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GEOLOGICAL SURVEY OF CANADA
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Abstract

Over the past four decades, the Near-Surface Geophysics group at the Geological Survey of Canada (GSC) has collected borehole geophysical logs in Quaternary sediments across Canada. Project work has primarily been driven by long term research programs related to permafrost, groundwater, and natural hazards. This work has resulted in a dataset of geophysical logs in 226 boreholes across the country. Primary logging methods include natural and active gamma, inductive conductivity and magnetic susceptibility, fluid temperature, and compressional and shear wave velocities. Over the years, tool calibration runs have been conducted at the Bell's Corners Borehole Calibration Facility in Ottawa, ON, to ensure that all the tools provide repeatable results which are in agreement with the standards published by the GSC. The compilation presented in this report provides logs as digital Log ASCII Standard (LAS) files, WellCAD files, and also in an interactive Google Earth format with links to PDF images of the log suites. The purpose of this Open File is to release the complete suite of geophysical logs so that the all members of the public may have access to this valuable national dataset.

Contents

1.0 Introduction

The Geological Survey of Canada (GSC) has had a long tradition of research and innovation in downhole geophysical data collection in Quaternary sediments, dating back to the 1960's. Data from 226 boreholes collected between 1993 and 2013 are presented in this national digital compilation of geophysical logs (Figure 1). Data were collected for permafrost, groundwater, and natural hazard research projects carried out across the country. Borehole depths are typically less than 100 m, though a significant number of boreholes are deeper than this (Figure 2).

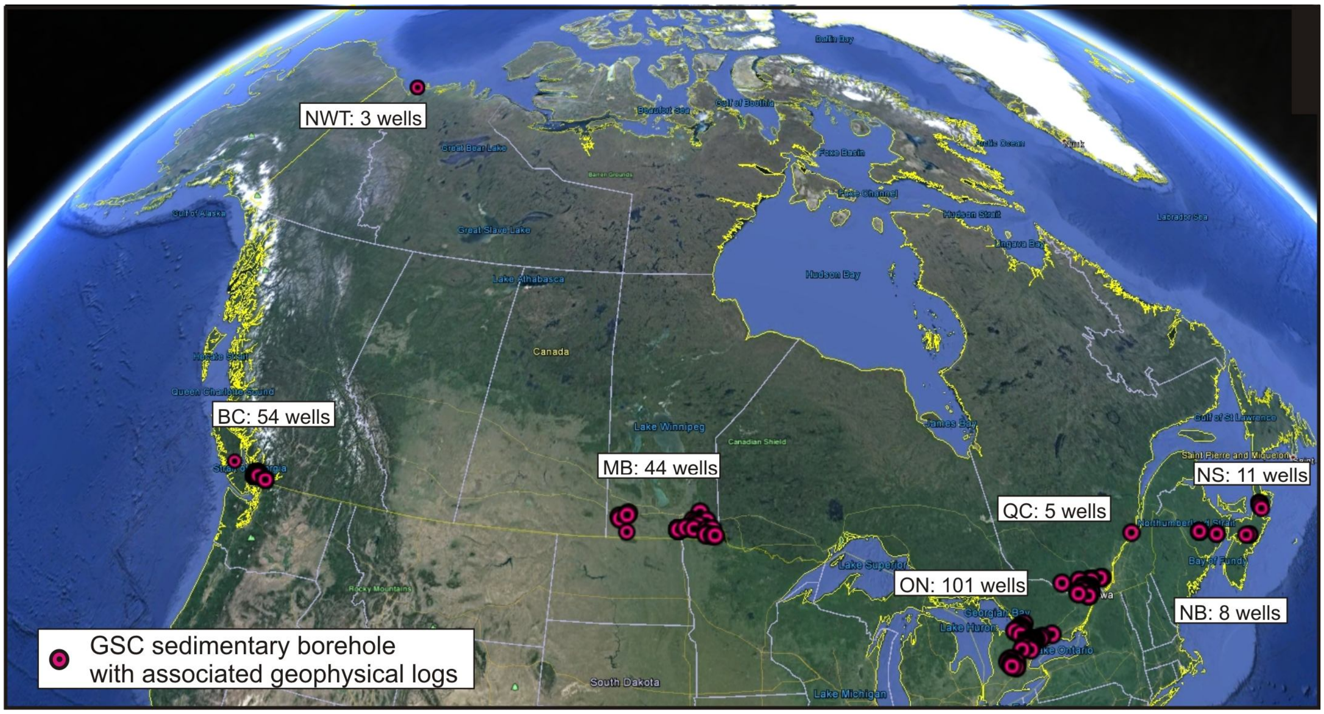

Figure 1. National map of boreholes logged in unconsolidated sediments throughout Canada. Data can be viewed using a Google Earth file in Appendix B (map image from © 2015 Google).

Downhole geophysical logs provide a means of identifying and characterizing lithological units based on variations in their chemical and physical properties. The primary logging techniques used in this compilation include gamma (natural and active) and neutron methods, induction methods (apparent conductivity and magnetic susceptibility), downhole seismic methods (compression (P) and shear (S) wave traveltimes), and fluid temperature logging. These data have been applied to various subsurface studies to examine vertical and lateral variability of sedimentary units (e.g. Pullan et al., 2002), infer groundwater movement in the subsurface (e.g. Taylor et al., 1999), predict regional variation in earthquake shaking (e.g. Hunter et al., 2010; Hunter and Crow, 2012), and indicate potentially geotechnically sensitive soil conditions warranting further engineering investigation (e.g. Hyde and Hunter, 1998; Aylsworth et al., 2003; Crow et al., 2014).

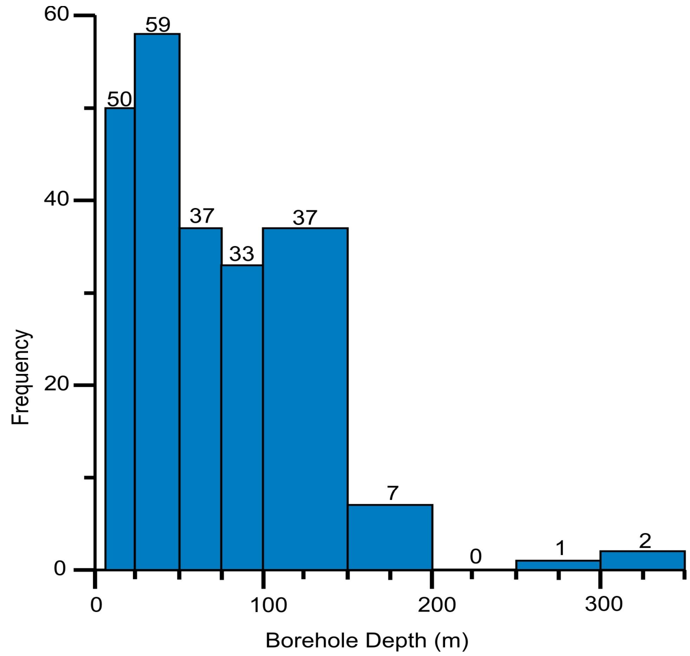

Figure 2. Histogram showing distribution of depths in 226 boreholes across Canada.

A number of the boreholes contained in this compilation are high quality reference boreholes called GSC "Golden Spikes" (Sharpe et al., 2003; Russell et al., 2003, 2004; Logan et al., 2008; Sharpe et al., 2011, Medioli et al., 2012, Crow et. al, 2012a). These sites are continuously cored and cased, resulting in a comprehensive dataset of core images, detailed core descriptions, laboratory test results (e.g. grain size, porewater chemistry, carbon content, etc.) and geophysical logs. Often, ground and air-based geophysical datasets have provided regional/local subsurface information used to select the drilling location of the Golden Spike. Links to these and other relevant GSC publications are provided in Table C-1 of Appendix C next to the corresponding borehole.

Over the years, tool calibration runs have been conducted at the Bell's Corners Borehole Calibration Facility in Ottawa, ON, to ensure that all the tools provide repeatable results that are in agreement with the standards published by the GSC (Bernius, 1996).

This unique compilation of 226 boreholes from across Canada provides geophysical logs as digital Log ASCII Standard (LAS) files, WellCAD files, and as an interactive Google Earth file with links to PDF images of the log suites. The purpose of this Open File is primarily to release the geophysical logs so that the all members of the public may have access to this valuable national dataset. To provide context for the log data, a summary of the history of near-surface logging at the GSC is provided, along with brief descriptions of the host Geoscience Programs.

1.1 Brief history of logging in unconsolidated sediments at the GSC (1970-90's)

Following the retirement of Jack Wyder from the GSC in the early 1970's, the Seismic Methods Section of the Terrain Sciences Division took over the responsibility of downhole geophysical logging in near-surface sedimentary materials. Wyder's work in Quaternary sediments in Alberta compared the results of borehole samples and outcrops to downhole geophysical logs, and led to a pioneering paper describing the usefulness of geophysical logs in the study of unconsolidated sediments (Stalker and Wyder, 1983).

In 1972, scientists from the Seismic Methods Section began taking the logging system to the Arctic, where project work involved determining the boundaries of segregated ice in permafrost soils using P- and S-wave velocity profiling techniques. Geophysical logs were collected primarily in seismic shot holes at that time, and were used to complement the seismic profiles. The analogue downhole data were recorded as paper records using a Gearhart-Owens slim-hole logging system which included natural gamma, gamma-gamma density, and single point resistivity sondes. Methods were also developed in the 70's using 12, and then 24, channel downhole geophone arrays to compute P-wave velocities, and an OYO 3-component wall locking geophone with an air bladder to record S waves (Hunter, 1977). These techniques were so successful in the assessment of physical soil properties that they were applied in the Megatransect project carried out on the Beaufort Sea Shelf east of the Mackenzie Delta in the early 1990's. For this project, logging in onshore boreholes provided critical data to tie borehole geological units onshore with those drilled offshore (Dallimore, 1991).

During the 70's and into the 80's, subsurface temperature readings in the Arctic were collected with thermistor cables installed in water-jet-drilled holes. These experiments were conducted to gain a better understanding of near-surface sediment temperature distribution, and focused on sub-seabottom permafrost in the Mackenzie Delta region (e.g. MacAulay et al., 1977). Thermistor measurement techniques were incorporated into high-resolution temperature logging tools developed by the GSC's Earth Physics Branch in the 1970's and 80's for deep-hole geothermal gradient studies across Canada (Jessop et al., 1984; Bristow and Conaway, 1984) and eventually near surface groundwater studies in unconsolidated studies (Drury and Jessop, 1982; Taylor et al., 1999).

In 1984-5, the Section (now called the Near-Surface Geophysics Section), purchased a Geonics logging system, which broadened the scope of study to non-permafrost sediments. Electromagnetic (EM) techniques were becoming increasingly popular and allowed for shallow lithological mapping without requiring contact with the borehole wall; ideal for PVC-cased wells in unconsolidated sediments (Taylor et al., 1989; McNeill et al., 1990). The Section supported the development of a high-resolution downhole induction magnetic susceptibility meter with Geonics for shallow lithological studies (McNeill et al., 1996). The Section also purchased high resolution temperature and spectral gamma tools from IFG Corporation in the late 1980's to assist in the differentiation of till units for Groundwater Program research underway in Oak Ridges Moraine in southern Ontario.

