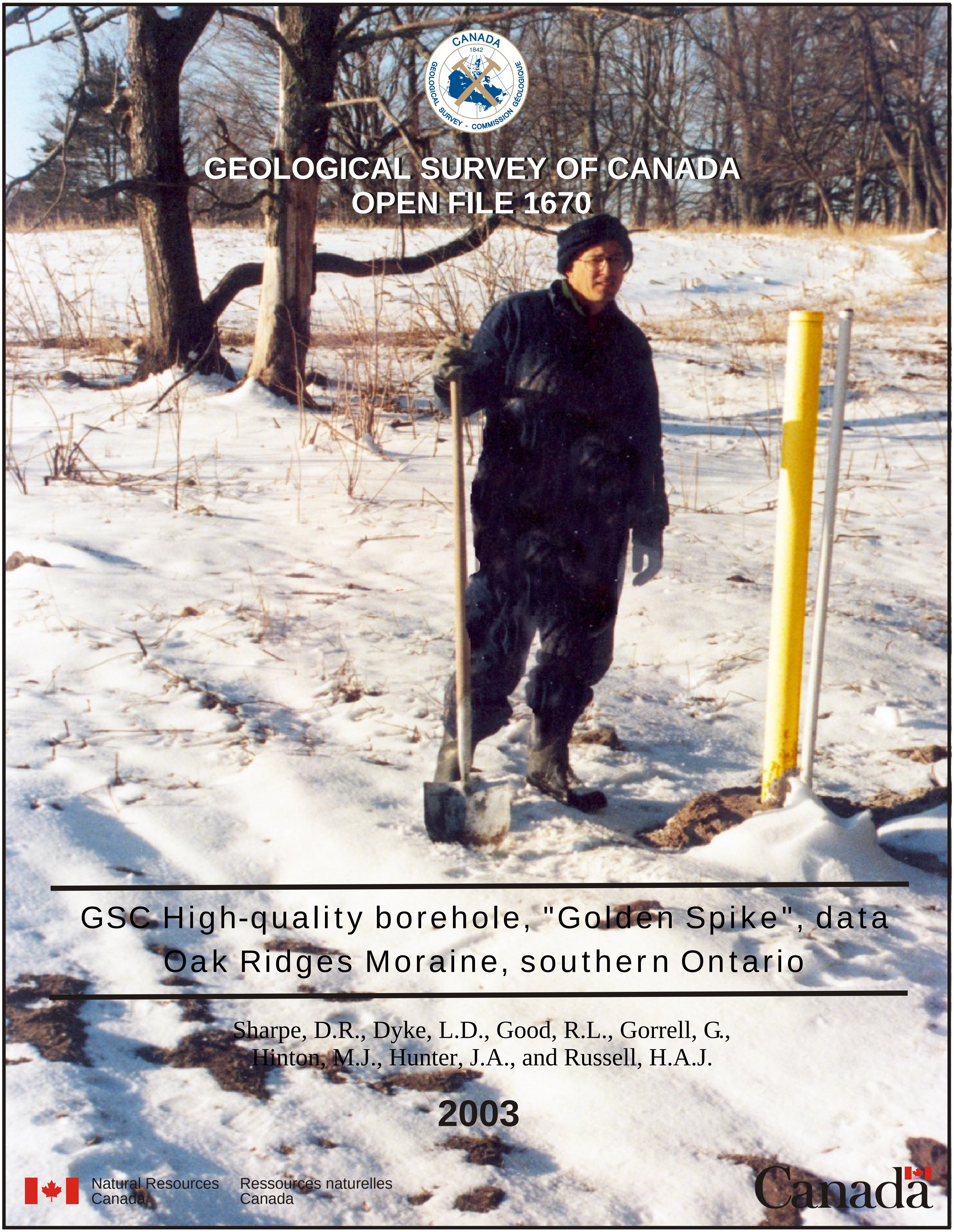

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 1670

GSC High-quality borehole, "Golden Spike", data
Oak Ridges Moraine, southern Ontario

Sharpe, D.R., Dyke, L.D., Good, R.L., Gorrell, G.,
Hinton, M.J., Hunter, J.A., and Russell, H.A.J.

2003

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Canada

GEOLOGICAL SURVEY OF CANADA

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GSC High-quality borehole, “Golden Spike” data, Oak Ridges Moraine, southern Ontario

D.R. Sharpe, L.D. Dyke, R.L. Good, G. Gorrell, M.J. Hinton,
J.A. Hunter, and H.A.J. Russell,

2003

Available from Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E8

Sharpe, D.R., Dyke, L., Good, R.L., Gorrell, G., Hinton, M.J., Hunter, J.A., and Russell, H.A.J, 2003.

2003: GSC High-quality borehole, “Golden Spike” data, Oak Ridges Moraine, southern Ontario, Geological Survey of Canada, Open File 1670, 21p.

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GSC High-quality borehole, "Golden Spike" data, Oak Ridges Moraine, southern Ontario

Geological Survey of Canada Open File 1670

Sharpe, D.R., Dyke, L., Good, R.L., Gorrell, G., Hinton, M.J., Hunter, J.A., and Russell, H.A.J, 2003.

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Abstract

This data release documents five continuously-cored boreholes, termed 'Golden Spikes' completed by the Geological Survey of Canada in the Oak Ridges Moraine Area. These boreholes provide stratigraphic references for developing a regional geological framework. The primary information presented for hydrostratigraphic analysis is two graphic logs for each site that: a) illustrate the sedimentary succession, stratigraphy, and piezometer installation; and, b) the geophysical log signatures. Related metadata tabulates information on the location, construction, piezometer installation, monitoring, water chemistry, sedimentology, and downhole geophyscis for each of the sites.

Introduction

The Geological Survey of Canada (GSC) completed a drilling program of five continuously-cored boreholes in the Oak Ridges Moraine (ORM) between 1994 and 1998 (Fig. 1). These boreholes were drilled as part of a regional geological and hydrogeological study of the Greater Toronto and Oak Ridges Moraine area (Sharpe et al. 1996). A focus of this study was to collect new geological and hydrogeological data that could contribute to the development of a regional stratigraphic-hydrostratigraphic framework of the area (Logan et al. 2002; Russell et al. 2003a,b; Sharpe et al. 2003a,b). These data complement regional drilling completed by the Ontario Geological Survey (Barnett, 1992), and by various consultants for the Interim Waste Authority (IWA, 1994; Fig. 1).

This report briefly documents the rationale for the drilling program and monitoring site development. The application to other regional hydrogeology studies is also briefly reviewed. The principal objective of this report is to provide graphic logs of the sediment descriptions, stratigraphic interpretation, downhole geophysical data, and the position of piezometers and water levels (Fig. 2- 6). These data are supplemented with metadata on the borehole location, construction, piezometer installation, monitoring, geology and downhole geophyscics (Table 1). Information in this report has been published as a GSC Open file and can be cited as Sharpe et al., 2003(c).

Regional Hydrogeological Knowledge and 'Golden Spike' boreholes

A regional knowledge of aquifer systems is essential for effective groundwater resource management. Improving regional knowledge, in light of sparse hydrogeological data, requires a geological understanding of the sedimentary basin that includes mapping and characterizing its reservoir potential through a basin analysis approach (Sharpe et al., 2002). Collection of high-quality subsurface data, such as cored-boreholes, aids in the development of this geological framework.

The Golden Spike

The term 'Golden Spike' has been coined to describe continuously-cored boreholes drilled to the target formation. These boreholes have a higher cost than other types of drilling (e.g. wash boring, split spoon sampling) due to core collection, detailed sediment logging, sampling and data processing. Continuously-cored boreholes, thus, are termed 'golden' because they are an invaluable aid to the development of geological and hydrogeological models. The core is commonly supplemented with borehole geophysics, sample testing and piezometer installations.

In glaciated settings, continuous core is specifically used in the development of stratigraphic and sedimentological models that can identify erosional breaks or unconformities (Barnett et al., 1998). The once-assumed, layer-cake till stratigraphic model of glacial basins is inappropriate for many areas. Instead the stratigraphy is often incised by deep erosional channels that provide hydraulic connectivity to lower aquifers (Sharpe et al., 2002). The use of borehole geophysics in glacial sediments is also aided by continuous core to permit facies correlation and indexing of the sedimentological, and ongoing definition of geophysical signatures (Pullan et al., 2002). Borehole 'golden spikes' when installed with appropriate monitors can also contribute to the quantification of regional flow systems by providing a foundation for stratigraphically-controlled hydraulic testing. This combination of geological understanding and hydrogeological quantification then permits the establishment of a framework for improved extrapolation of hydrogeological parameters throughout an aquifer, watershed or basin.

Regional Information Gaps

In the last 50 years, groundwater management has relied heavily on water well records as a primary source of regional hydrogeological information (Cherry et al., 1988). Although potentially useful in large numbers in simple geological settings, or in conjunction with a sound conceptual geological model and geostatistical analysis, water well records are regarded as being of limited usefulness (Russell et al., 1998). They are inadequate by themselves for 3-D stratigraphic delineation in the ORM (Logan et al., 2001). Unfortunately, groundwater resource evaluations have infrequently involved the collection of high-quality subsurface information (Sibul et al., 1977, Gerber and Howard, 2002) and quality data has been acquired ad-hoc and restricted to a relatively small number of site-specific locations such as at landfills (e.g. IWA, 1994). Thus, the widespread reliance on the water well-drilling approach and the scarcity of information from water resource evaluations has resulted in inadequate regional hydrogeological data to manage and protect the resource (e.g. Singer, 1974; Sibul et al., 1977). This situation is in stark contrast to the practice of basin analysis and regional database development based on the acquisition of high-quality subsurface geological data for petroleum reservoir characterization.

