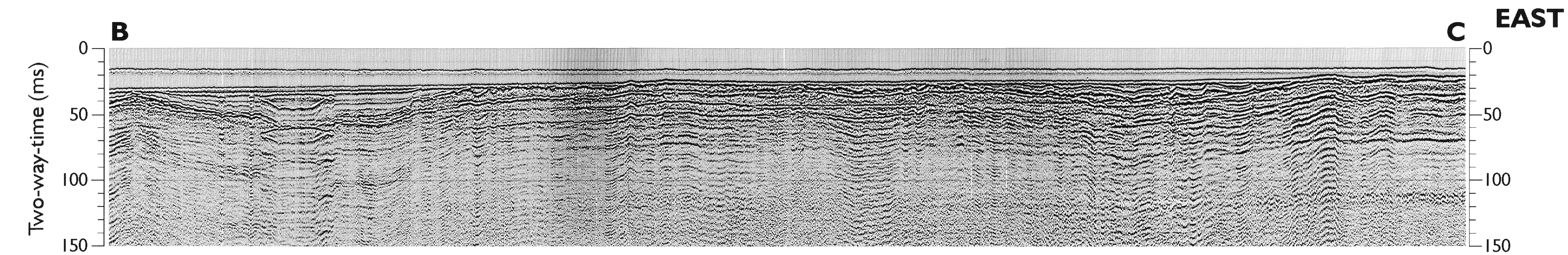
Distance (km)

**To accompany GSC Open File 3037**

# LAKE SIMCOE SEISMIC PROFILES

## LINE 93-9




V.E. (@1500 m/s)=11.6X

0 1 2

Distance (km)

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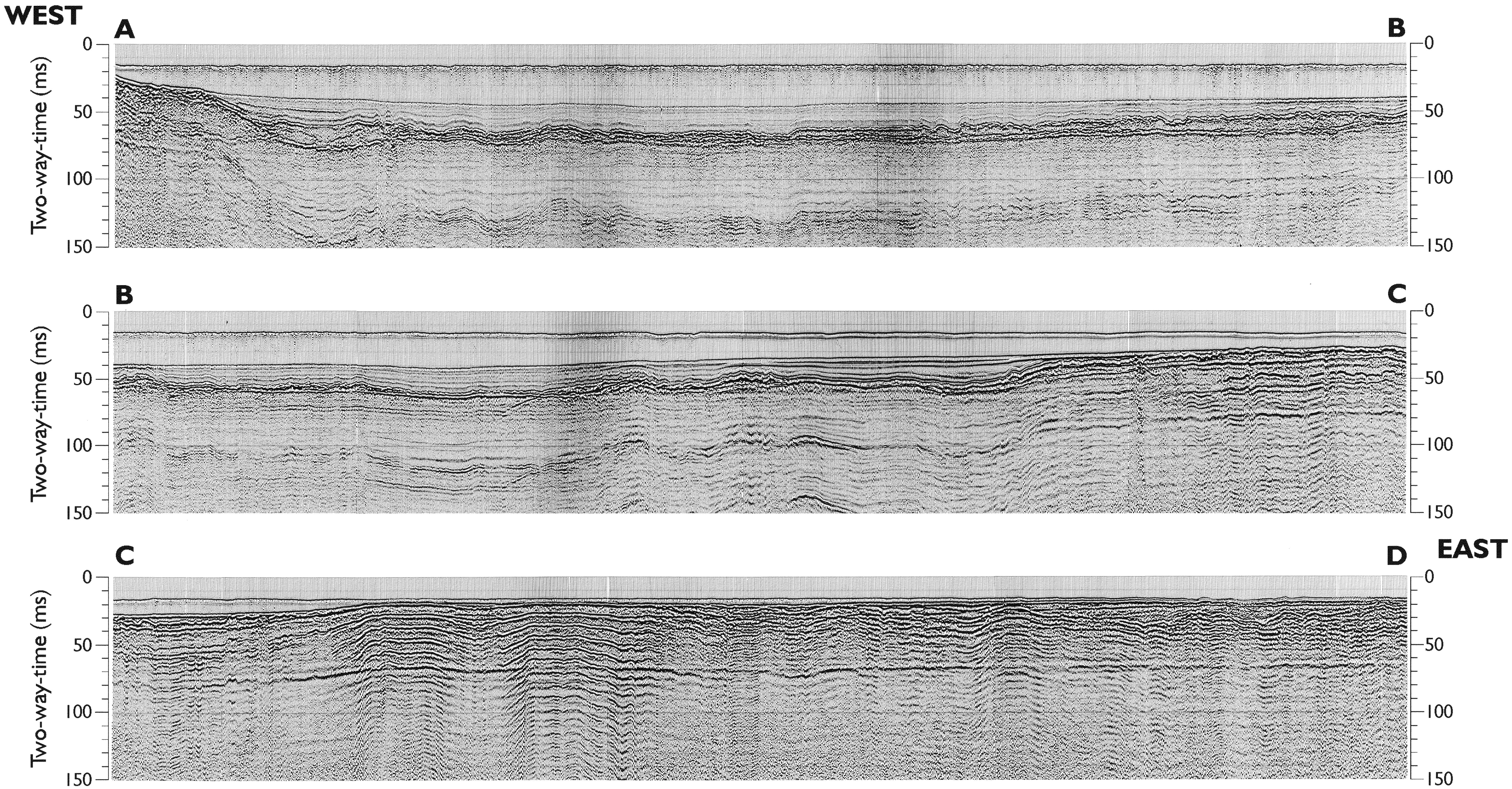
# LAKE SIMCOE SEISMIC PROFILES