Logging in southern and urban areas of Canada continued through the mid 80's and 90's primarily in support of groundwater and geohazard programs at the GSC. Key projects during this time period included the Oak Ridges Moraine Groundwater Project in Ontario, the Red River Floodplain Study in Manitoba, and the Natural Hazards of the Fraser River Delta study in BC; these projects are discussed in more detail in Section1.2. In 1993, a compilation of digital downhole geophysical logs was initiated and has been growing with the addition of all logs collected through the end of 2013.

1.2 Data distribution in hydrogeological regions of Canada

To provide a national hydrogeological context for the dataset, borehole locations are presented on the Hydrogeological Regions Map of Canada (Figure 2). These nine regions have distinct groundwater systems, based on geology, physiography, and frozen ground (Sharpe et al., 2008; Sharpe et al., 2013). Geology primarily controls the major landforms and bedrock contacts that define the geological terrains and basins, but also the characteristics of subsurface water-bearing sediments. Physiography is influenced by geology, but also divides hydroregions where topography plays a large role in drainage/recharge. Frozen ground in the permafrost region has a dominant effect on regional flow due to the presence of massive ground ice. Within these major regions, borehole geophysical data are collected in the surficial sediments of all but two of the regions. This provides a unique opportunity to study the hydrostratigraphic properties of the near-surface sediments in populated centers across Canada using downhole geophysical tools. Table C-1 in Appendix C classifies the boreholes by their hydrogeological region and province.

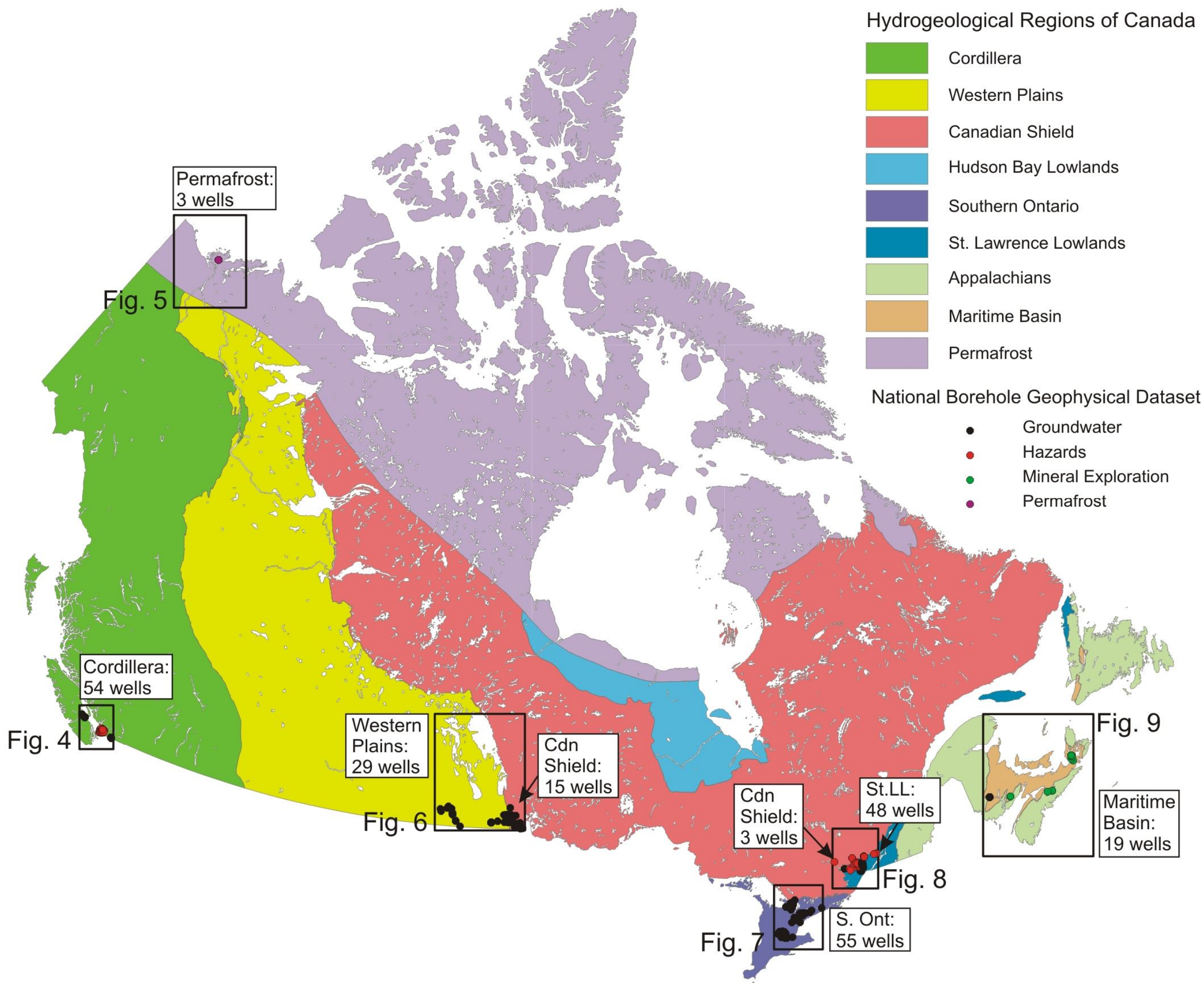

Figure 3. Borehole distribution throughout hydroregions of Canada (after Sharpe et al, 2008).

Borehole locations are presented at a regional scale in Figures 4 – 9 over the surficial sediments map compiled by Fulton (1995). Quaternary sediments in each of these regions are uniquely influenced by glacial processes occurring during the last Pleistocene glacial advance/retreat.

Cordilleran Hydroregion Boreholes (Figure 4)

Data are concentrated in two regions of the Cordillean region of British Columbia: the Nanaimo Lowlands (Crow et al., 2014) and the Lower Fraser delta (Hunter, 1995; Hunter et al., 1998a) and Abbotsford Suma area (Ricketts, 1995).

Nanaimo Lowland Region, BC

In the Nanaimo region four boreholes were logged to study the geological and hydrogeological properties of the surficial deposits and to ground truth seismic profile data. The boreholes penetrate the clastic Quaternary stratigraphy of the area and provide the first downhole geophysical characterization of the stratigraphy to depths of 125 m (Crow et al., 2014). Units intercepted, from oldest to youngest include, Mapleguard, Dashwood, Cowichan, Quadra Sand, Vashon, and Capilano formations (e.g. Fyles, 1963). Consequently the data provides insight into the geophysical signature of a variety of diamicton, mud, and sand and gravel units of glaciomarine, glacial outwash, estuarine, deltaic and alluvium environments. The induction logs (conductivity and magnetic susceptibility) were used to identify changes in the main stratigraphic units. Velocity logs revealed highly variable stiffness in the diamictons, indicating a complex subglacial structure, possibly caused by multiple glacial advance and retreat cycles. The fluid temperature logs indicated that groundwater temperatures are primarily controlled by depth below ground surface (in equilibrium with the thermal gradient), although material type (i.e. aquitard vs. aquifer) also can influence the temperature gradients (Crow et al., 2014).

Fraser Delta, BC

Quaternary sediments, up to several hundred metres thick, underlie much of the Fraser Lowland and Fraser Delta. This succession consists of sediment deposited during at least three glaciations and intervening interglaciations, and is made up of till and stratified sediment packages separated by unconformities (Clague et al., 1991; Clague, 1998). Interglacial paleosols and associated sediment occur locally.

Logging was conducted in 46 boreholes to determine the structure and geotechnical parameters of the delta and glacial stratigraphies in support of earthquake hazard studies in the region (e.g. Hunter et al., 1994; Hunter, 1995; Luternauer and Hunter, 1996; Hunter et al., 1998a,b). Boreholes intercept sediment consisting of alternating strata of mud and sand interpreted to be Holocene topset and foreset deposits of the Fraser River delta, and underlying Pleistocene sediment (Hunter et al., 1998a; Christian et al., 1998). The deepest well is the Richmond well (FD96-1) drilled by the GSC to a depth of 330 m (Dallimore et al., 1995, 1996). These data are further supported by logs in a 600 m deep borehole, the Conoco Dynamic Mud Bay well that penetrates to Miocene age sediment (not part of this data release). Most of the dataset consists of three logs (natural gamma, inductive conductivity and magnetic susceptibility) and P-wave and S-wave downhole measurements.

Fraser Lowlands, BC

In the Abbotsford – Suma area, near the United States border, four holes were logged to depths of 30 m in 1995 for a regional groundwater study (Ricketts, 1995). This GSC work was an early example of integrating a suite of geophysical tools to advance understanding of the local hydrogeology. The shallow stratigraphy in the area consists of sand and gravel interstratified with diamicton and assigned to the Sumas Drift. Logs included natural gamma and inductive conductivity and magnetic susceptibility.

Permafrost Hydroregion Boreholes, NWT (Figure 5)

In 1993, three shallow (16 – 21 m) geotechnical boreholes were logged near Ya Ya Lake south-west of Tuktoyaktuk on the McKenzie Delta. This was carried out in conjunction with a ground penetrating radar (GPR) study to investigate the near-surface geology and presence of massive ground ice in the region (Dallimore and Davis, 1992). Natural gamma, inductive conductivity and magnetic susceptibility logs effectively identified changes in the coarse grained glaciofluvial sediments.

Western Canada Sedimentary Basin Hydroregion Boreholes (Figure 6)

Data collection was carried out during multiple programs over the past 20 years with a range of hydrogeological and geological objectives. Downhole geophysical logs collected in Southern Manitoba include; 10 boreholes for the Red River floodplain study; 7 boreholes in the Sandilands (Hinton, 2003); 5 boreholes drilled by Manitoba Water Stewardship (MWS) in the Brandon Area (Toop, 2009; Crow et al., 2012b), 2 boreholes of the Killarney Monitoring Network drilled in 2009 (Crow et al., 2012b), and the GSC Spiritwood "Golden Spike" borehole (Crow et al., 2012a).

Southern Manitoba

Fourteen boreholes (BR92-series, X99-series) were logged as part of the Southern Manitoba study between 1992 and 1999 in an area south of Lake Winnipeg. They range in depth from 20 to 160 m with an average depth between 40-60 m. The borehole logs consist of sediment facies descriptions (diamicton, sand and gravel) but no integration into regional Prairie stratigraphy is provided (e.g. Christiansen, 1992; Cummings et al., 2012).

Red River Valley, MB

Ten boreholes (99RR-series) were logged within the Red River Valley, principally within the Red River flood plain, and extend to depths of 20 m. The stratigraphy is mapped as either silty clay or clayey silt, and in a few cases, record thin sand horizons. The logs are generally relatively low amplitude and record fining upward trends.