Key Data for Developing Geological and Groundwater Flow Models

The collection of continuous-core is a critical step in developing a sound 3-D geological framework and defendable geological models (Sharpe et al., 2002). The framework is best advanced when continuous core is combined with high-quality data from detailed geological mapping, seismic profiles and borehole geophysical surveys (e.g. Pugin et al., 1999). This allows for a more effective integration of abundant archival data to extend geological understanding within the basin (Logan et al., 2002). The addition of 'golden spike' data to enhance the utility of water well records, permits hydrogeologists to: i) better define the hydrostratigraphy; and, ii) more confidently regionalize sparse hydraulic data.

Detailed sediment cores and related data allow for:

i) enhancement and integration of lower-quality archival data (e.g. water well records)
ii) collection of sedimentological data for constructing depositional models,
iii) development of regional 3-D geologic and stratigraphic models,

iv) better characterization of hydrostratigraphic units, water levels and vertical gradients, and,
v) use of enhanced quantitative methods, e.g. transitional probabilities (Weissman et al., 1999).

We propose that fully-cored boreholes, termed "golden spikes", be considered as a general approach for high-quality borehole installation as documented in the ORM area. They provide stratigraphic benchmarks for developing a regional geological framework, thus creating critical context for integrating related monitoring and hydraulic test data for hydrogeological characterization and quantitative flow system analysis.

Borehole Metadata

Metadata are central to viable hydrogeological databases (Russell et al., 1996) and provide users with important information about the collected data and the integrity of these database elements. This report provides details regarding the location, drilling, piezometers, monitoring, sediment logs, and borehole geophysics of the five GSC 'golden spikes' in the ORM area (Table 1) and some of these are discussed below.

The data for each borehole is supplemented with two figures. The first figure for each borehole documents the sedimentary succession, piezometer installations and static water levels. The second figure provides a summary of the geophysical log signatures (Pullan et al. 2002). The geophyscial data has been previously released on the Geological Survey of Canada website for the national compilation of geophysical logs in surficial sediments. Additional details on logging methodology and measurements can also be found at the site and in Douma et al. (1999). (http://sts.gsc.nrcan.gc.ca/clf/borehole_geophysic.asp)

Metadata Notes

Location
The location of all five boreholes was surveyed by Delph and Jenkins North Ltd, Aurora to a vertical resolution of mm and a horizontal resolution of cm.

Drilling methods
Two different companies completed drilling of the five boreholes. The first three boreholes (Vandorf, Ballantrae and McCowan) were drilled using a mud rotary system and a 10-foot core barrel sampling system. The next 2 boreholes (Aurora and Nobleton) were drilled using mud rotary with wireline retrieval for rapid core barrel recovery particularly at depth. Sampling on the later 2 boreholes used a Christiansen core barrel with 2.5 and 5-foot lengths to improve core recovery.

Borehole Construction
Borehole construction was completed using 3" PVC well casing and standard sand filter packs and bentonite grouting. The wells were secured in the near surface by cement grouting.

Piezometers
Piezometers were installed in the principal 3" well and some cases a 1" PVC casing was placed inside the 3" casing for monitoring. Also several additional wells were drilled to house separated piezometers set in key horizons.

Water Levels
Water levels were taken following well development and stabilization. Later, water levels are being recorded using 'continuous' data loggers. These results will be reported separately and ongoing well responsibility and monitoring has been transferred to York Region.

Sediment logs
Sediment logs reported here are generalized from detailed descriptions and related information. The logs (Figs. 2-6) were produced from bed by bed description of the lithofacies, sedimentary structure, correlation with downhole geophysics, as well as notes from drill site inspection and drilling rate for unrecovered core. The first three boreholes (Vandorf, Ballantrae and McCowan) had approximately 80 % of core recovery from a 10 feet core barrel. Higher recovery (~95 %) was achieved using 2.5 and 5-foot core barrels on the Aurora and Nobleton cores. Higher core recovery and a more systematic core logging procedure including detailed core by core photography, led to more detailed logs at the later two sites. All the details on core recovery, photography, sampling, laboratory results and detailed sediment description will be released as a comprehensive digital data file and poster (e.g. Russell et al., 2003c). For example, laboratory work included water content, grain size and total organic content. The borehole database will be added to the national groundwater database under the GSC Hydrogeology program.

Geophysical logs
A wide suite of geophysical logs was acquired in the five GSC boreholes and details are available at: http://sts.gsc.nrcan.gc.ca/clf/borehole_geophysic.asp.

The GSC boreholes have been used for additional borehole geophysical logging, testing and calibration and these results will soon be available from Steve Holysh, Conservation Authority Moraine Coalition.

Summary

Improved hydrogeological understanding of a region requires the collection of high quality sedimentological and hydrogeological data. 'Golden Spikes' provide data necessary to develop robust geological models, e.g. event-stratigraphic models and depositional facies models, important in delineating stratigraphic architecture and aquifer properties. The relationship between sediment facies with hydrogeological properties allows for geostatistical characterization of aquifer heterogeneity.

Note:
A detailed description of the top ~70m of the Vandorf golden spike can be found in: Gilbert, R., 1997, Glaciolacustrine sedimentation in part of the Oak Ridges Moraine: Géographie physique et Quaternaire, v. 7, no. 1, p. 55-66.

Acknowledgments

We appreciate access to private property and property of the Regional Municipality of York for borehole installation and ongoing testing and monitoring. We thank the following landowners: Mark and Stacey Falkenberg, present owners, and, Mr and Mrs. Campbell Snider, former owners, Nobleton; Dr. Peter Van Nostrand, Vandorf; Mr. P.G. (Gren) Schoch, Aurora.

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Table 1 Metadata[1] for GSC 'Golden Spike' Boreholes

Borehole location

Site ID		GSC-BH-VSR	GSC-BH-MSR	GSC-BH-BAL	GSC-BH-NOB	GSC-BH-AUR
Main road		Vandorf SR	McCowan Rd	McCowan Rd	15th SR	Vandorf SR
cross roads		Woodbine-Warden	Davis-Vivian	Aurora SR-J. Thompsor	7th-8th Con	Bayview-Leslie
Old ID (piezometer ID)		VD	1MC	2MC	Nob	Aur
MOE well ID		6922750	6922752	6922751	6923544	6926102
Drillers report #		144038	144039	144040	54124	54185
Owner		Dr. Van Nostrand	York Region	York Region	M. Falkenberg	P. Schoch
Map UTM	Easting	630090	633400	634650	611100	626120
(NAD27, Zone17)	Northing	4873000	4882400	4876150	4864650	4871860
Map Elevation		302	279	332	268	267
Surveyed XY_2	Easting	630,185.37	633,438.58	634,705.81	611,195.48	626,137.85
(NAD 83, Zone 17)	Northing	4,873,233.97	4,882,567.09	4,876,370.37	4,864,941.62	4,871,862.81
Surveyed Z		302.8	278.6	332.4	268.3	266.9
Site Map / Photo		see ORM website	see ORM website	see ORM website	see ORM website	see ORM website

Borehole construction (ID01=deepest)

Start of drilling	15/3/94	30/3/94	10/5/1994	Nov-95	21/3/1998
Drilling method	Mud rotary	Mud rotary	Mud rotary	Mud rotary/wireline	Mud rotary/wireline
Sampling method	Cont. core	Cont. core	Cont. core	Cont. core/wireline	Cont. core/wireline
Total depth of borehole (m)	132.6	108.5	159.1	192.8	140.3
Core sampler length (ft)	10	10	10	2.5-5	2.5-5
Contractor	Alan Wright	Alan Wright	Alan Wright	All Terrain Drilling	All Terrain Drilling
Drilling fluids used	mud (Baroid)	mud (Baroid)	mud (Baroid)	mud (Quickgel)	mud (Quickgel)
Date of completion	25/3/94	7/4/1994	20/5/94	Jan-96	Apr-97
Drill bit diameter (")	6 1/8	6 1/8	6 1/8	5.063	5.063
Core barrel length (ft)	10	10	10	5	5
Core casing type	steel	steel	steel	steel	steel
Casing diameter (")	6 1/4	6 1/4	6 1/4	6.5 (OD)	6.5 (OD)
Casing intervals (ft):	0-20	0-20	0-20	0-40	0-20
Sleeve casing int. (m)	\	\	\	0-61	\
Core diameter (")	3	3	3	3-3.25	3-3.25
Top grouting (m)	0-20	0-22	0-20	varies (cement)	varies (cement)
Well casing type	3" ID PVC	3" ID PVC	3" ID PVC	3" ID PVC	3" ID PVC
Grouting type	Bentonite	Bentonite	Bentonite	Bentonite	Bentonite
Filter pack	sand	sand	sand	sand	sand
Backfill	native soil	native soil	native soil	native soil	native soil
Well development (initial):	25/3/94	7/4/1994	27/5/94	Jan-96	Apr-97
Development method	air lift	air lift	air lift	pumped from base	pumped from base
Additional wells on site	\	w	w; see OGS-93-16	ID1,2	ID 2, 3, 4