## LINE 93-10




V.E. (@1500 m/s)=11.6X

0 1 2

Distance (km)

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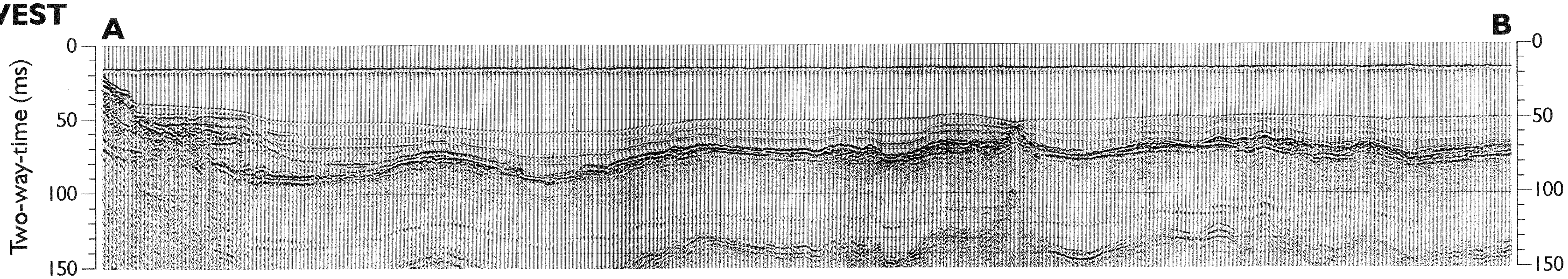
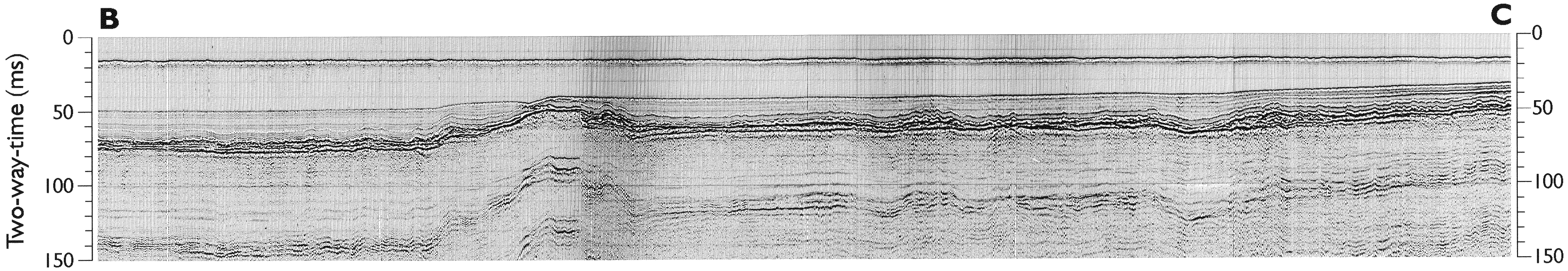
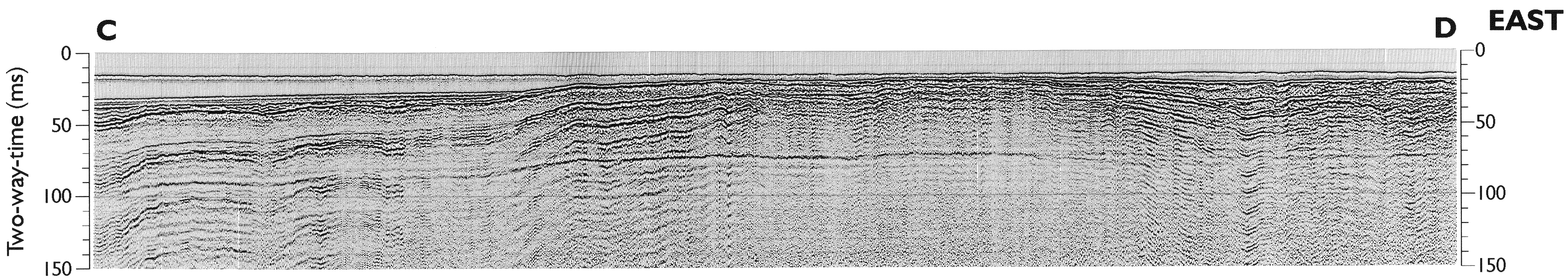
# LAKE SIMCOE SEISMIC PROFILES