Sandiland Moraine, MB

The seven Sandiland boreholes (07RS-series) drilled as part of a groundwater study range in depth from 68 to 110 m. The stratigraphy encountered consists predominantly of fine to coarse sand and minor mud and diamicton. In some cases, the stratigraphic context of the boreholes is supported by seismic reflection data (unpublished). The downhole data set consists of gamma, conductivity, magnetic susceptibility, relative density, spectral density and temperature logs. Borehole sediment descriptions provide basic sediment facies information. All of the boreholes have various log signatures reflective of changes in sedimentary facies, such as fining and coarsening upward trends over 5 to 10 m. A number of logs also have low amplitude trends which approach 80 m in length. Some of the Sandiland boreholes have temperature data that were integrated into a recharge study and documented by Ferguson et al. (2003).

Killarney and Brandon Hills, MB

The MWS and Town of Killarney boreholes range from 22 to 72 m depth. The three Killarney wells (TH-series) terminate in sand and gravel and intercept a succession of interstratified till, mud and sand beds ranging in thickness up to ~15 m. The five MWS wells (DT-series) all terminate in bedrock but only one hole has casing which extends into the bedrock (DT-10-06), interpreted at this location to be the Odannah Shale formation. The log suite includes gamma, conductivity, magnetic susceptibility, density, and temperature. The geological descriptions provide basic sedimentary facies information but no regional stratigraphic correlation. The Quaternary stratigraphy consists generally of sand and gravel on bedrock, overlain by massive mud till, in turn succeeded by minor mud and sand and gravel with interbeds of diamicton. Variations in log responses register major lithofacies boundaries.

For the Spiritwood groundwater study a GSC borehole (GSC-BH-SW-07) was drilled to 97.54 m depth within the Spiritwood buried valley as delineated by a seismic profile and regional airborne electromagnetic survey (Crow et al., 2012a; Pullan et al., 2013). The borehole stratigraphy consists of a basal interbedded sand, gravel, and diamicton which is 13.5 m thick. Sand and gravel layers include fining upward sequences with minor silt, and clay. This is overlain by poorly sorted-to-massive, very stiff, dark grayish-brown stony diamicton with a silt-rich matrix containing angular to subangular carbonate and shale granules and pebbles (Crow et al., 2012a). Geophysical log response within this diamicton unit is relatively low amplitude, as might be anticipated for a massive diamicton succession. However, significant sediment facies changes can be identified on the geophysical logs.

Southern Ontario Lowlands Hydroregion Boreholes (Figure 7)

Data collection was carried out in southern Ontario in three distinct moraine settings: the Waterloo Moraine (14 boreholes ranging in depth from 15 – 98 m; Bajc and Hunter, 2006), the Oak Ridges Moraine (27 boreholes ranging in depth from 18 – 187 m), and the Oro Moraine in the Barrie – Wasaga Beach area (14 boreholes ranging in depth from 20 – 116 m). Within each of these regions the drilling and borehole geophysical logging was used as ground truth for seismic data collected across buried valleys, moraine uplands, and the unconformable surface of regional till bodies (e.g. Pugin and Pullan, 1998; Sharpe et al., 2002). The Quaternary stratigraphy is up to 200 m thick and consists of a succession of sedimentary units separated by distinct erosional surfaces that often have considerable relief due to incision by paleo-valley-forming processes (Russell et al., 2006; Sharpe et al., 2004). The geophysical data thus provides characterization of a range of glacial and proglacial sedimentary settings that consist of laminated muds, sand and gravel, mud diamictons, and sandy diamictons (Sharpe et al. 2002; Bajc et al., 2014). The geophysical signatures are diverse and range from saw-tooth responses in the sediment dominated by high-energy and rapid depositional events to classic hour glass and reverse hour-glass signatures in lower energy rhythmically stratified mud and fine sand (Pullan et al., 2002; Logan et al., 2008). Downhole log responses highlight the high seismic velocities of Newmarket Till, which are similar in P-wave velocity to the local bedrock (Pullan et al., 2002). Depositional settings range from tunnel valley fills, subaqueous fans, and glaciolacustine and lacustrine settings (Sharpe et al., 2002; Barnett et al., 1998; Russell et al., 2003, 2004, 2006). This dataset provides the most comprehensive downhole geophysical characterization available of the classic Late Wisconsin stratigraphy identified at the Scarborough Bluffs and is shown to have extensive subsurface extent (Sharpe et al., 2002).

St Lawrence Lowlands Hydroregion Boreholes (Figure 8)

South Nation, ON

Two borehole geophysical datasets were collected as part of the South Nation Source Water Protection Study (SNC-series boreholes). Most wells were located to provide ground truthing for seismic reflection profiles and to install piezometers in esker sediment. Thirteen wells were logged for the Vars-Winchester esker study, and 6 holes were logged for the Crysler-Finch esker study. The Vars-Winchester boreholes range from 11 to 37 m depth; the Crysler-Finch boreholes range from 14 to 25 m. The intercepted stratigraphy is predominantly Champlain Sea mud with underlying glaciofluvial esker sand and gravel, and diamicton. Bedrock penetration was generally limited to a few metres. Sediment facies of mud vs sand are well delineated by the gamma, conductivity and magnetic susceptibility logs. Differentiation of diamicton from sand and gravel based on the logs can be more difficult.

A series of GSC boreholes were drilled in the late 1990's to study the geotechnical properties of sensitive Champlain Sea silts and clays along the banks of the South Nation River north of Casselman, and near Lefaivre, ON. These include the CASS-series and LB-series boreholes, and LV96-1, -2, LV-97-2, -3. The log suite collected included gamma, conductivity, magnetic susceptibility, and shear wave velocity (Vs) logs. Vs data from these and eight other boreholes along the Ottawa-Montreal corridor was published by Hunter et al. (2007) as the first compilation of its kind as a guide for geotechnical engineers in the estimation of soil response to earthquake shaking.

As part of the GSC's Ottawa Valley Landslide Project (1994-2004), five boreholes were drilled north of Alfred, ON (JA-series). The area exhibits near-surface deformation of marine sediments (silts, clays, and sands) where evidence suggests that a high-magnitude earthquake (>M6.5) 7060 y BP induced widespread ground disturbance throughout the region (Aylsworth et al., 2000). Prior to drilling, GSC seismic surveys mapped the existence of a large, deep, bedrock basin (~180 m maximum depth) underlying the disturbed area (Benjumea et al., 2003). Borehole locations were chosen to intersect the deepest part (JA02-3, -4), the margin (JA02-6), and outside (JA02-5), the bedrock basin. The log suite collected included gamma, conductivity, magnetic susceptibility, fluid temperature, relative density, spectral density ratios, and P- and S-wave velocity logs. The magnetic susceptibility tool effectively identified intervals containing sands within the clay and silt deposits, and conductivity mapped variations in porewater salinities within the fine grained sediments. Together, these parameters can assist in the assessment of ground stability during strong earthquake shaking (Crow et al., 2014).

Kinburn, ON

The Kinburn borehole was drilled to a depth of 96.7 m to ground truth a seismic profile and to provide core data on a thick Champlain Sea mud succession (Medioli et al., 2012). A full suite of geophysical logs was collected and results are supported by a suite of laboratory data (moisture content, shear strength, sensitivity, grain size, total organic carbon, geochemistry, micropaleontology, and pore-water chemistry). The stratigraphy consists of a basal interstratifed sequence of mud and sand (5.5 m thick) overlain by 91.5 m of mud that is divisible into a number of mud facies on the basis of stratification, colour and bioturbation. Downhole logs provide reasonable signal discrimination of the mud facies, and clearly delineate the basal unit from the overlying mud.

Canadian Shield Hydroregion, QC (Figure 8)

Five logs are reported from two areas in the Ottawa Valley region of Quebec: two from the Lièvre River valley near Notre-Dame-de-la-Salette (LV96-3 & -4), one in the Ottawa River valley near Campbell's Bay (LV96-7), and two in Oka near Montreal (OK00-series). The logs collected in the LV-series holes include gamma, conductivity, and magnetic susceptibility; in addition to these logs, the two Oka holes also include relative density, spectral density ratio, temperature and downhole seismic logs. The sediment facies of the LV-series' holes is predominantly the mud of the Champlain Sea, and boreholes were drilled to investigate sensitive clay landslides in the region (Aylsworth et al., 1997). The Oka boreholes, drilled as part of a groundwater study in the region (which included seismic profiling) intersect mud in the upper 20 to 40 m, underlain by gravel and diamicton (Ross et al., 2001, Benjumea et al., 2001). Signal response from gamma logs within the mud indicate the unit is relatively homogenous, but all logs show a strong response that identifies the upward transition from the underlying sand, gravel and diamicton into the muds.

Maritimes Basin Hydroregion Boreholes (Figure 9)

Borehole logs from three separate mineral exploration studies pertaining to Cretaceous sand deposits are included in this dataset. Two datasets are from the Shubenacadie area and Musquodoboit Valley regions in Nova Scotia (3 boreholes ranging in depth from 103 – 144 m; Stea and Pullan, 2001), and from southern Cape Breton (8 boreholes ranging in depth from 16 – 94 m; Stea et al., 2003). In New Brunswick the third dataset was collected near Poodiac and the Atlantic Silica mine (2 boreholes; 21 and 23 m). Most of the holes penetrated bedrock, and were drilled up to 100 m into bedrock. Unconsolidated sediments are generally less than 20 m thick, but can be up to 80 m and are dominated by till with local occurrences of muds and gravel. With the exception of the Poodiac logs there is an accompanying sediment facies log, but no stratigraphic designations. Additional details for the Nova Scotia boreholes are available in the two articles by Stea and Pullan (2001), and Stea et al. (2003). Stea and Pullan note that the magnetic susceptibility logs have good signal discrimination in the surficial units and Cretaceous deposits. The data collected include gamma, conductivity, magnetic susceptibility, relative density, spectral density ratio, and P-wave.

Appalachians Hydroregions Boreholes (Figure 9)

Within the Appalachian hydroregion, borehole logs were collected in 6 boreholes (steel-cased in surficial sediments) intersecting an esker valley aquifer and sandstone bedrock in Fredericton, New Brunswick (Nadeau et al., 2004). Boreholes ranged in depth from 40 – 71 m, and data collected include gamma, conductivity, magnetic susceptibility, relative density, spectral density ratio, temperature, and P- and S-wave velocities. The dataset is part of a more extensive geophysical dataset that investigated aquifer recharge, and includes seismic reflection data and EM-34 conductivity mapping (Butler et al., 2006). The bedrock boreholes also include single point resistivity (SPR) and self potential (SP) logs. Three boreholes are drilled in surficial sediments, terminating in top of bedrock, and three boreholes are drilled in mudstone and sandstone bedrock. In two of the three surficial wells, the gamma log clearly differentiates between the near surface muds and deeper sand and gravel deposits. Magnetic susceptibility is available for one borehole and identifies the two distinct sediment facies. Shear wave velocities increase significantly in the transition from mud to sand and gravel. P-wave velocities are less variable within the different sediment facies.