Piezometer description:

Number		2	2	3	2	3
water table well		yes (broken)	yes(0.73	yes (0.72)	no	yes
Labelled in field		no	no	no	no	no
Screen size:		#10 slot	#10 slot	#10 slot	#10 slot	#10 slot
Screen opening (")		1/100	1/100	1/100	1/100	1/100
Point of measurement (m asl)		303.49	279.45	333.12	269.20	268.18
Measuring point	ID-1	0.73	0.84	0.8	\	0.86
stick-up (m):	ID-2	0.74	0.84	0.78	0.79	0.72
	ID-3	\	\	0.75	0.86	0.68
	ID-4	\	\	\	\	0.79
Screen int. (size"):	ID-1	61.0-64.0 (1")	44.2-47.2 (1")	36.6-39.6 (1")	56.7-59.7 (2")	3-4.6 (1.5")
(m below 0)	ID-2	123.4-126.4 (3")	89.9-93 (3")	91.4-94.4 (1")	186.7-189.8 (3")	13.4-16.5 (1.5")
	ID-3	\	\	131.7-134.7 (2")	16-18	28.0-31.1 (2.5")
	ID-4	\	\	WT=8.1-11.1	\	134-137 (2.5")
Seal intervals	ID-1	55-58; 67-70	37.5-39.6;50.9-52.7	27.4-29.9;46.0-48.8	0-12.2	0-2.4
(top; bottom)	ID-2	117-120	77.7-81.7; 99.6-100.(	82.0-84.7;102.1-104.8	6.4-48.8	0-12.2
	ID-3			122.8-125.6;142.3-145.1	64-183.5	16.8-25.9
					4) 0-132.6	
Seal type:		Bentonite	Bentonite	Bentonite	Cement/bentonite	Bentonite

Monitoring

Water levels: (m bgs)						
Static after completion:						
Meas. level:	Wtable	1.33 (8/94)			yes	1.23
	ID-1	16.7	5.35	10.82	1.14	-0.17
	ID-2	32.16	9.54	24.95	19.47	-0.13
	ID-3			48.71		19.97(sed. in water)
Date of monitoring		30/6/94	30/6/94	30/6/94	28/6/96	12-Jun-97
Meas. level:	Wtable	broken	5.43	dry		dry
	ID-1	16.17	5.07	12.65	1.33	-0.02
	ID-2	32.01	9.54	27.03	19.65	-0.01
	ID-3			50.68		18.85
Date of monitoring		12-Mar-01	14-Mar-01	19-Mar-01	13-Mar-01	18-Nov-97
Datalogger record (current)		VD-2,VD-1 (York)	1MC;1 MC-2 (York)	2MC-2 (York)	Nob-2	Aur-3; Aur-4 (York)
Graph of data		y	n	?	?	y
Data release[1]		OFdata report	OFdata report	OFdata report	OFdata report	OFdata report
Monitoring contact		York Region (2002)	York Region (2002)	York Region (2002)	York Region (2002)	York Region (2002)
Water chemistry:						
Date of sampling		19-Jul-96	22-Oct-96	22-Oct-96	11-Jul-97	5-Aug-97
Well sampled		w, -1, -2	ID-1,-2	ID-1,-2	ID-1,-2	w, -1, -2

Sediment log

Graphic file	ORM website	ORM website	ORM website	ORM website	ORM website
(published)	Barnett...1998_7b	/	Pugin...1999_9	Pugin...1999_4	Sharpe…2000_4
Coding file	ORM website	ORM website	ORM website	ORM website	ORM website
Detailed[1]	OFdata report	OFdata report	OFdata report	OFdata report	OFdata report
Geological setting					
Map	jpeg file	jpeg file	jpeg file	jpeg file	jpeg file
Seismic profile	Pugin et al., 1999	ORM website	Pugin et al., 1999	Pugin et al., 1999	Sharpe/Russell, 2000

Downhole geophysics

Tool	**Y=yes; Survey date**				
N. gamma (Geo.EM39)	11/9/1995	9/11/1996	9/11/1996	17/07/96	9/7/1997
Cond. (Geo.EM39)	11/9/1995	9/11/1996	9/11/1996	17/07/96	9/7/1997
Mag. Sus. (Geo.EM39)	11/9/1995	9/11/1996	9/11/1996	17/07/96	9/7/1997
P-wave vel.	8/11/1994	5/11/1994	6/11/1994	19/07/96	10/7/1997
s-wave	\	\	\	\	y
VSP	y	y	y	y	y
Rel Den. (IFG)	5/11/1996	5/11/1996	5/11/1996	7/11/1996	8/7/1997
Gamma spec ratio (IFG)	5/11/1996	5/11/1996	5/11/1996	7/11/1996	8/7/1997
Temp/T grad. (IFG)	y	y	y	y	y
Seismic profile	y	y	y	y	y
Graphic log	jpeg file	jpeg file	jpeg file	jpeg file	jpeg file
Published (jpeg)	ORM web 2003	ORM web 2003	ORM web 2003	Pullan et al., 2001	ORM web 2003
Digital files[1]	OFdata report	OFdata report	OFdata report	OFdata report	OFdata report

Notes:
1. Open file data reports are in preparation for release in 2003.
2. Surveyed by Delph & Jenkins North Ltd, Aurora Ontario, April 2001

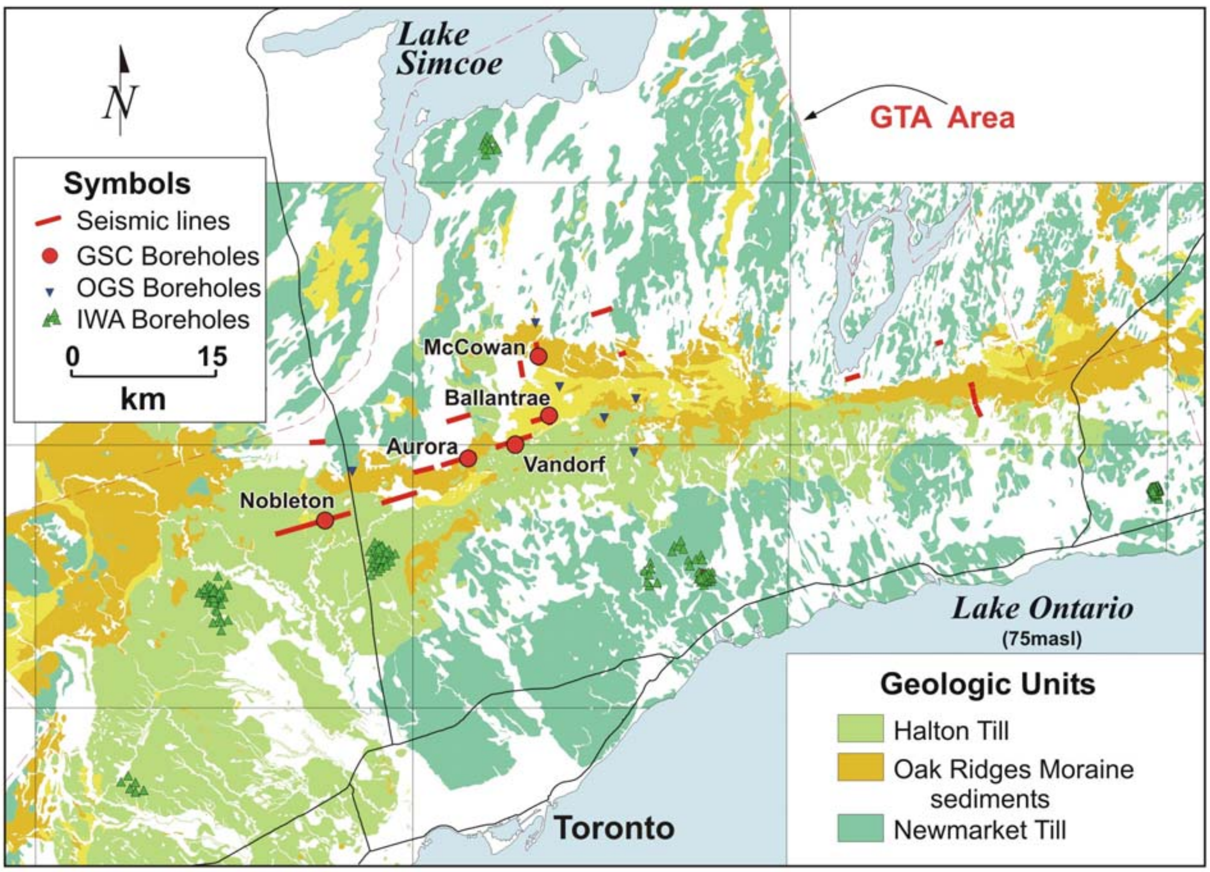
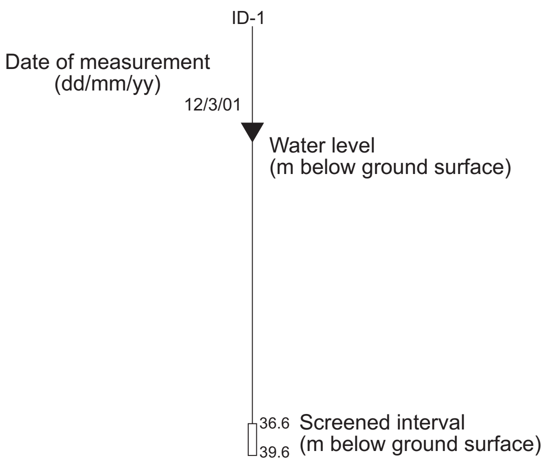