## LINE 93-11




V.E. (@1500 m/s)=11.6X

0 1 2

Distance (km)

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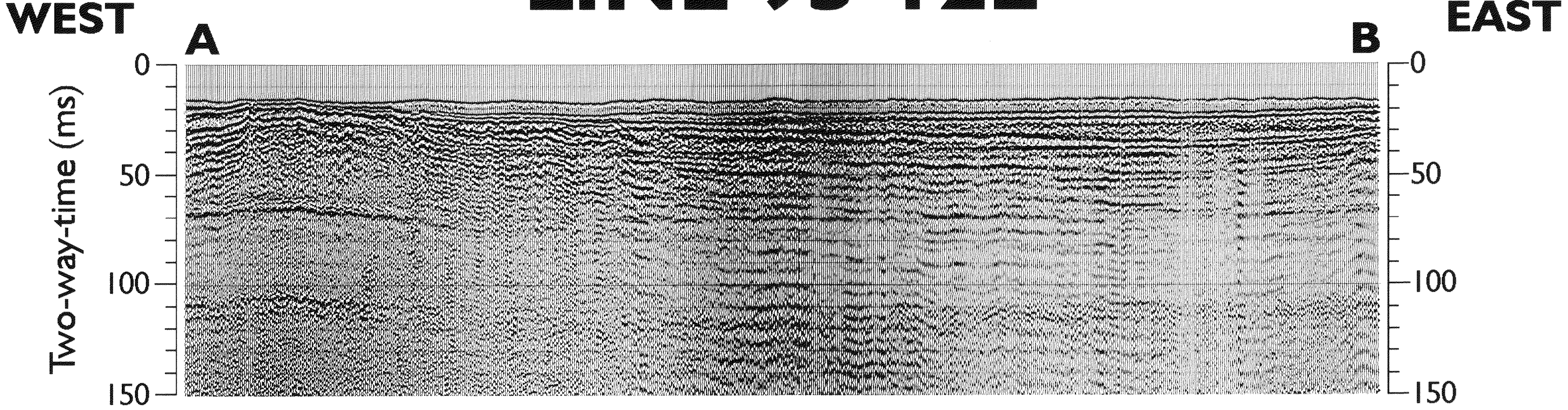
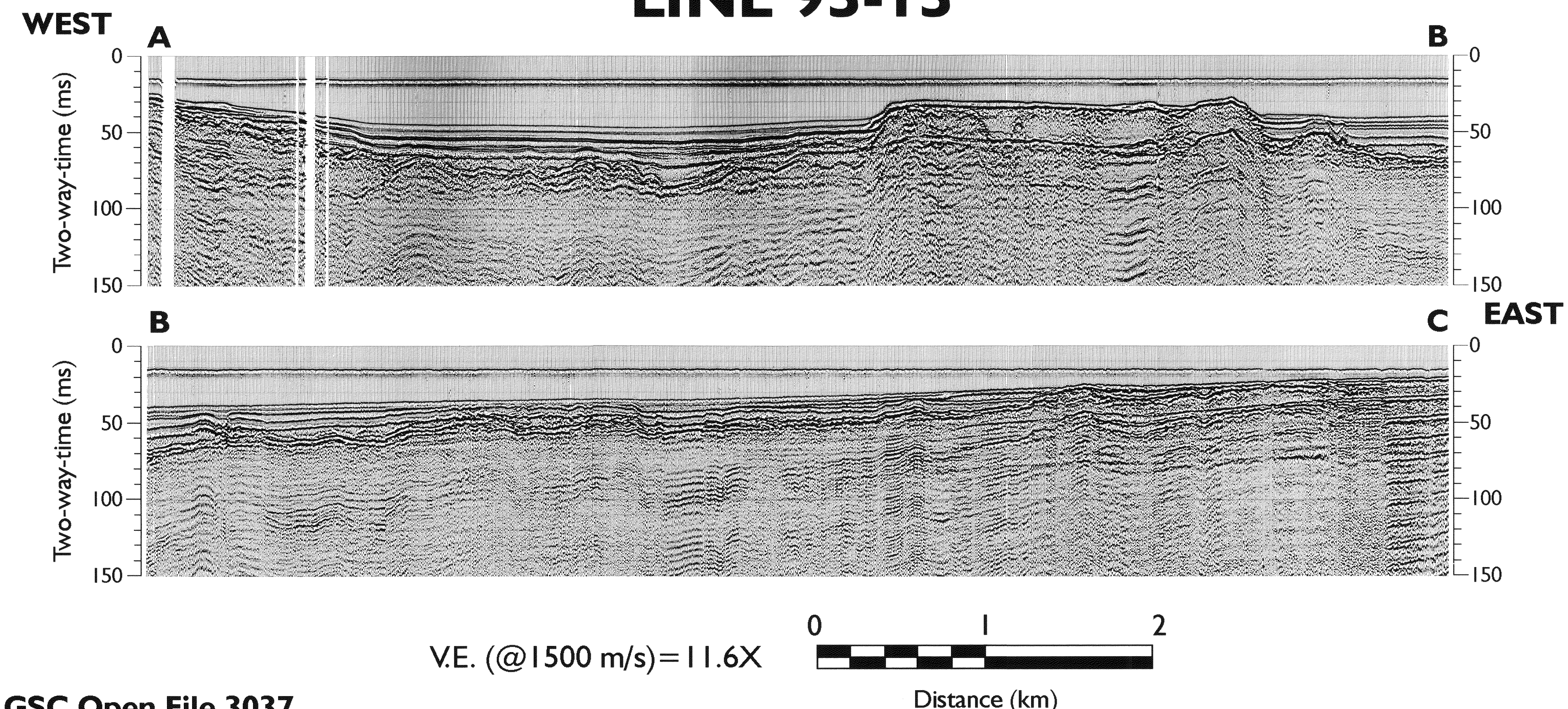
# LAKE SIMCOE SEISMIC PROFILES