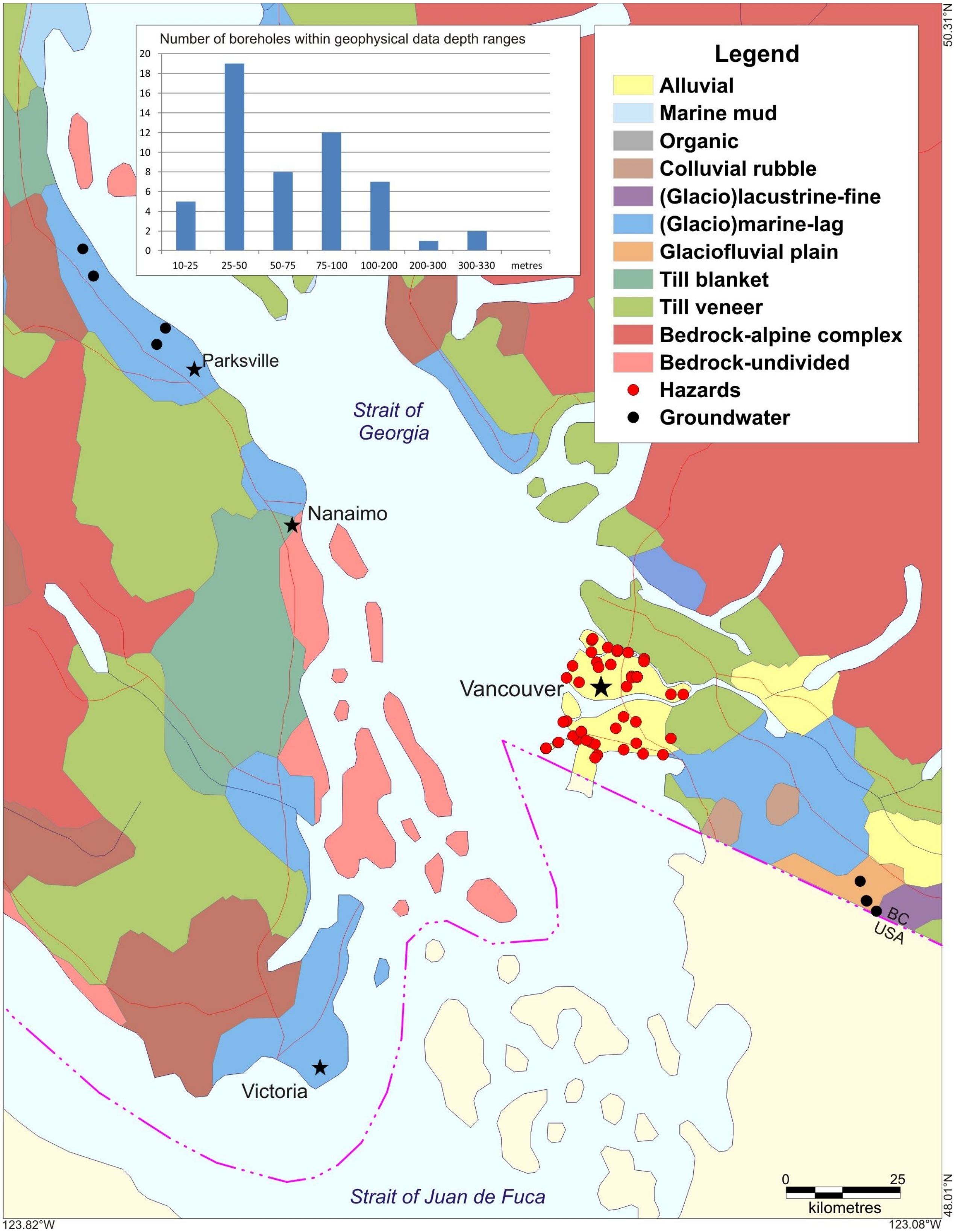

Figure 4. Boreholes on the BC mainland (Fraser delta and Abbotsford), and in the Nanaimo lowlands near Parksville on Vancouver Island. Surficial geology modified from Fulton (1995). Total of 54 boreholes in this region.

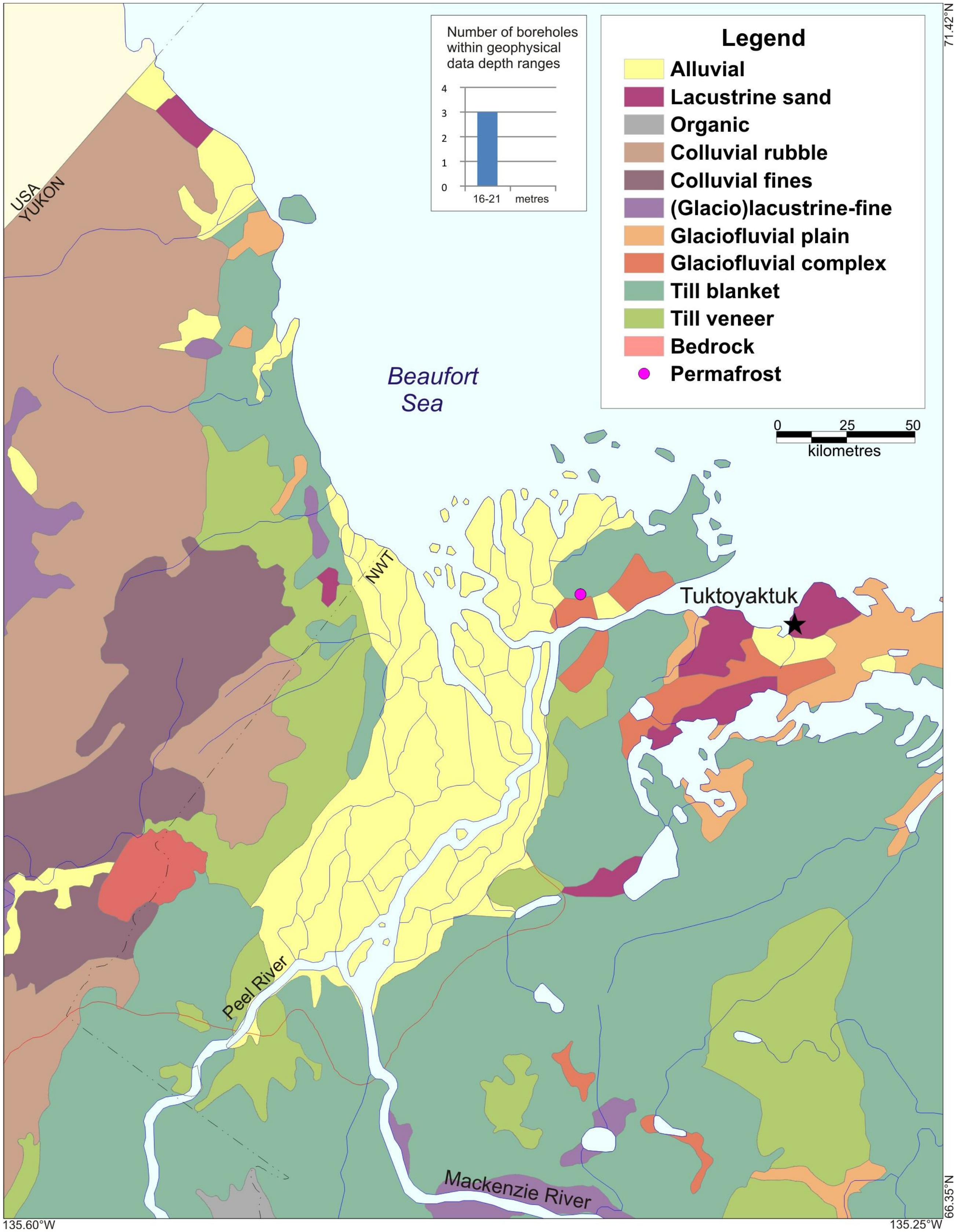

Figure 5. Borehole locations (3 closely spaced) near Ya Ya Lake, west of Tuktoyaktuk, NT. Surficial geology modified from Fulton (1995).

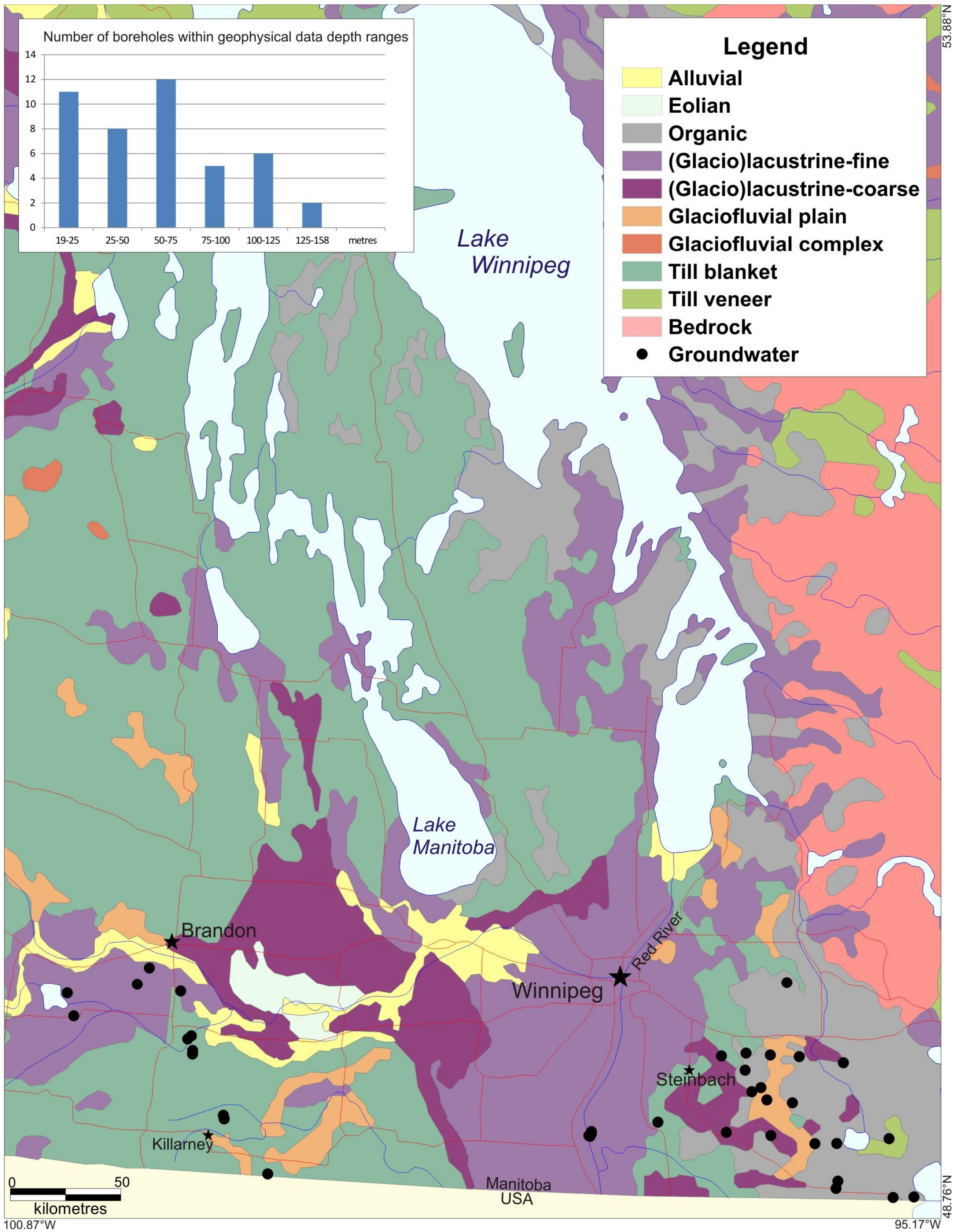

Figure 6. Southern Manitoba borehole locations in the Sandilands region east of Steinbach, the Red River Valley south of Winnipeg, and along the Spiritwood buried valley extending SE from Brandon to Killarney. Surficial geology modified from Fulton (1995). Total of 44 boreholes in this region.