Lake Simcoe
N
GTA Area
Symbols
Seismic lines
GSC Boreholes
OGS Boreholes
IWA Boreholes
0
15
km
McCowan
Ballantrae
Aurora
Vandorf
Nobleton
Lake Ontario
(75masl)
Geologic Units
Halton Till
Oak Ridges Moraine sediments
Newmarket Till
Toronto

Figure 1

Borehole Legend

Piezometers



Coarsening upward trend

Fining upward trend

Ripples

Organics

Dewatering structure

Stratigraphy

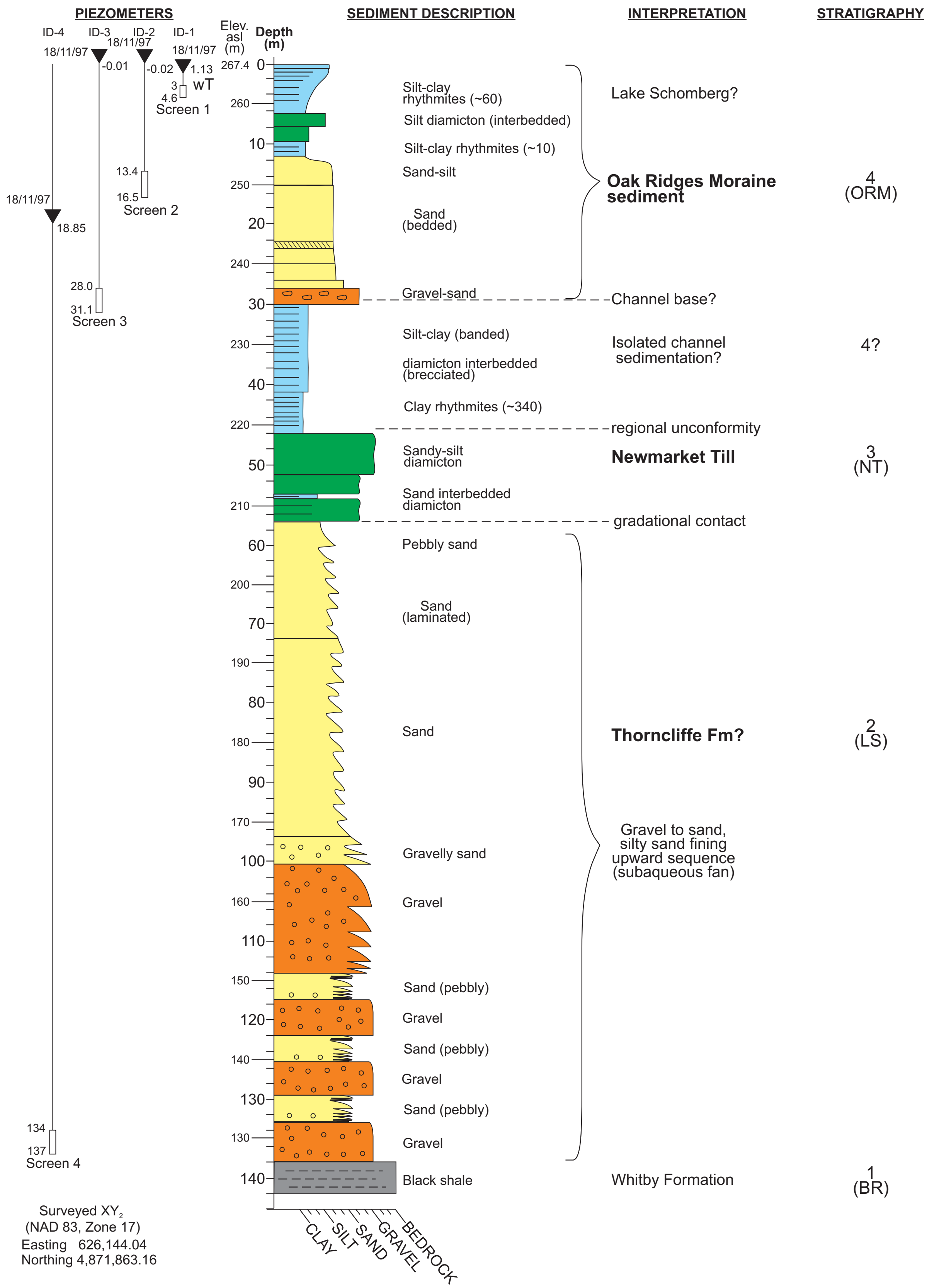
4 (ORM) **Oak Ridges Moraine**

3 (NT) **Newmarket Till**

2 (LS) **Lower Sediment**

1 (BR) **Bedrock**

GSC AURORA BOREHOLE (Golden Spike Monitor) (GSC-BH-AUR)



Surveyed XY_2
(NAD 83, Zone 17)
Easting 626,144.04
Northing 4,871,863.16

Figure 2a

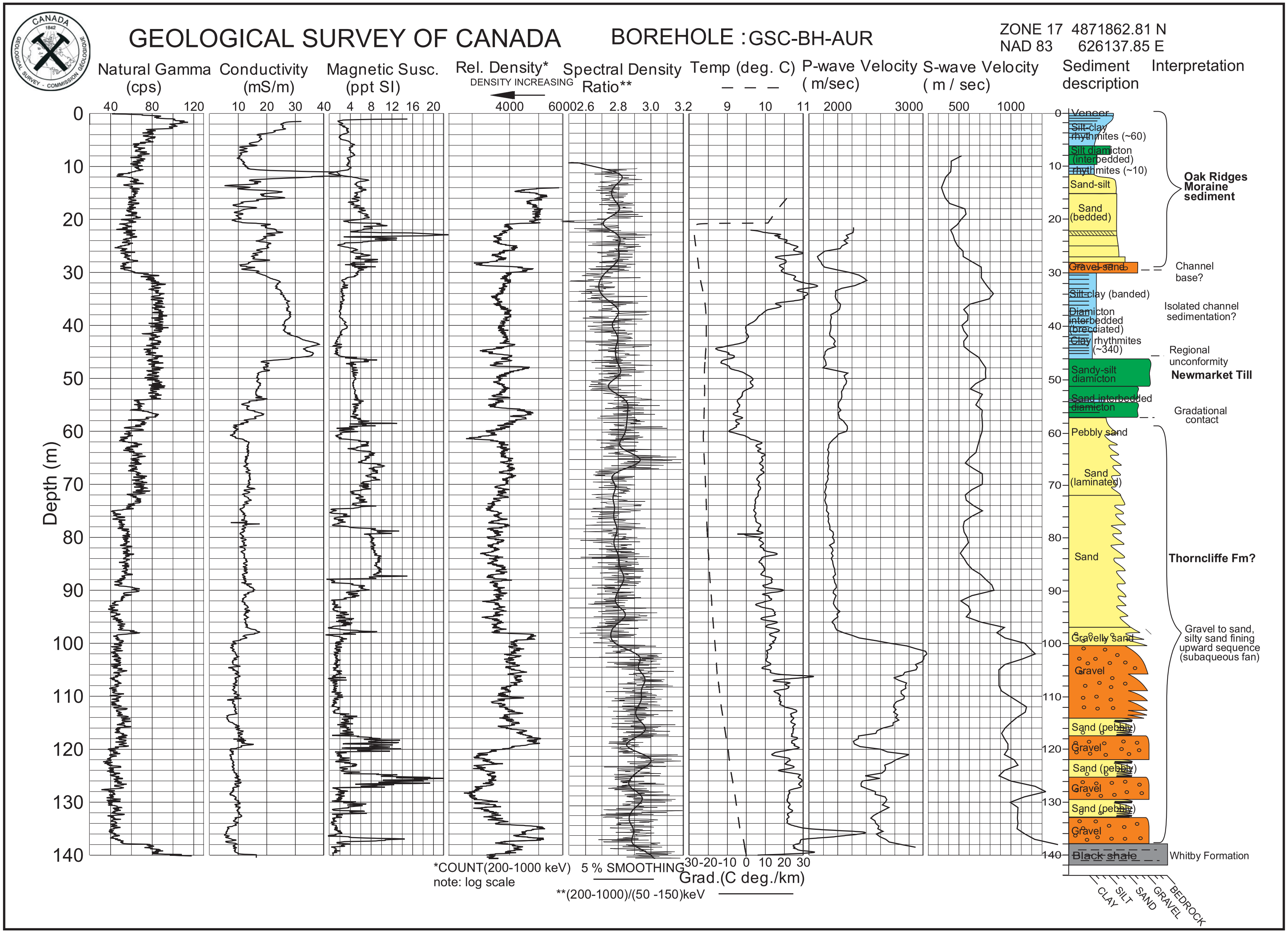

GEOLOGICAL SURVEY OF CANADA
BOREHOLE : GSC-BH-AUR
ZONE 17 4871862.81 N
NAD 83 626137.85 E
Natural Gamma (cps)
Conductivity (mS/m)
Magnetic Susc. (ppt SI)
Rel. Density*
DENSITY INCREASING
Spectral Density Ratio**
Temp (deg. C)
P-wave Velocity (m/sec)
S-wave Velocity (m / sec)
Sediment description
Interpretation
Depth (m)
Veneer
Silt-clay rhythmites (~60)
Silt diamicton (interbedded)
rhythmites (~10)
Sand-silt
Sand (bedded)
Gravel-sand
Silt-clay (banded)
Diamicton interbedded (brecciated)
Clay rhythmites (~340)
Sandy-silt diamicton
Sand interbedded diamicton
Pebbly sand
Sand (laminated)
Sand
Gravelly sand
Gravel
Sand (pebbly)
Black shale
CLAY
SILT
SAND
GRAVEL
BEDROCK
Oak Ridges Moraine sediment
Channel base?
Isolated channel sedimentation?
Regional unconformity
Newmarket Till
Gradational contact
Thorncliffe Fm?
Gravel to sand, silty sand fining upward sequence (subaqueous fan)
Whitby Formation
*COUNT(200-1000 keV)
note: log scale
5 % SMOOTHING
**(200-1000)/(50 -150)keV
Grad.(C deg./km)