J. Ross Mackay 1992-1993

## LINE 93-12E




## LINE 93-13

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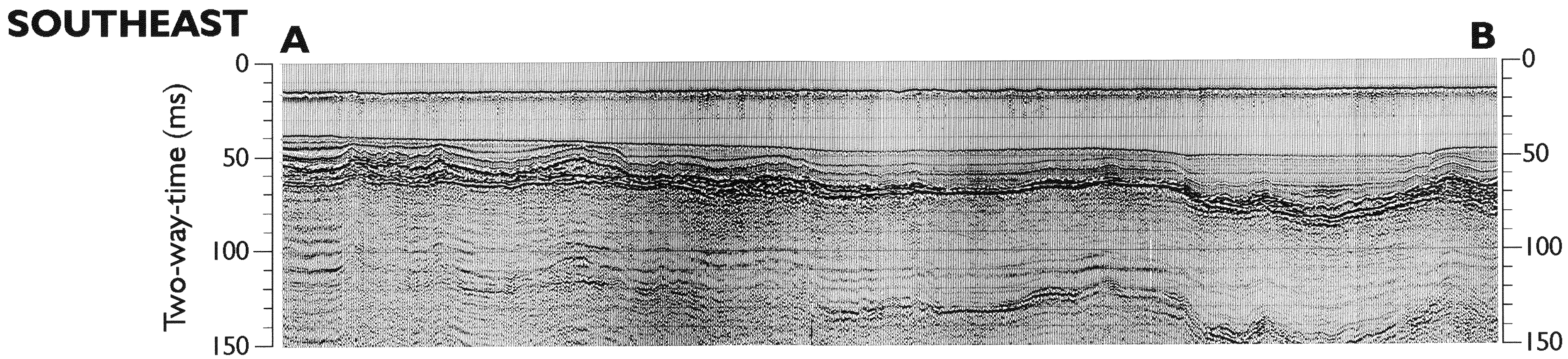