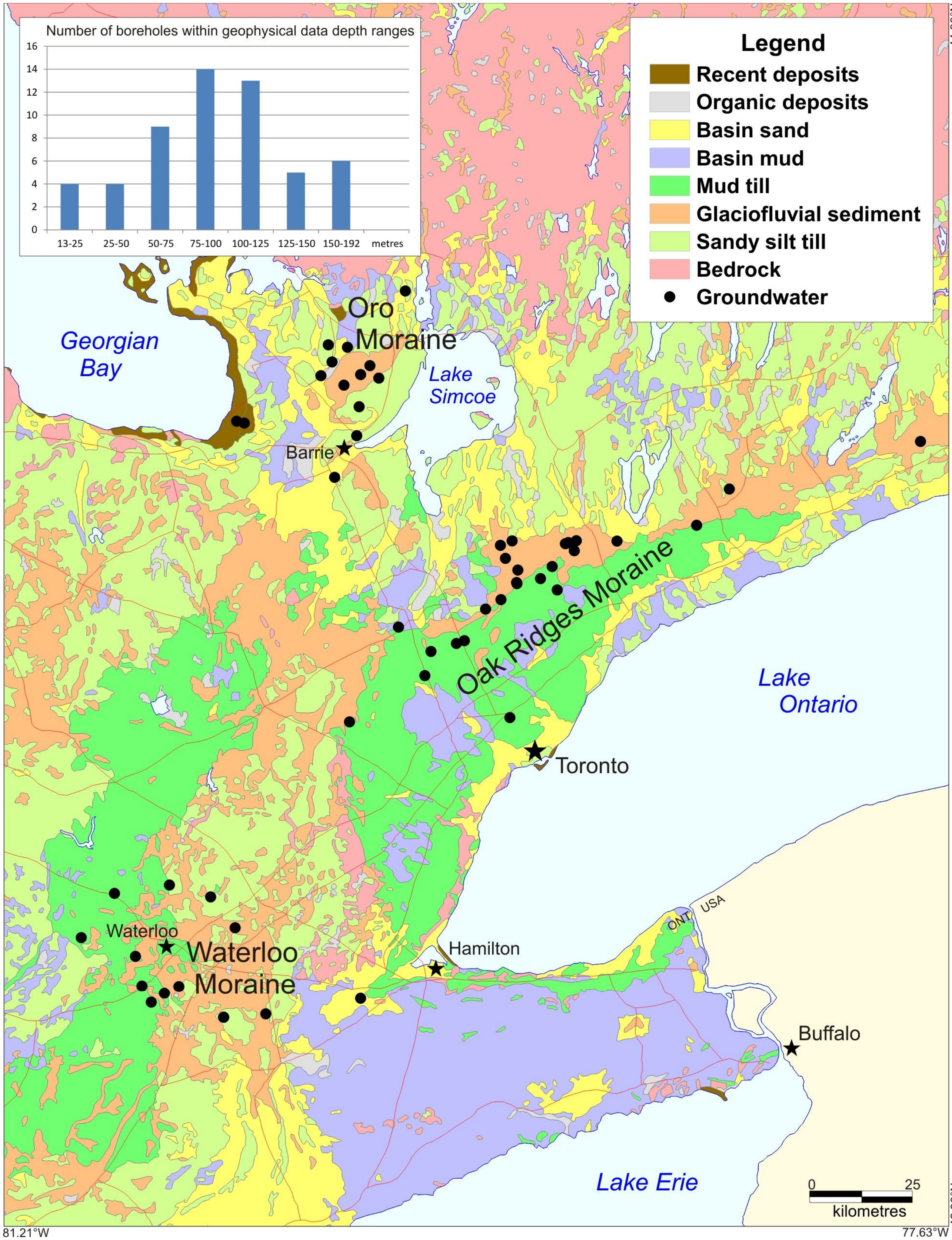

Figure 7. Borehole locations in Southern Ontario indicating three study areas: the Waterloo Moraine, the Oak Ridges Moraine in the Greater Toronto Area, and the Barrie and Oro Moraine areas. Geology modified from Barnett et al (1991). Total of 55 boreholes in this region.

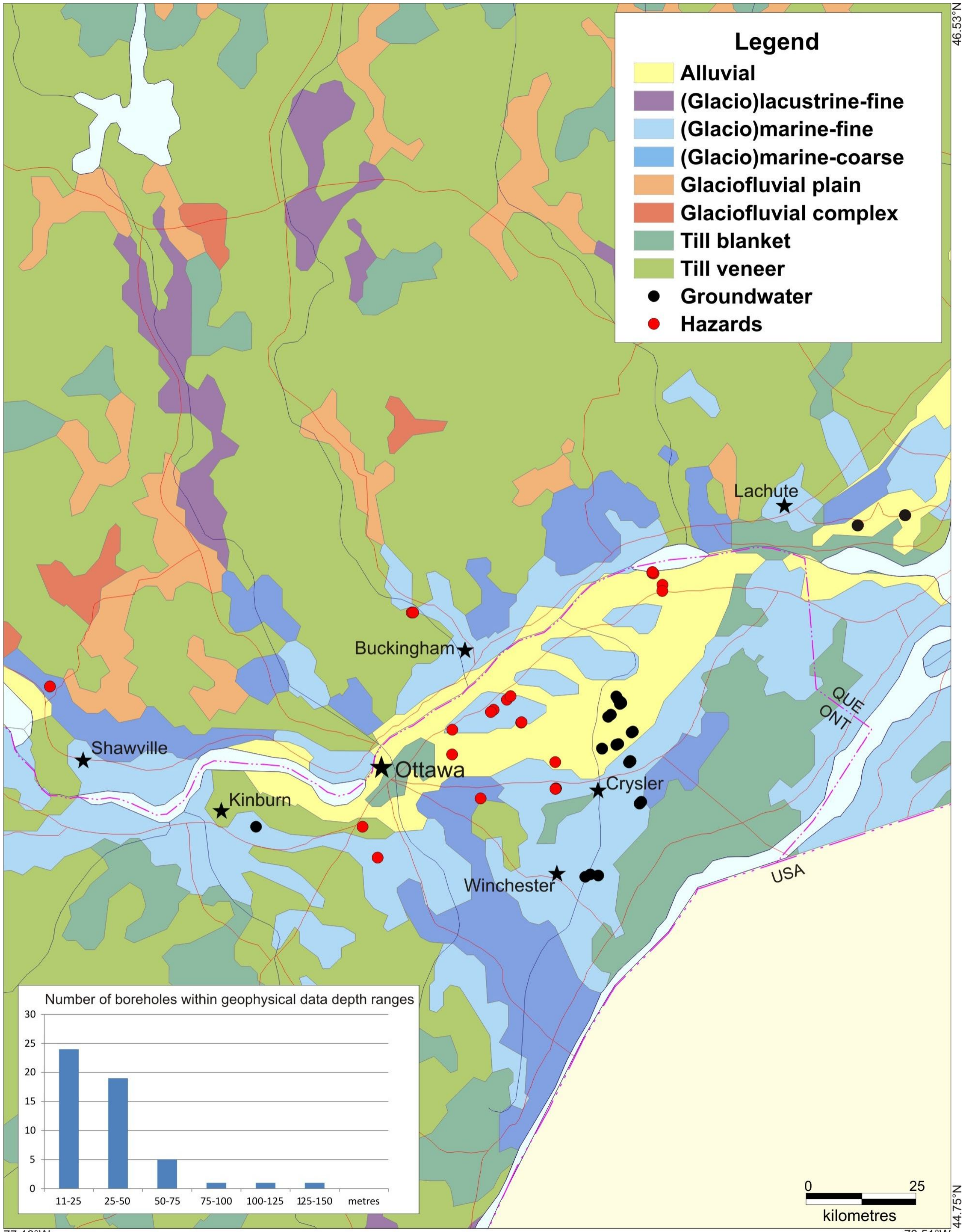

Figure 8. Borehole locations in the Ottawa-Montreal corridor. Geology modified from Fulton (1995). Total of 51 boreholes in this region.