Figure 2b

GSC BALLANTRAE BOREHOLE (Golden Spike Monitor)
(GSC-BH-BAL)

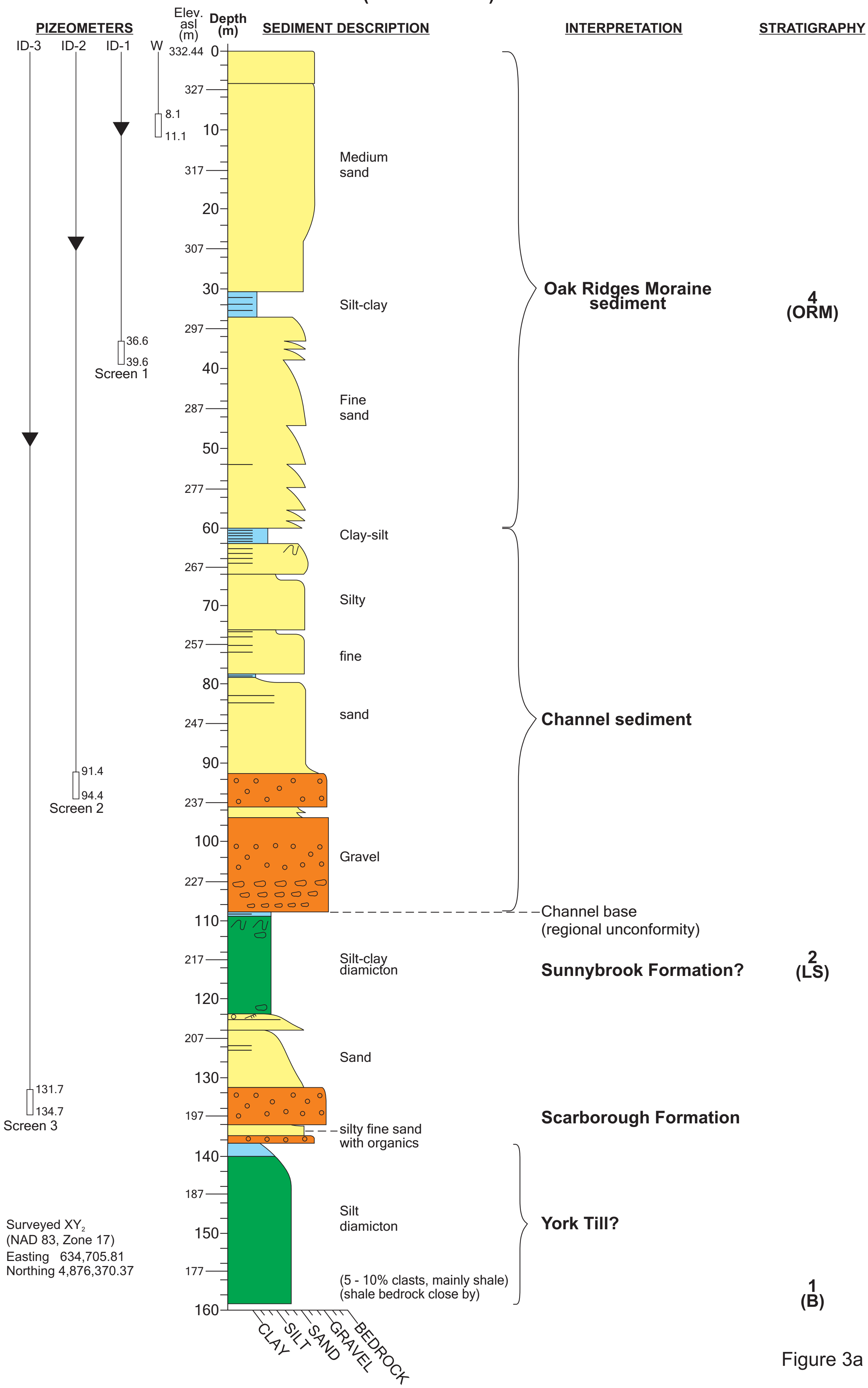


Figure 3a

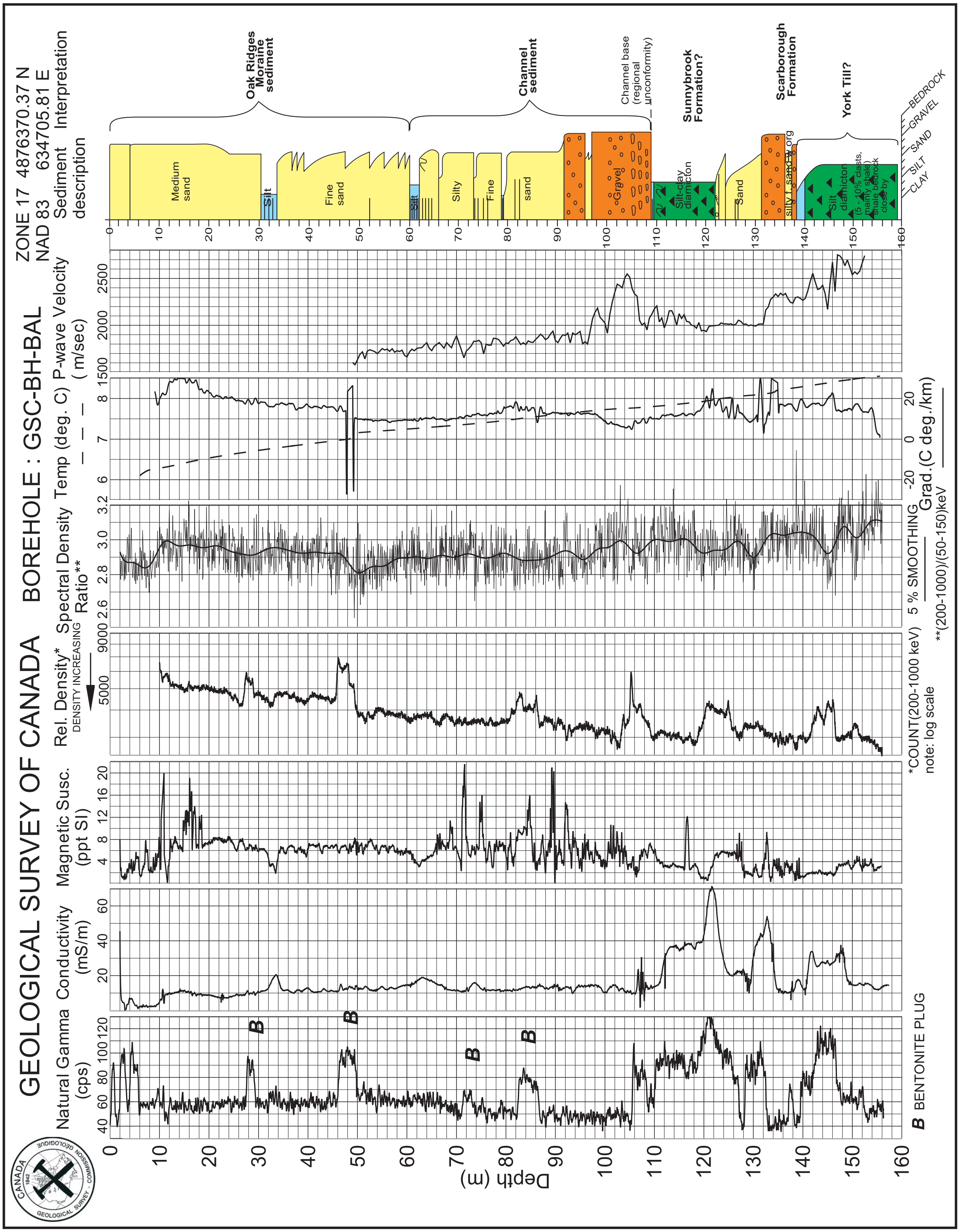

GEOLOGICAL SURVEY OF CANADA
BOREHOLE : GSC-BH-BAL
ZONE 17 4876370.37 N
NAD 83 634705.81 E
Natural Gamma (cps)
Conductivity (mS/m)
Magnetic Susc. (ppt SI)
Rel. Density*
DENSITY INCREASING
Spectral Density Ratio**
Temp (deg. C)
P-wave Velocity (m/sec)
Sediment description
Interpretation
Depth (m)
Grad.(C deg./km)
5 % SMOOTHING
*COUNT(200-1000 keV)
note: log scale
**(200-1000)/(50-150)keV
B BENTONITE PLUG