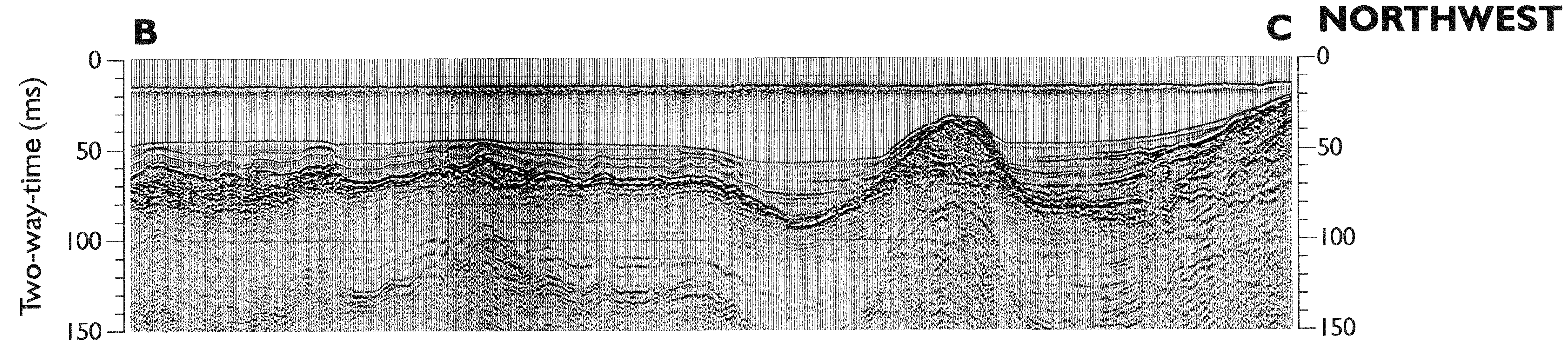
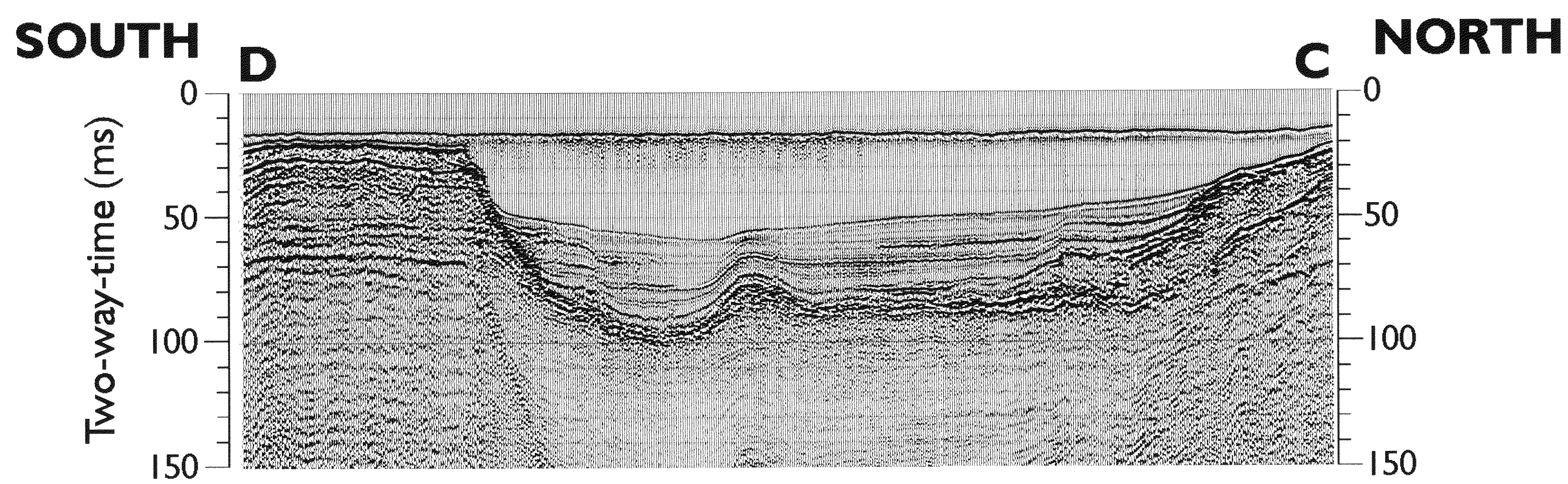
# LAKE SIMCOE SEISMIC PROFILES