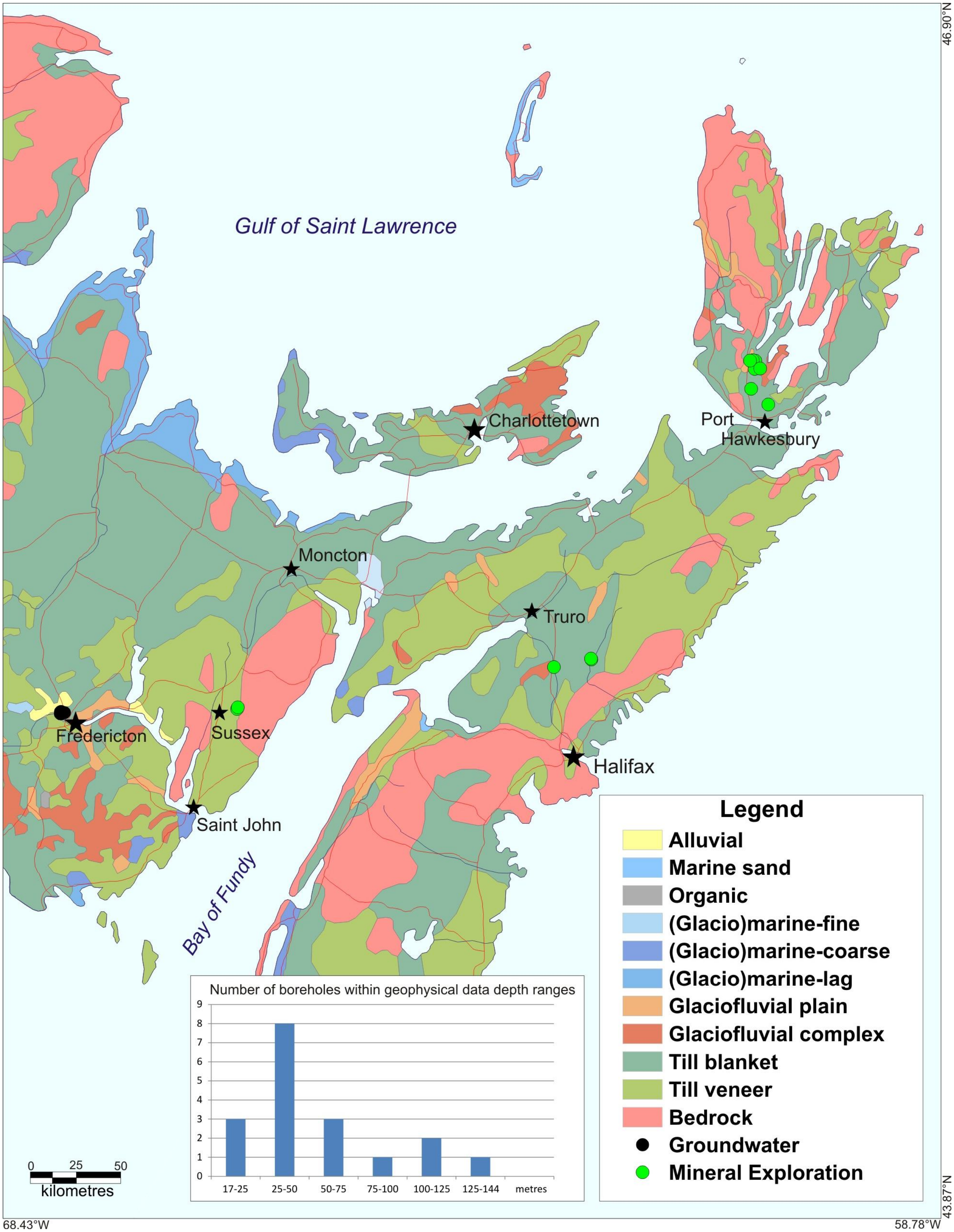

Figure 9. Borehole locations in the Maritime provinces, predominantly within the Maritime Basin Hydrogeological Region. Geology modified from Fulton (1995). Total of 19 boreholes in this region.

2.0 Data Collection

2.1 Logging Methods

Logging techniques carried out by the GSC fell into five broad categories:

Nuclear techniques:
- passive gamma
  - natural gamma (or gamma-ray) logs
- active gamma
  - relative gamma-gamma density logs
  - calibrated gamma-gamma density logs
  - spectral density ratio (SDR) logs
  - neutron logs

Induction techniques:
- apparent conductivity
- magnetic susceptibility

Fluid techniques:
- fluid temperature

Velocity logging techniques:
- downhole shear wave velocity (Vs)
- downhole compression wave velocity (Vp)

The following section provides an overview of each of these logging methods. Table 1 provides a brief summary of the quantities measured, data resolution, logging details, and the practical interpretation of each log. More detailed descriptions of these logging techniques can be found in Douma et al. (1999). A description of the logging systems used for the data collection can be found in Section 2.2.

Table 1. Summary of borehole geophysical log types collected by the GSC between 1993 and 2013.

Downhole Geophysical Log	**Logging Unit**	**Radius of Investigation** ***[Vertical resolution]***	**Practical Interpretations**
Natural Gamma	Counts per second (cps)	0.3 - 0.6 m *[centimetres, function of logging speed]*	relative grain size, lithology; presence of radioactive elements
Relative Gamma-Gamma density	Counts per second (cps)	0.2 - 0.3 m *[sub-metre]*	bulk relative soil density, water table
Spectral Gamma-Gamma Density Ratio (SDR)	Counts per second (cps)	0.2 - 0.3 m *[sub-metre]*	relative variation in heavy mineral content
Calibrated Gamma-gamma Density (Cs-137 source)	g/cm^3	0.15 – 0.25 m *[centimetres, function of logging speed]*	density (when casing coupled with formation), lithology
Neutron log (collected by outside organization)	Counts per second (cps)	0.15 - 0.25 m [function of hydrogen content in formation, source-detector spacing, source energy] *[centimetres, function of logging speed]*	porosity (when casing coupled with formation), lithology
Apparent Conductivity	milliSiemens/metre (mS/m)	0.3 m *[submetre]*	formation conductivity (grain and/or porewater conductivity), lithology
Magnetic Susceptibility	parts per thousand SI (ppt SI)	0.3 m *[submetre]*	magnetite (magnetic mineral) concentration, lithology

Downhole Geophysical Log	Logging Unit	Radius of Investigation *[Vertical resolution]*	Practical Interpretations
Temperature	Celsius (°C)	Influenced by surrounding materials *[logging interval]*	lithology (as related to thermal conductivity), anomalies due to groundwater flow (from gradients)
Compressional (P) Wave	m/s	Wavelength-dependent (metre scale) *[metre scale]*	variation in lithology, compaction, identification of reflecting horizons
Shear (S) Wave	m/s		

2.1.1 Nuclear Logs

Passive Techniques

Natural gamma logs are the most widely used of the nuclear logs. Probes measure radioactivity by converting gamma rays (photons) emitted from the formation surrounding the borehole into electronic pulses using a scintillator crystal (detector) in the tool. The tool records these pulses in counts per second (cps). Radioactive decay is statistical in nature and photon emission follows a Poisson's distribution. The standard deviation of the count number will be its square root. The accuracy of the measurement is therefore greatest at high count rates over slower logging speeds (≤1 m/min).

Generally, clay and silt-sized materials emit more gamma radiation than coarser grained quartz sands and gravels. Therefore changes in count rates can be used in a qualitative manner to estimate changes in grain size, allowing for interpretation of lithological variation downhole, and correlation from well to well.

Active Techniques

Gamma-gamma density logging uses an artificial gamma source to bombard the formation with gamma rays; the GSC has used Cobalt-60 and Cesium-137 gamma sources. Two shielded detectors on the tool at near and far points from the source are used to measure formation response. Gamma-gamma logging is based on the principle that attenuation of gamma radiation is related to the electron density of the materials through which it passes. Radiation from Compton scattering detected by the tool will result in a count rate which is inversely proportional to the electron density of the formation (i.e. counts will be lower in denser materials) (Keys, 1997). As with the passive gamma log, the detector response is recorded in terms of counts per second.

The **relative gamma-gamma density** and **spectral gamma-gamma density ratio (SDR)** logs are derived from a spectral gamma-ray logging tool with a weak (10 millicurie = 370 MBq) gamma-ray source (^{60}Co) on the nose of the probe. Back scattered gamma-ray spectra were recorded in 1024 channels over an energy range up to 1.0 millielectron Volts [MeV]. The relative density information is derived from the count rates in the energy window below 200 meV with increasing number of counts indicating decreasing density. The SDR log contains information about the heavy element content of the materials surrounding the borehole and is computed from a ratio of counts in two energy windows: one above 200 meV, and one below 200 meV. This ratio increases when the probe passes through zones containing heavy elements. Thus the log can be considered as a heavy element indicator, and can be calibrated in bedrock boreholes to produce an assay tool for quantitative determination of the heavy element concentration for mining applications (Killeen and Mwenifumbo, 1988). In unconsolidated sediments, this log is useful as a lithological indicator, and as a potential indicator of sediment provenance.

In **calibrated gamma-gamma density logging**, counts are converted to 'near' and 'far' densities using a calibration procedure employing two pure blocks of known density (1.28 and 2.60 g/cm^3). In open boreholes where the detectors and source are ideally in contact with the formation wall, the near and far detector densities are compensated using compensation curves determined for the tool at downhole calibration facilities. This takes into account the variability of the borehole wall and any mudcake which may be present. In cased boreholes where the formation is separated from the casing wall by an annular region which is generally filled with grout or backfilled material, the calculation of density becomes more complicated. The compensation correction tends to overcompensate in these conditions leading to an overestimation of formation density. In these cases, the far density detector, which 'sees' farther into the formation provides a more realistic density estimate. The tool is very sensitive to variation in the borehole wall (void space caused by washouts or poor grouting, etc) but these effects can be inferred by unusual drops in density values at near *and* far detectors.

Neutron logging is carried out with an active high-energy neutron source (most commonly americium-beryllium) and two detectors on the probe body. Most of the neutron interactions are related to hydrogen content, which is primarily a function of groundwater presence in the materials surrounding the borehole. The count rate decreases as saturated porosity or moisture content increases, therefore, neutron logs are used to infer downhole porosity. The neutron logs available in this report were recorded by project partners licensed to conduct downhole neutron logging.

2.1.2 Electromagnetic Induction Methods

The **apparent conductivity** logging tool uses an alternating 40 kHz AC current in a dipole transmitter to generate a magnetic field which induces electric fields in the formation. A dipole receiver in turn measures the responding signal, whose quadrature phase is proportional to the conductivity of the materials intersected by the borehole. Additional coils are used to focus the current out into the borehole to reduce the sensitivity of the tool to the borehole fluid and improve the vertical resolution of the tool.

In soil and rock logging, the apparent conductivity measured is a bulk conductivity, meaning that the grains and pore water both contribute to the total conductivity values. Studies on the resolution of the apparent conductivity tool have shown that the instrument's minimum bed thickness required to accurately measure conductivity is 4 m, but thin beds can be detected if the conductivity contrast between adjacent beds is large enough (Taylor et al, 1989). If the porewater is saline or otherwise conductive (e.g. leachate contamination), this will overwhelm the conductivity of the soil/rock matrix. In absence of conductive porewater, the conductivity tool provides a method of identifying litho-stratigraphic units, and tends to mirror the trends of the natural gamma log, where fine grained materials tend to be more conductive than coarse grained materials.

The **magnetic susceptibility** measurement is the ratio between the primary magnetic field and the in phase component of the magnetic field produced by the host material. Although traditionally used for downhole mineral exploration due to sensitivity to magnetic minerals (e.g. magnetite, ilmenite, pyrrhotite), the susceptibility tool has been shown to be extremely useful for lithological logging in unconsolidated sediments of low susceptibilities (McNeill et al., 1996). This requires a very sensitive magnetic susceptibility logger in the sub-parts-per-thousand SI with a high degree of temperature compensation. Therefore, induction susceptibility loggers require a slightly different coil configuration and enhanced temperature compensation electronics than the conductivity models.

2.1.3 Fluid Temperature Logs

Temperature tools are composed of a thermistor mounted inside a probe tip made of a high thermal conductivity material to ensure fast response time. The end of the probe is usually encased in a protective cover which is designed to channel fluid past the sensor. Prior to logging, the borehole must have been undisturbed for at least 24-48 hours to thermally equilibrate. To measure variations of temperature on the order of hundredths of a degree Celsius, the temperature probe must be the first instrument to enter the borehole fluid, the log must be recorded downward, and run slowly (~1m/min) to avoid any mixing of the fluid ahead of the tool.