Medium sand
Silt
Fine sand
Silty
Fine
sand
Gravel
Silt-clay diamicton
Sand
silty f. sand w org
Silt diamicton (5 - 10% clasts, mainly shale) shale bedrock close by
Oak Ridges Moraine sediment
Channel sediment
Channel base (regional unconformity)
Sunnybrook Formation?
Scarborough Formation
York Till?
CLAY
SILT
SAND
GRAVEL
BEDROCK
CANADA
GEOLOGICAL SURVEY
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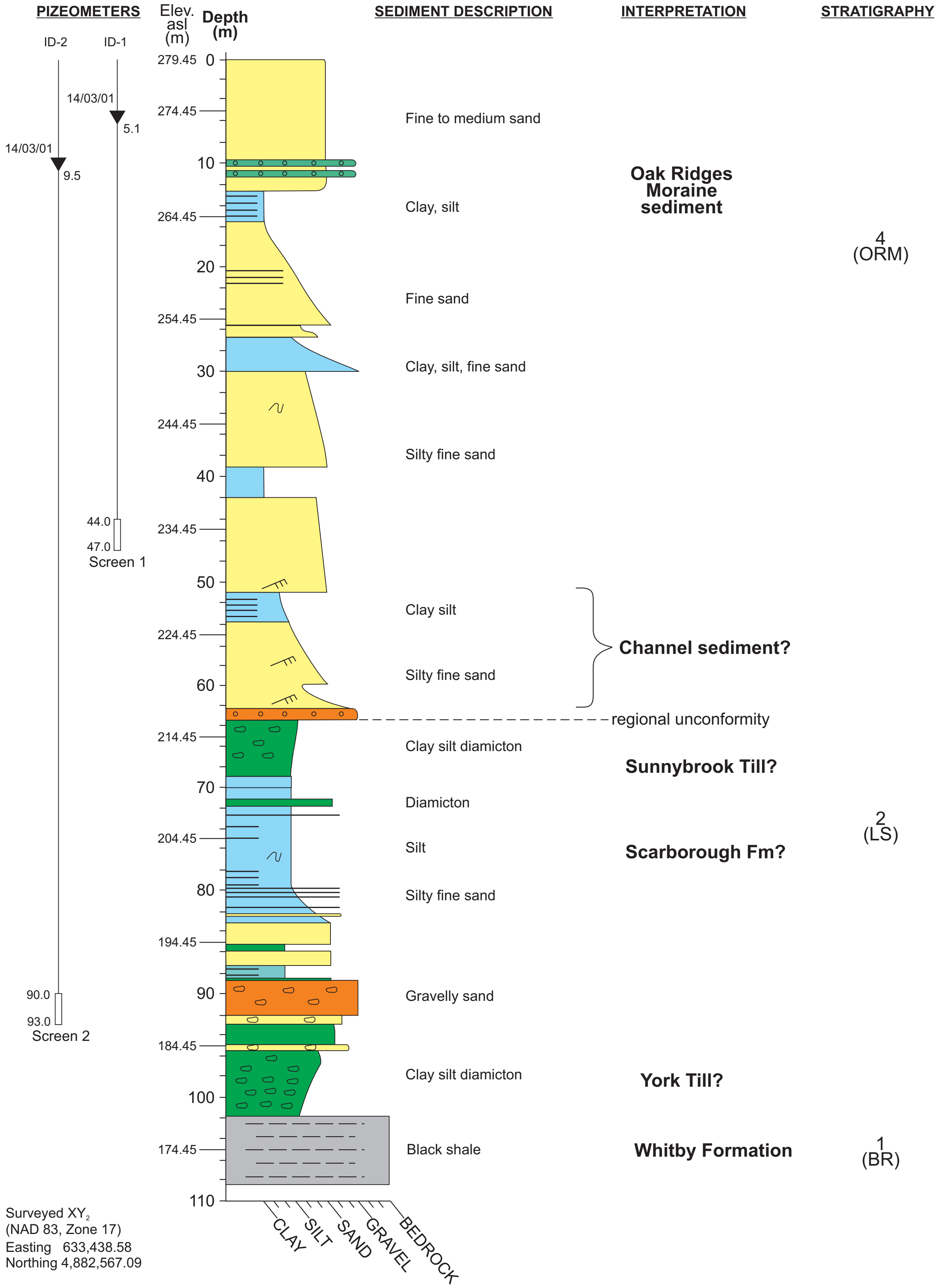
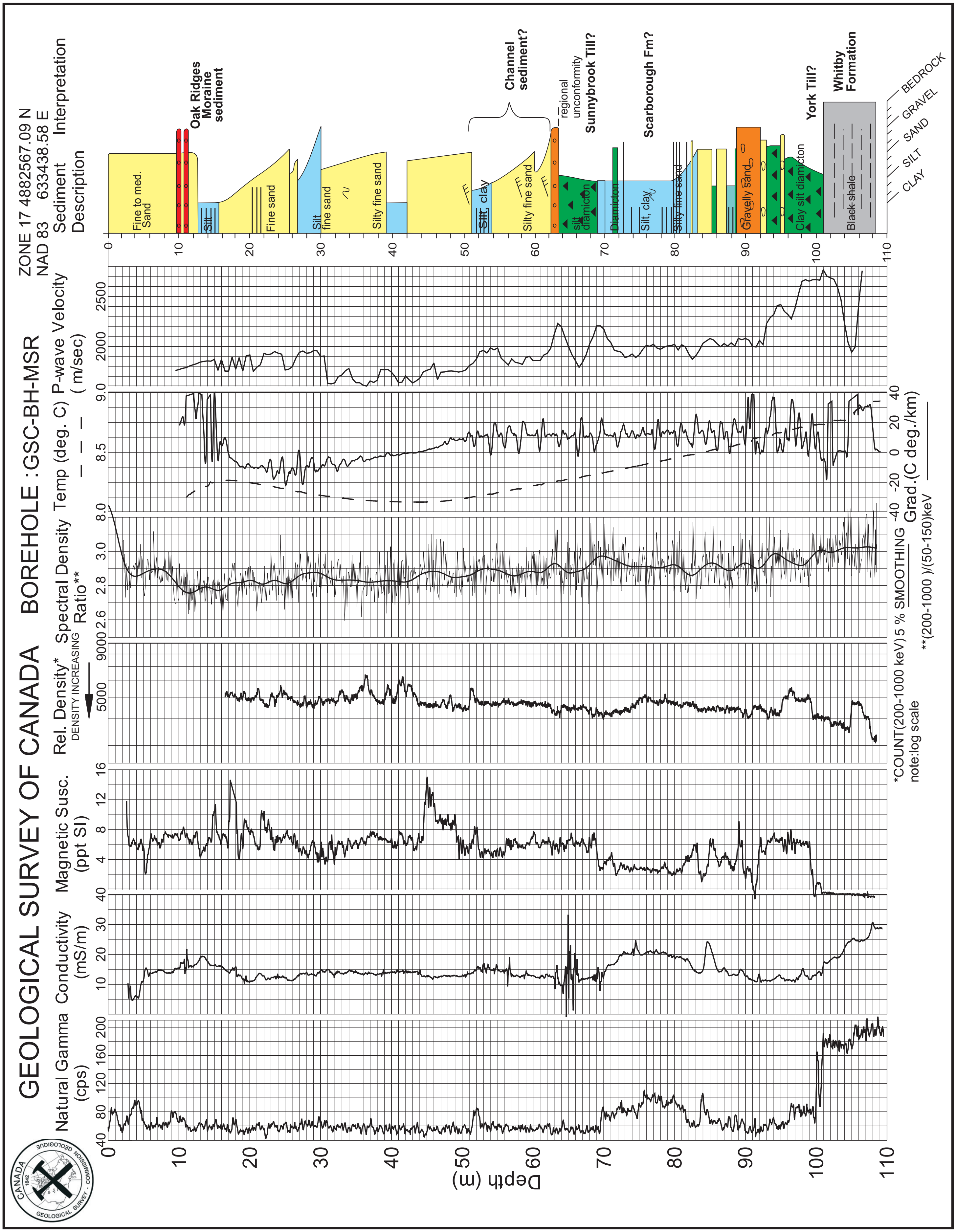
Figure 3b

GSC McCowan Borehole (Golden Spike Monitor)
(GSC-BH-MSR-McCowan and Davis)