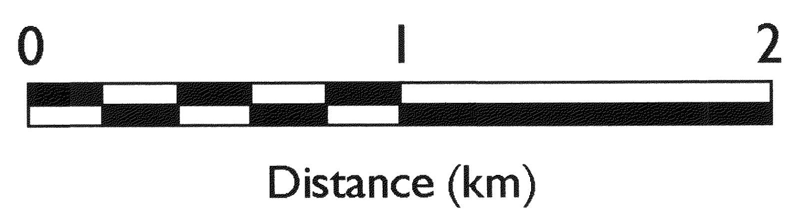
## LINE 93-14a



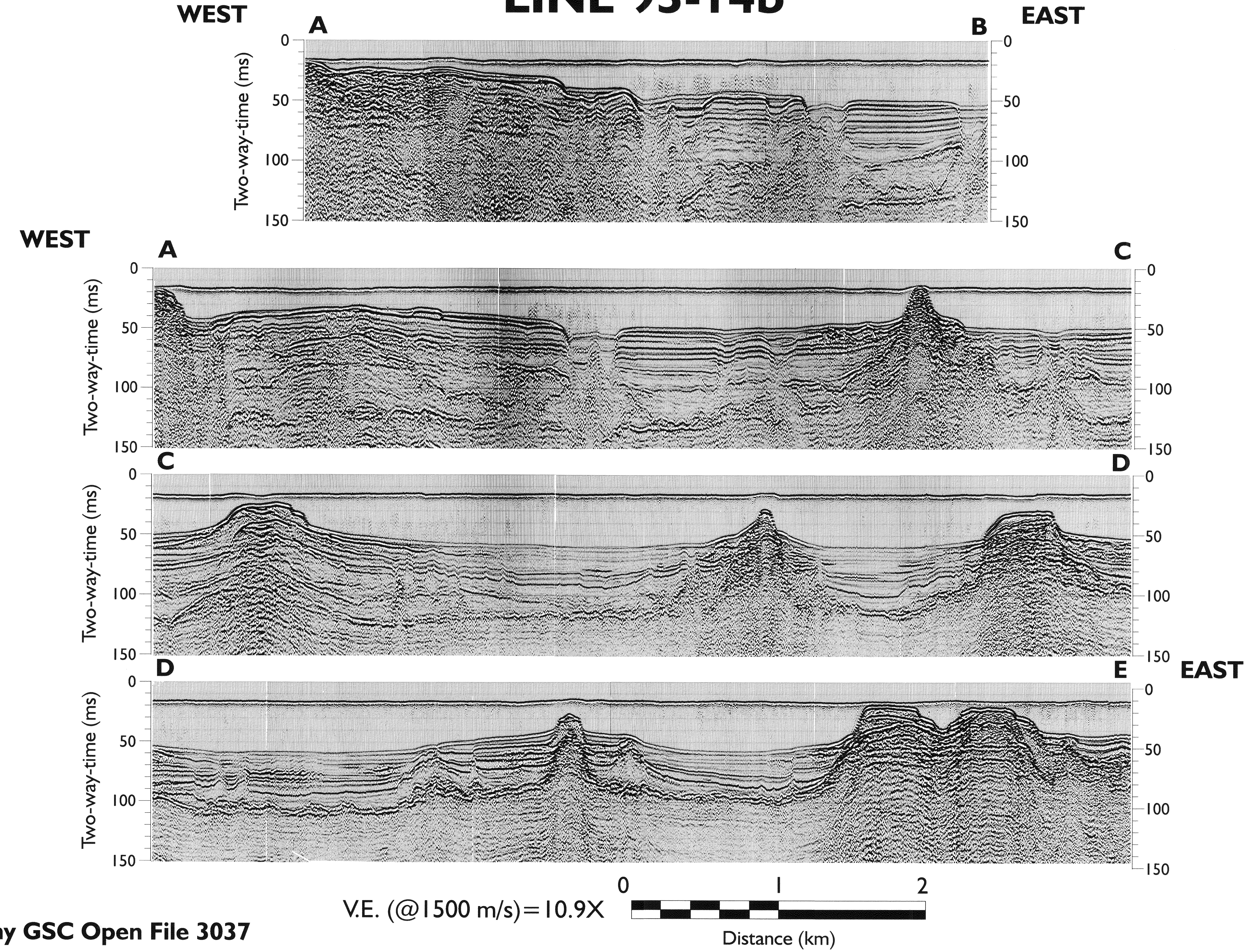

V.E. (@1500 m/s) = 11.6X




**To accompany GSC Open File 3037**