Inside cased, fluid-filled boreholes, movement of groundwater behind the casing wall, or, to a lesser degree, changes in lithology intersected by the borehole, cause slight variations in fluid temperature which can be detected by a high-sensitivity temperature tool. Temperature surveys were used extensively by the GSC's Earth Physics Branch in the 1970's and 80's to examine geothermal gradients in deep bedrock boreholes. As a result of this work, articles described the detection of fluid-bearing fractures in bedrock (Drury and Jessop, 1982; Drury et al, 1984; also see Conaway, 1987) and in sediments (Taylor et al., 1999).

2.1.4 Downhole Seismic Surveys

Downhole, or vertical seismic profiling (VSP) is a method used to calculate seismic velocities (compression (Vp), or shear (Vs)) by measuring the traveltimes of waves propagating from a source on surface to a downhole receiver. The entire wave train is recorded, allowing for the interpretation of later arriving events (e.g. reflections below the bottom of the borehole, converted waves, tube waves, etc.). The systems and procedures developed for downhole P- and S-wave logging are described in greater detail in Hunter et al. (1998c).

P-wave velocities in unconsolidated materials are strongly affected by the velocity of the pore fluids, while the S-wave velocities are transmitted through the material grains, making them much less sensitive to pore water composition. However, S-wave velocities are influenced by overburden pressures and the degree of consolidation. Together, P and S-wave velocity logs provide a means of identifying changes in lithology and water saturation, as well as changes in stiffness, or material compaction. Velocity logs also provide velocity-depth functions which can be used to correlate seismic reflections to depth. Shear wave velocities are also required as input for geotechnical studies related to the amplification and/or resonance of earthquake-induced shaking in soft soils (e.g., Hunter et al., 2007; Hunter et al., 2010).

2.2 Logging Systems

The data have been collected over two main time periods using different portable, 'slim hole' logging systems (Table 2). The first period occurred between 1985 and 2008, and the second began in 2008 when a new logging system was purchased to replace the two older systems in use. The data collected over these two time periods remain consistent, with the exception of the natural and active gamma (density) logs, described below. Downhole P-wave logs have been acquired using the same downhole hydrophone array since 1993, and S-wave logs have been acquired using the same model of downhole triaxial geophone configuration since 1997.

During the first period, a Geonics logging system (with an EM-39 electrical conductivity probe, an EM-39S magnetic susceptibility probe, and a Gamma39 total count natural gamma probe) were employed. An IFG Corp. logging system was used to run the fluid temperature BTM-01 probe and a BSC-01spectral gamma-gamma relative density probe.

In 2008, new 512-channel passive spectral gamma tool (2SNA) was acquired, replacing the Gamma 39 natural gamma probe previously in use (see Table 2). Although the detectors are the same size, the new model strips out the counts in the lowest 200 meV of the gamma energy spectrum because they are not needed in spectral analyses. This results in a 2/3 reduction of total counts recorded by the new spectral tool, but the trends remain the same (Figure 10).

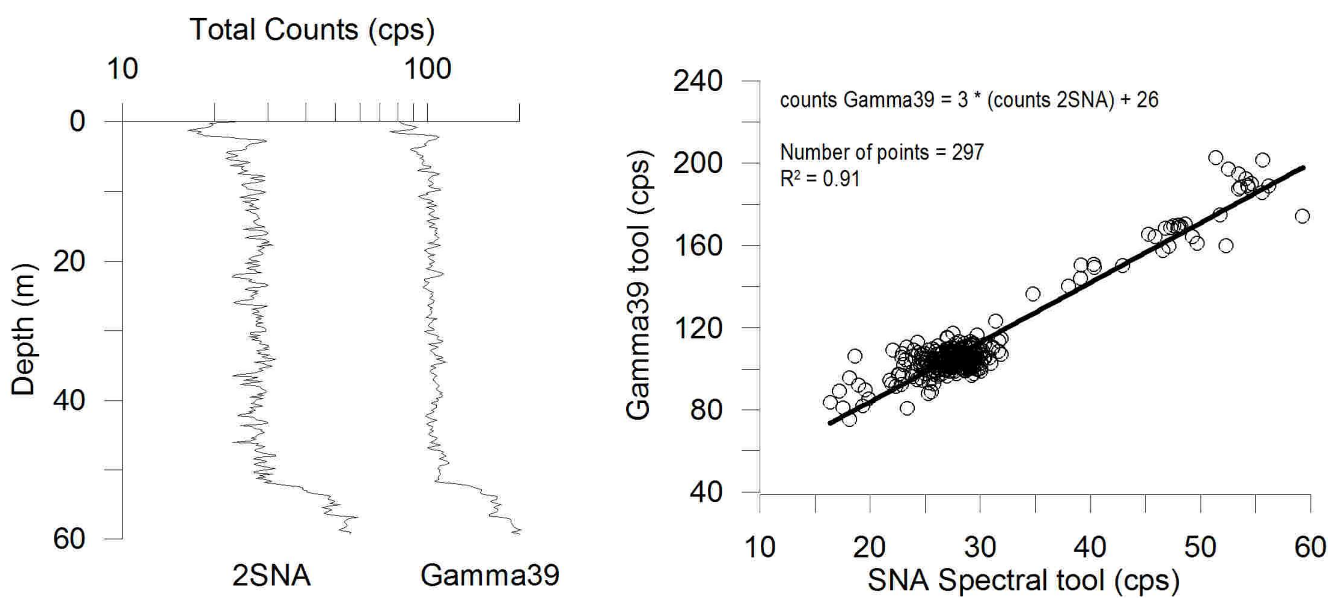

Figure 10. Count comparison between the total count Gamma39 tool and spectral gamma tool 2SNA model. The relationship between the total number of counts is approximately 3:1. Data collected in borehole AR93-1.

From 1995 to 2008, the relative density tool recorded count levels using a small 10 mCi (0.37 GBq) Cobalt-60 source. The density tool put into operation in 2009 uses a larger 100 mCi (3.7 GBq) Cesium-137 source and records calibrated densities in g/cm^3.

Table 2 – Logging systems and years in use at the GSC.

Log	Years in use	Model	Manufacturer
Natural Gamma	1993 – 2007	Gamma39 Natural Gamma Probe	Geonics Ltd.
	2008 - 2013	2SNA-1000S Spectral Gamma Probe	Mount Sopris Ltd.
Active Gamma	1995 - 2008	256-ch. BSC-01 Spectral Gamma Probe (relative density using 10 mCi ^{60}Co source)	IFG Corporation
	2009 - 2013	2GDA-1000 Density Probe (calibrated density using 100 mCi ^{137}Cs source)	Mount Sopris Ltd.
Induction Conductivity	1993 - 2007	EM39 with Geonics logging system	Geonics Ltd.
	2008 – 2013	EM39 with Mount Sopris logging system (new probe)	Geonics Ltd. / Mount Sopris Ltd.
Induction Magnetic Susceptibility	1993 - 2007	EM39S mated with Geonics logging system	Geonics Ltd.
	2008 – 2018	EM39S mated with Mount Sopris logging system (same probe with new adaptor head)	Geonics Ltd. / Mount Sopris Ltd.
Fluid Temperature	1993 - 2011	BTM-01 Temperature (resolution ±0.005ºC)	IFG Corporation
	2011-2013	In house temp tool (resolution ±0.001ºC)	GSC
Downhole P wave	1993 – 2013	12 or 24 channel AQ16-AQ300 or AQ1000 systems	Pro-Seismic Services Ltd.
Downhole S wave	1997 - 2013	15Hz-triaxial clamping borehole geophone	Geostuff Ltd.

2.3 Tool Calibrations

The GSC's Deep Borehole Calibration Facility in Ottawa, ON, was built by the GSC in 1981 to provide a site where downhole geophysical tools could be calibrated against national standards. The site is composed of six deep bedrock boreholes, ranging in depth from 120 m to 300 m, which intersect Paleozoic and Precambrian bedrock units of varying rock properties and structures. Downhole datasets collected in these boreholes can be used to calibrate instruments for porosity, resistivity, IP (induced polarization), conductivity, sonic velocity, natural gamma, magnetic susceptibility, and temperature measurements (Mwenifumbo et al., 2005).

From time to time, tool calibration runs have been conducted at the Deep Borehole Facility to ensure that all the GSC's tools provide repeatable results, which are in agreement with the standards published by the GSC (Bernius, 1996). In addition, since 2009, laboratory calibrations have been performed prior to leaving for the field with the fluid tool using temperature-monitored baths (0°C and 25°C), and density calibration blocks of 1.28 and 2.60 g/cm^3 for the gamma-gamma density tool. For safety reasons, the active gamma-gamma tool is not run down open (uncased) calibration boreholes.

At field sites, prior to logging, conductivity and magnetic susceptibility tools were nulled in the air. Since 2008, the Mount Sopris conductivity tool has also been calibrated at a second higher point using calibration coils of 95, 460, or 1690 mS/m depending on the conductivity range encountered in the ground. At the end of the runs, the tools are again recalibrated to provide a measure of drift. Repeat runs are also recorded and overlaid during processing to check for (and correct) tool drift, if present.

Between 1993 and 2007, periodic calibrations of the IFG temperature tool were carried out in temperature controlled baths to sensitivities of 0.005°C at Carleton University's permafrost laboratory.

2.4 Field Procedures

Water level was measured in each borehole upon arrival on site. The fluid temperature tool was the first instrument lowered into the borehole to collect the log in undisturbed fluid. A period of 10-20 minutes was allowed for the tool to thermally equilibrate in the top of the water column before the downward logging began. Following fluid logging, induction and nuclear logs could be run in any order, generally followed by the seismic surveys. Logs were corrected for casing stick up and sensor offset, and recorded relative to ground surface.

The seismic surveys were carried out using a downhole receiver array and a source on surface several metres (generally 3 m to 5 m) from the borehole collar, depending on hole depth. The cables were lowered by hand to the bottom of the hole, and pulled uphole at one or half metre spacings where readings were taken. Data were obtained for the P-wave surveys using a multi-channel hydrophone array (12 or 24 hydrophones at 1 or 0.5 m spacings, respectively) in the water-filled portion of the borehole. Shear (S) wave logs were obtained using a clamped, 3-component downhole receiver with 15 Hz geophones. Various sources have been used, but most often the source was a sledge hammer (or in some cases, a small metal hammer) striking a metal plate vertically (P-wave) or at a 45° angle (S-wave). The plate was coupled with the ground by either removing the top few centimetres of soil and driving onto the levelled plate, or by wedging a metal piece of I-beam into the soil. Data were recorded on an engineering seismograph (most recently a Geometrics 24-channel Geode). The systems and field procedures developed for downhole P- and S-wave logging are described in greater detail in Hunter et al. (1998c).

2.5 Data Processing

Due to pre-logging calibration procedures, natural gamma, induction (when formation conductivities ≤200 mS/m), and fluid temperature logs did not require post-processing. Processing techniques for induction logs at elevated conductivities, spectral density ratio logs, and velocity log calculations using traveltime measurements are described below.