Surveyed XY₂
(NAD 83, Zone 17)
Easting 633,438.58
Northing 4,882,567.09

Figure 4a


GEOLOGICAL SURVEY OF CANADA
BOREHOLE : GSC-BH-MSR
ZONE 17 4882567.09 N
NAD 83 633438.58 E
Natural Gamma (cps)
Conductivity (mS/m)
Magnetic Susc. (ppt SI)
Rel. Density*
DENSITY INCREASING
Spectral Density Ratio**
Temp (deg. C)
P-wave Velocity (m/sec)
Sediment Description
Interpretation
Depth (m)
Grad.(C deg./km)
*COUNT(200-1000 keV) 5 % SMOOTHING
note:log scale
**(200-1000)/(50-150)keV
Fine to med. Sand
Silt
Fine sand
Silt fine sand
Silty fine sand
Silt, clay
silt diamicton
Diamicton
Silt, clay
Silty fine sand
Gravelly sand
Clay silt diamicton
Black shale
Oak Ridges Moraine sediment
Channel sediment?
regional unconformity
Sunnybrook Till?
Scarborough Fm?
York Till?
Whitby Formation
CLAY
SILT
SAND
GRAVEL
BEDROCK
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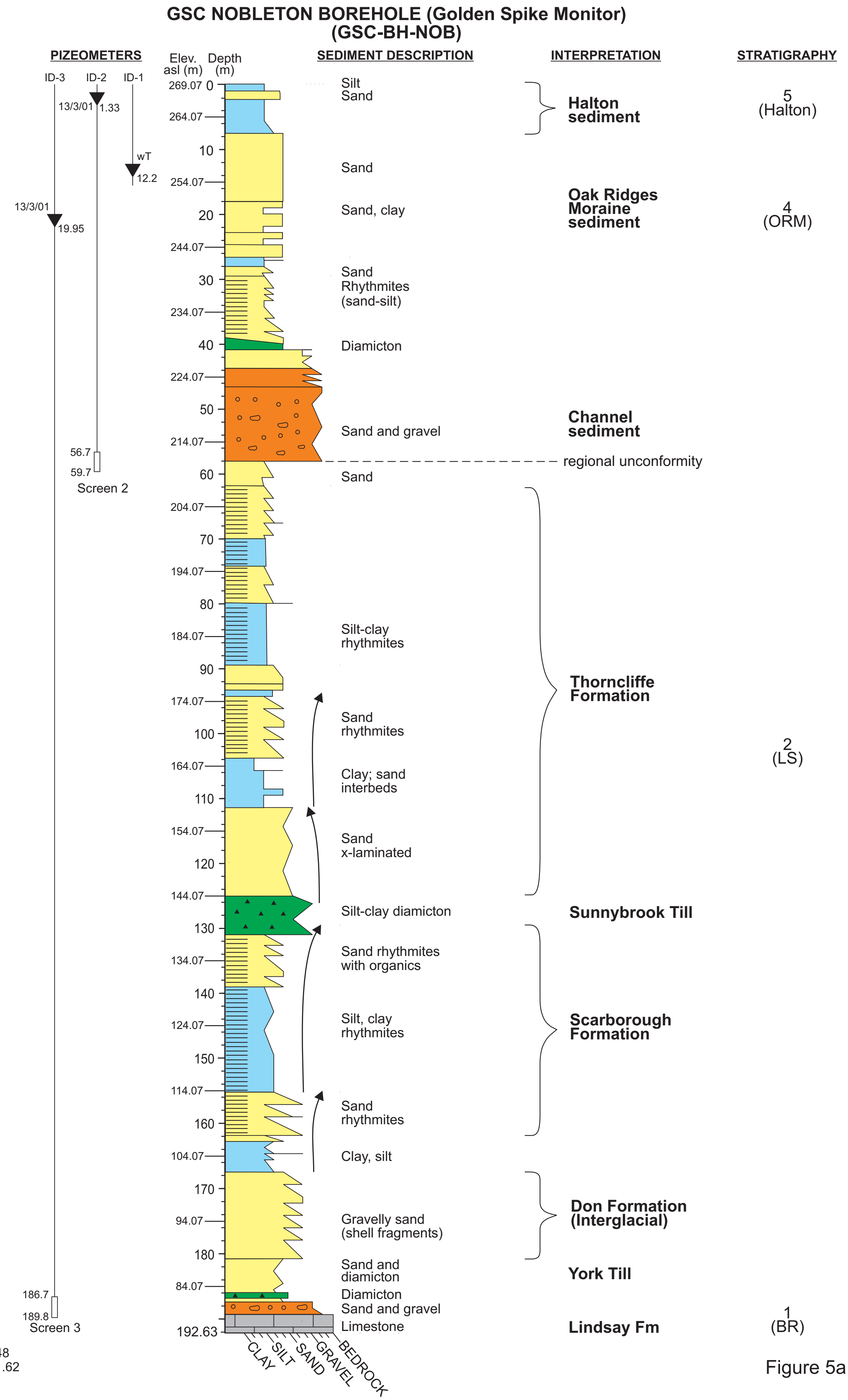
CANADA
1842

Figure 4b



Surveyed XY_2
(NAD 83, Zone 17)
Easting 611,195.48
Northing 4,864,941.62

Figure 5a

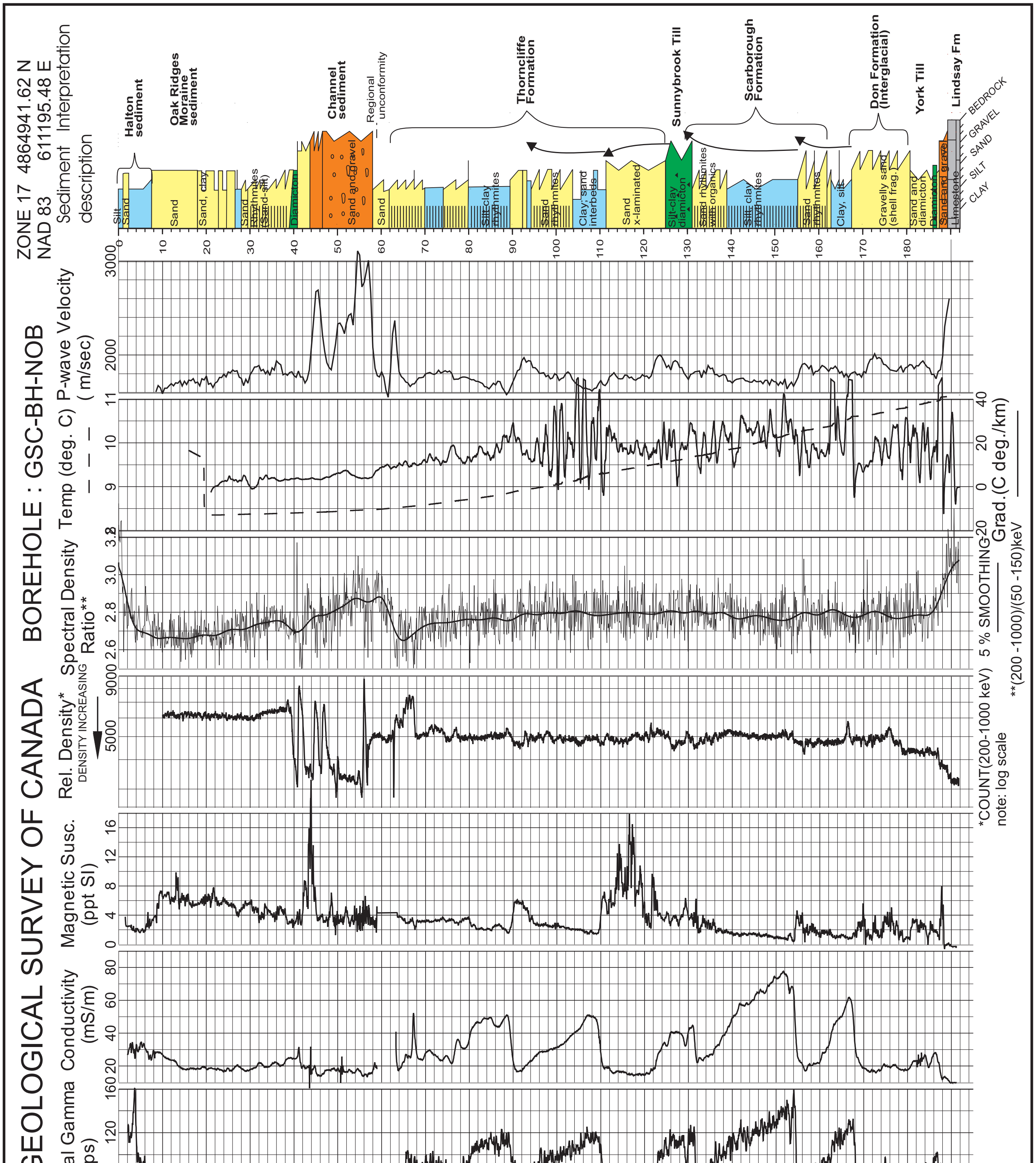
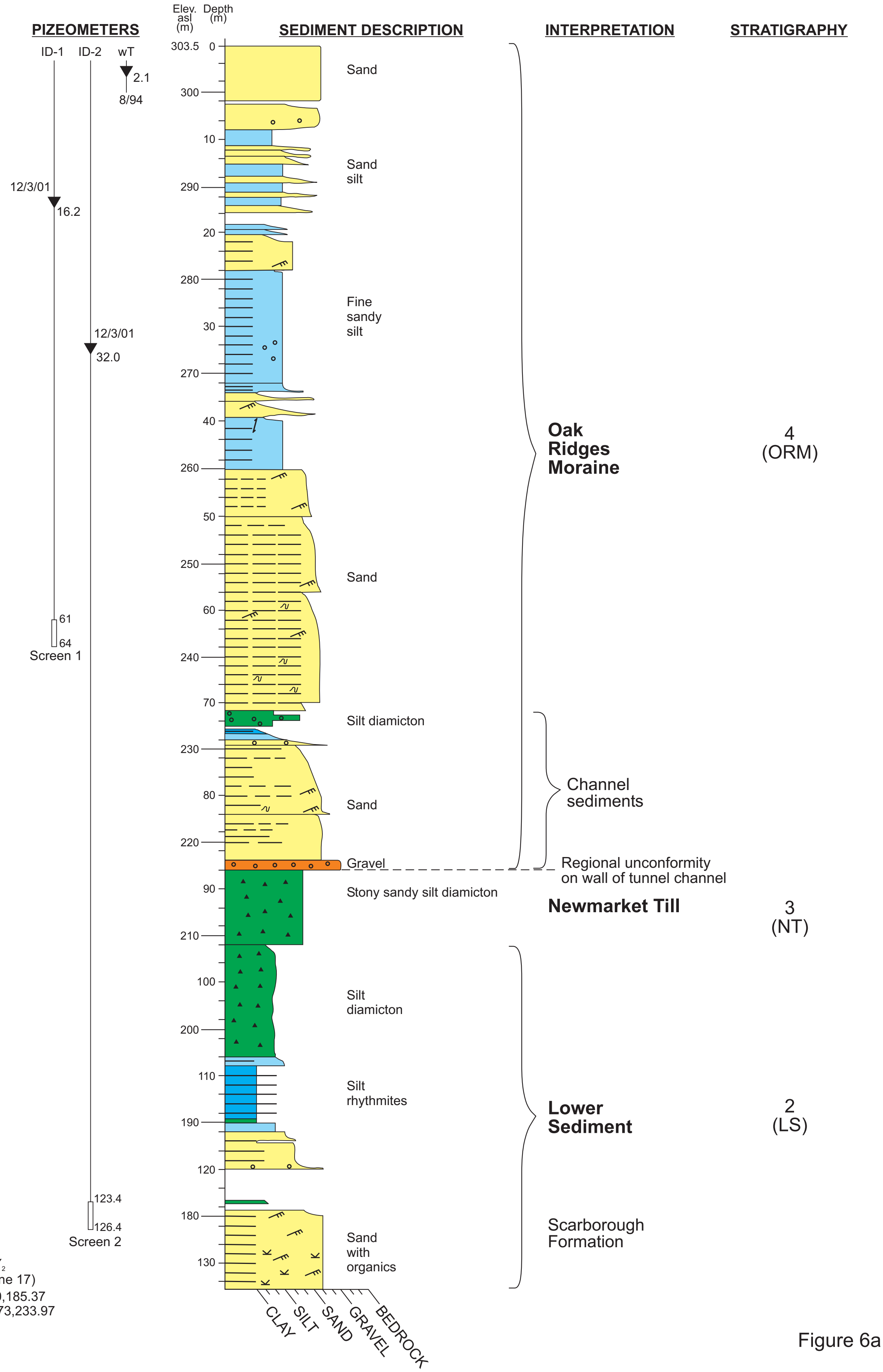