# LAKE SIMCOE SEISMIC PROFILES

## LINE 93-14b

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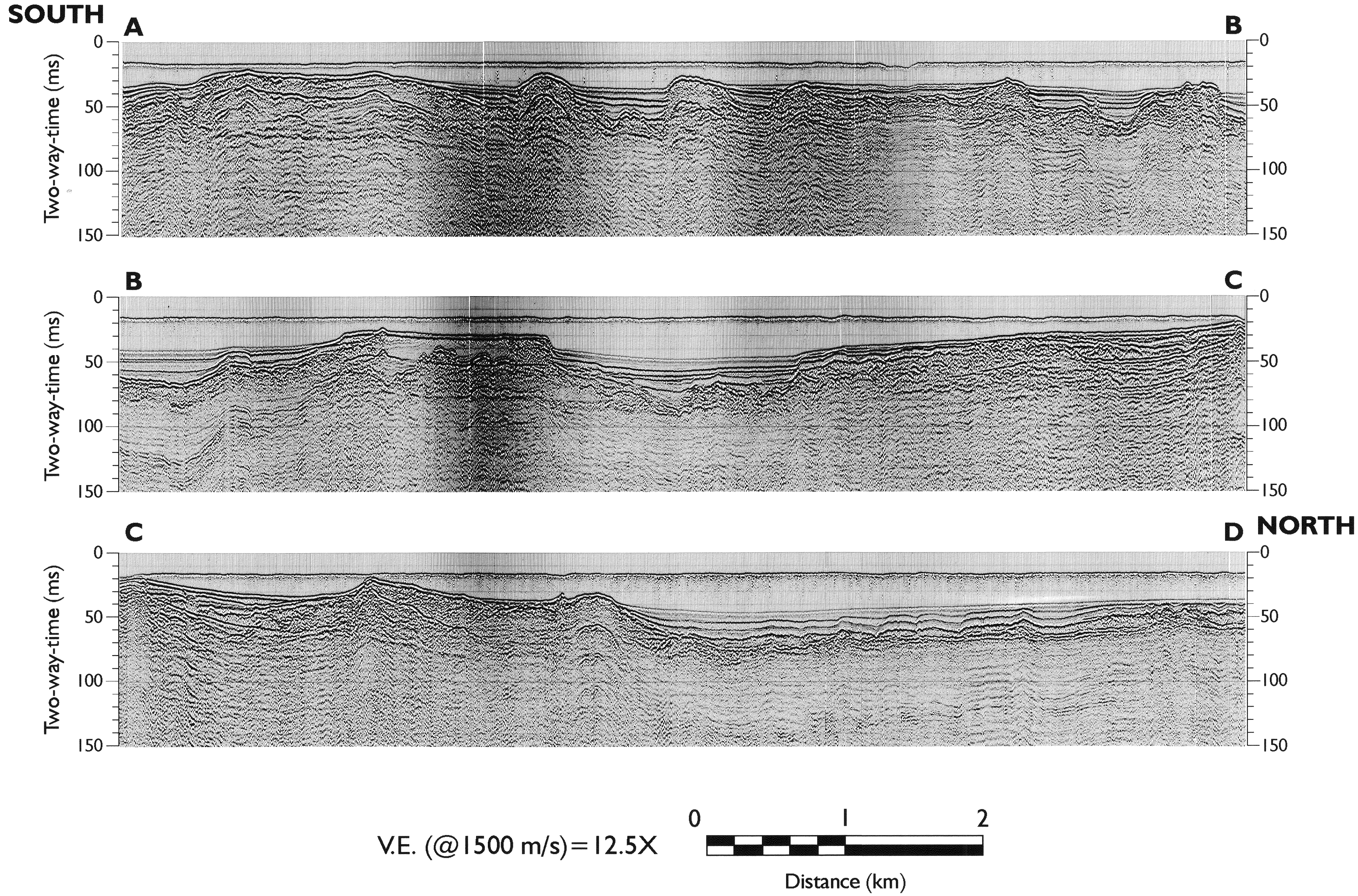
# LAKE SIMCOE SEISMIC PROFILES