The induction logging tool has a non-linear response at conductivities greater than 200 mS/m resulting in measured values being approximately 20% lower than in situ values. To correct for this effect, a post-acquisition correction was applied using the calibration curves given by McNeill (1986). Similarly, a correction for conductive effects was made to raw magnetic susceptibility data when formation conductivities exceeded 200 mS/m, as described in McNeill et al. (1996).

The spectral density ratio (SDR) log is calculated by taking the ratio of counts in the 200 – 1000 meV window (the relative density count window) to counts in the 50 – 150 meV window (as described in Section 2.1.1). This low energy window is affected by both formation density and the presence of elements with high atomic numbers (heavy elements), while the higher energy window is mainly affected by density. Therefore, the SDR can be used to obtain information on changes in heavy elements, which is used in this dataset as an indicator of stratigraphic variation. In bedrock boreholes, this log can be calibrated as an assay tool for quantitative determination of heavy element concentration downhole (Killeen and Mwenifumbo, 1988).

Until the early 2000's, the first arrivals of the P and S seismic pulses were picked by hand on paper or in digital records and processed using subroutines written to calculate velocities. More recently, multi-fold P-wave and single fold S-wave travel times were picked using a semi-automatic picking program with a pick-to-pick cross correlation (Ivanov and Miller, 2004). This method selects arrival times through cross correlation and using spline interpolation. Interval velocities were then computed by dividing the receiver spacing by the time difference between two consecutive stations. See Hunter et al. (1998c).

3.0 Downhole Data

The data products contained in this report are available in the Appendices in several formats, briefly described in this section.

Raw data were originally collected at 1.0 cm to 2.0 cm sampling intervals in a variety of downhole logging file formats, and, after processing, were entered into an Access database. Downhole traveltime measurements were recorded at 0.5 or 1.0 m intervals. Visual Basic for Applications (VBA) code was written to export data in LAS 2.0 and 3.0 formats. During this export, downhole log data were resampled at common 2.0 cm intervals, with the exception of the velocity logs which were kept at their original sampling intervals.

3.1 LAS digital format

The Log ASCII standard (LAS) file was developed by the Canadian Well Logging Society (CWLS) in 1990, and has since become the most commonly used format worldwide for industry to store and share well logging information. A LAS file can only contain data for one borehole, but may contain any number of geophysical logs collected in that well, all at a common depth scale. The LAS file also contains a header which stores details about the drilling and logging history of the well. The structure of the file is controlled so that the format is identical for all LAS files (CWLS, 2014).

LAS Version 2.0 was released in 1992 and contains a common header section with a single depth column and multiple data columns. Version 3.0 was released in 2000 and was redesigned to allow for other data types, including geological or core data (with "from" and "to" depth format), and additional header content.

The LAS 3.0 structure can become quite complex, and not all logging software is able to import type 3.0 files yet. Therefore, LAS files in this report are presented as both V2.0 and 3.0. Stratigraphic data have been included in the LAS 3.0 file headers. LAS file format data are available in Appendix A.

3.2 Stratigraphic data

The GSC's Groundwater Geoscience Program has developed standardized geological descriptions for common unconsolidated materials across Canada (Russell et al., 1998). These codes have been assigned to all the materials in this dataset based on the often varied descriptions provided in the logs (Table 3). This step simplifies and standardizes all the sediment information. Sediment data appear in the headers of the V3.0 LAS files in Appendix A.

3.3 WellCAD files

For users wanting to view downhole data with a log software package, WellCAD files are provided in Appendix A. Data users without a WellCAD licence can view the files by installing a free WellCAD Reader, also provided in Appendix A, or freely available for download online in 32- or 64-bit versions at http://www.alt.lu/downloads.htm. The Reader allows users to open, view, and print WellCAD files at various depth scales.

3.4 Google Earth KML file

Google Earth provides a map-based method to view and interact with the dataset. The Google Earth .KML file can be found in Appendix B. When a borehole is selected, a dialogue box provides well metadata and a link to a PDF file displaying the suite of geophysical logs. To view the PDF links, two key boxes must be checked in the Google Earth 'Tools' menu, as shown in Figure 11.

When copying or moving Appendix B, the subfolder containing the PDF files must remain with the KML file. The relative path structure is programmed to look for the files in a subfolder within the same folder as the KML file.

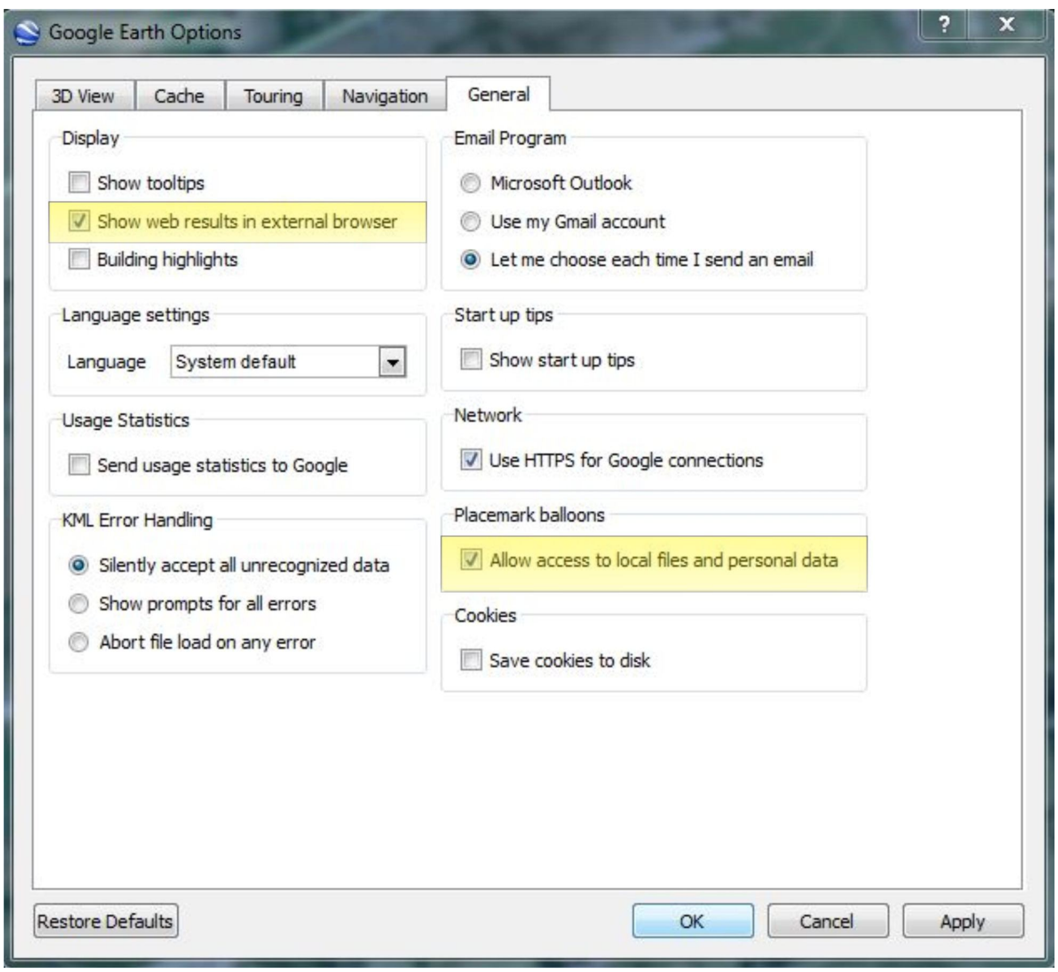

Figure 11. To be able to view PDF links to geophysical log suites, ensure the highlighted boxes under Tools → Options (General tab) are checked in Google Earth.

Table 3 – Sediment codes for sediments in geophysical database based on Russell et al. (1998).

1. **Rock**
    - 1.1. Limestone
    - 1.2. Shale
    - 1.3. Granite (or probable boulder)
    - 1.4. Dolomite
    - 1.5. Potential Bedrock
    - 1.6. Sandstone
    - 1.7. Interbedded Limestone/Shale

2. **Diamicton: silty/sandy to sandy matrix**
    - 2.1 diamicton: silty/sandy to sandy, stony
    - 2.2 diamicton: silty/sandy to sandy, with gravel/sand/silt/clay interbeds
    - 2.9 diamicton: silty/sandy to sandy, muck, peat, wood fragments

3. **Diamicton: silty to sandy/silty matrix**
    - 3.1 diamicton: silty/sandy to sandy, stony
    - 3.2 diamicton: silty/sandy to sandy, with gravel/sand/silt/clay interbeds
    - 3.3 diamicton: texture unknown
    - 3.8 diamicton: silty/sandy to sandy, topsoil
    - 3.9 diamicton: silty/sandy to sandy, muck, peat, wood fragments

4. **Diamicton: clay to clayey/silty matrix**
    - 4.1 clay to clayey/silty, stony
    - 4.2 clay to clayey/silty, with gravel/sand/silt/clay interbeds
    - 4.8 clay to clayey/silty, topsoil
    - 4.9 clay to clayey/silty, muck, peat, wood fragments

5. **Gravel, gravelly sand**
    - 5.1 gravel, gravelly sand, with rhythmic/graded bedding
    - 5.8 gravel, gravelly sand, topsoil
    - 5.9 gravel, gravelly sand, muck, peat, wood fragments

6. **Sand, silty sand**
    - 6.1 sand, silty sand, with rhythmic/graded bedding
    - 6.8 sand, silty sand, topsoil
    - 6.9 sand, silty sand, muck, peat, wood fragments

7. **Silt, sandy silt, clayey silt**
    - 7.1 silt, sandy silt, clayey silt, with rhythmic/graded bedding
    - 7.8 silt, sandy silt, clayey silt, topsoil
    - 7.9 silt, sandy silt, clayey silt, muck, peat, wood fragments

8. **Clay, silty clay**
    - 8.1 clay, silty clay, with rhythmic/graded bedding
    - 8.8 clay, silty clay, topsoil
    - 8.9 clay, silty clay, muck, peat, wood fragments

9. **Organic Material**
    - 9.8 Organic topsoil

10. **Fill** (incl. topsoil, waste)
11. **Covered, missing, previously bored**
99. **No obvious material code**

Summary

Over the past four decades the Geological Survey of Canada (GSC) has collected borehole geophysical logs in Quaternary sediments across Canada. This work has resulted in a dataset of geophysical logs in 226 boreholes across the country. Primary logging methods include natural and active gamma, inductive conductivity and magnetic susceptibility, fluid temperature, and compressional and shear wave velocities. A unique aspect of this dataset are the calibrations that have been conducted at the Bell's Corners Borehole Calibration Facility in Ottawa, ON, to ensure that all the tools provide repeatable results which are in agreement with the standards published by the GSC. With the transition from analog data recording to digital data and ability to integrate data collected over multiple field campaigns, projects, and time, this provides a valuable dataset that is internally consistent.

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