GEOLOGICAL SURVEY OF CANADA
BOREHOLE : GSC-BH-NOB
ZONE 17 4864941.62 N
NAD 83 611195.48 E
Natural Gamma (cps)
Conductivity (mS/m)
Magnetic Susc. (ppt SI)
Rel. Density*
DENSITY INCREASING
Spectral Density Ratio**
Temp (deg. C)
P-wave Velocity (m/sec)
Sediment description
Interpretation
Depth (m)
*COUNT(200-1000 keV)
note: log scale
5 % SMOOTHING
**(200 -1000)/(50 -150)keV
Grad.(C deg./km)
Halton sediment
Oak Ridges Moraine sediment
Channel sediment
Regional unconformity
Thorncliffe Formation
Sunnybrook Till
Scarborough Formation
Don Formation (Interglacial)
York Till
Lindsay Fm
BEDROCK
GRAVEL
SAND
SILT
CLAY

Figure 5b

GSC Vandorf borehole (Golden Spike) (GSC-BH-VSR)



Surveyed XY_2
(NAD 83, Zone 17)
Easting 630,185.37
Northing 4,873,233.97

Figure 6a

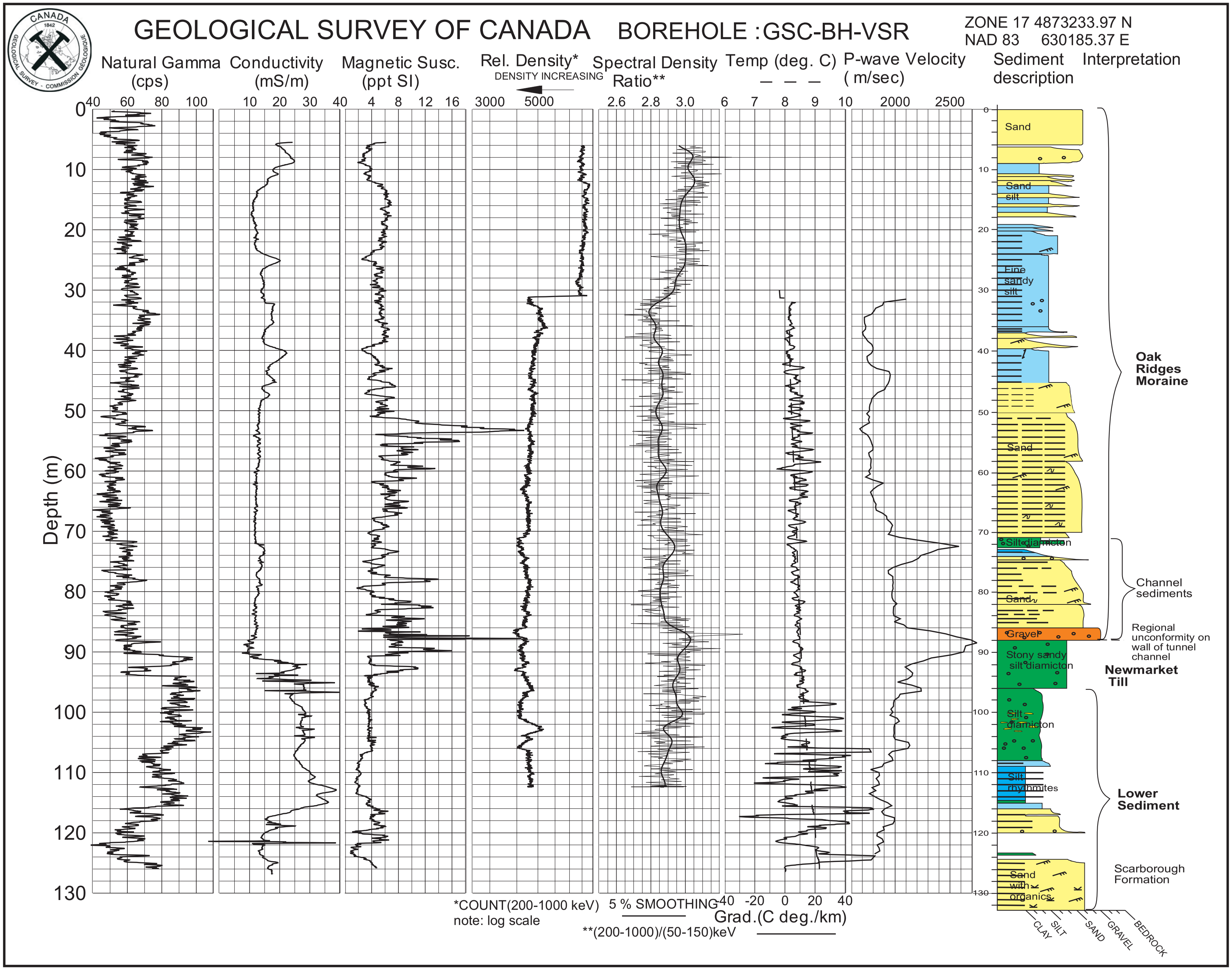

GEOLOGICAL SURVEY OF CANADA
BOREHOLE :GSC-BH-VSR
ZONE 17 4873233.97 N
NAD 83 630185.37 E
Natural Gamma (cps)
Conductivity (mS/m)
Magnetic Susc. (ppt SI)
Rel. Density*
DENSITY INCREASING
Spectral Density Ratio**
Temp (deg. C)
P-wave Velocity (m/sec)
Sediment description
Interpretation
Depth (m)
*COUNT(200-1000 keV)
note: log scale
5 % SMOOTHING
**(200-1000)/(50-150)keV
Grad.(C deg./km)
Sand
Sand silt
Fine sandy silt
Silt diamicton
Gravel
Stony sandy silt diamicton
Silt diamicton
Silt rhythmites
Sand with organics
CLAY
SILT
SAND
GRAVEL
BEDROCK
Oak Ridges Moraine
Channel sediments
Regional unconformity on wall of tunnel channel
Newmarket Till
Lower Sediment
Scarborough Formation

Figure 6b