## LINE 93-15a

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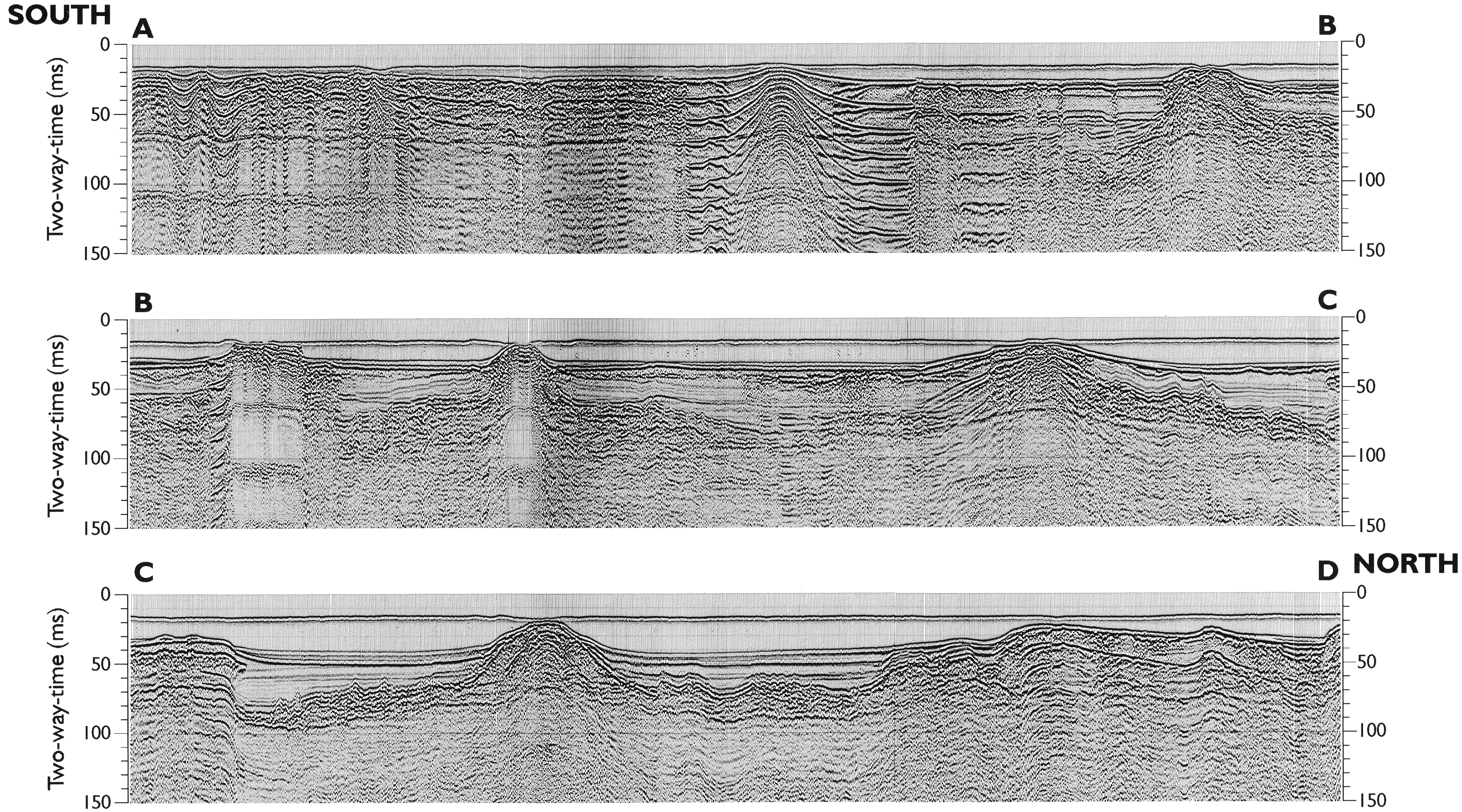
# LAKE SIMCOE SEISMIC PROFILES

J. Ross Mackay 1992-1993

## LINE 93-15b




V.E. (@1500 m/s) = 13X

0 1 2

Distance (km)

**To accompany GSC Open File 3037**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