GEOLOGICAL SURVEY OF CANADA
OPEN FILE 6731

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Summary

Current hydrocarbon and environmental interests in part of the central Laurentian Channel, south of Burgeo Bank, demands a review of the current understanding of the area's shallow geological conditions. Multi-layered map themes, both new and old, show the distribution and attributes of the bedrock and overburden. Broadly folded and faulted Carboniferous siliciclastics and evaporites of the Sydney Basin floor the entire area. The bedrock surface is glacially smoothed and overlain by a simple stratigraphic series of one or two tills, up to 60 m thick, followed by glacimarine deposits, up to 30 m thick. Both are turbated by relict iceberg scours. At the seafloor muds are common below about 250 m water depth and patchy sand and gravel shallower than about 80 m, while till and glacial sediments underlie most of the area, yet crop out over large areas.
Physical properties indicate competent tills with strengths of 150 kPa, much softer overlying glacimarine muds (ca. 10-20 kPa) and very thin covering muds (<10 kPa). GSC-A data holdings include no biological observations; other areas of the Channel with muddy seafloor support moderate sponge and sea pen populations with anemones and greater diversity on harder (generally glacial) substrate. Geo-features of potential interest to engineering application include shallow gas and pockmarks, rare buried channels and submarine sediment mass failure (old), heavily relict iceberg-scoured terrain and both hard and soft sediments. Neo-tectonic activity level around salt diapirs and faults are inconclusive in terms of magnitude and timing.

1.0 Introduction

Current interest in the surficial geological condition of the central Laurentian Channel area stems from a CNLOPB hydrocarbon exploration license in the Sydney Basin and also, but quite independently, from a fisheries and habitat preservation viewpoint. The hydrocarbon exploration interest is the current Husky Energy EL1115 license in connection with Environmental Assessment and foundation engineering. Interest in the habitat protection arises from two concurrent suggestions from Department of Fisheries and Oceans (DFO) to initiate "Areas of Interest" (AOI), one on each side of the provincial boundary. Declaring AO is a significant step in investigating the level of biota and habitat protection, whereby "Marine Protected Area" status may arise.

The map area falls within the Laurentian Channel, seaward of Cabot Strait and east of Cape Breton, Nova Scotia Fig. 1. It covers the breadth of the Laurentian Channel south of Newfoundland, south of Burgeo Bank and west of St. Pierre Bank, spanning about 250 km (E-W) by 110 km (N-S). It covers water depths from just under 80 m to over 400 m. Bedrock and surficial elements are shown in Figures 2 through 8.

An ongoing GSC-A project includes surficial and shallow bedrock geological mapping and establishment of databases with cataloguing of surficial and shallow geologic features across parts of Grand Bank. This and a recently completed surficial geological map (Cameron and King, 2010) provide the capacity to excerpt some of the geological characterization into a set of map themes for the Laurentian area.

This report includes a general bathymetric presentation, the coverage of GSC-A data (geophysics and samples) a summary of the bedrock structure, the Quaternary stratigraphy and distribution as well as surficial and shallow potential geohazards (gas and buried channels). Sub-surface overburden information includes mud and till thickness distribution map layers as well as geologic sections derived from legacy high resolution air-gun data. GSC-A holdings of seabed samples (grabs and cores) is also presented together with some grainsize and summary descriptions of the cores. Also included are interpreted geologic sections, grainsize and core descriptions, where available.

Presentation of the maps is via ESRI's ArcMap™ GIS (Geographic Information System) into Adobe™ PDF-format with layered map element themes which can be selectively viewed and overlain, allowing for better customize viewing and derivative illustrations. A single legend explaining all features on the various maps and layers is included at the beginning of the illustrations. Some layers (themes) overlap others so viewing with the "Expand All" option in the "Layers" tap is recommended to facilitate viewing flexibility. There are some limitations with such an interactive display; it does not lend itself well to titles and symbols legends on the map itself as these are fixed display and not interactive with the chosen layer displays. Accordingly, one master symbols legend is presented (Fig. 2).

The object of this compilation is not so much to present the geological history and processes as it is to provide specific attributes of the bedrock and overburden sediment as known from GSC data holdings and current, though incomplete value-added compilations of these data.

2.0 Geologic Cross-sections

Several geologic cross-sections presented in Fig. 3 enable ready visualization of the stratigraphy and geometry of the bedrock and overlying deposits in the following maps. They are generated from high resolution air-gun and sleeve-gun reflection seismic transects. To enable correlation between cross-section and map, each profile has a Julian day and time scale across the bottom with corresponding daytimes on the accompanying map. In this presentation, the seismic section reproduction resolution is low compared to the original but the emphasis is on the line-drawing interpretation. These profiles do not sufficiently resolve the thin muds overlying till which are well characterized in 3.5 kHz and deep-towed boomer from which surficial mapping and core sampling targets are derived, as illustrated in Figures 9 through 12. Note also the occasional presence of shallow gas; that, though recognized in Profile 1, has not yet been entered into the buried features database and subsequently does not show on the map.

3.0 Bedrock

Bedrock geology comprises Carboniferous age siliciclastic (silica-rich sedimentary rocks) and evaporites (limestones, salts) and chalks, reaching 6000 m thick, in the Sydney Basin (Sanford and Grant 1991). The rocks are not well differentiated lithologically, lacking any well control in the map area, but rather stratigraphically into one unit. Equivalents on Cape Breton include Windsor, Horton, Canso, Riversdale, Mabou, Cumberland, Pictou, and Morien Groups. Lithologies from these land occurrences are summarized in the legend (Fig. 2)

The strata are broadly folded and locally faulted. Sanford and Grant (1991) differentiated the mid-Mississippian age Windsor and Horton and Pennsylvanian Canso/Riversdale formations in the central basin, mapping the boundary just north of EL 1115 but well/age control is limited. Windsor Group rocks on land comprise 600 m of mainly shallow water deposits of limestone, dolomite, gypsum, anhydrite, red shale, and sandstone conglomerate in local alluvial fans. The offshore extent of fine-grained continental clastics of the Canso and Riversdale Groups is not known. Much of the basin thickness comprises overlying Pictou Group fluvial and fluviolacustrine origin siliciclastics containing coal seams correlated from land (Hacquebard 1986) but measures may cross the basin.

Most of the map area is floored with Carboniferous strata with the exception of late Proterozoic volcanics extending from St. Pierre et Michelon at the easternmost map extremity. An outlier of Cretaceous strata is preserved on northernmost Burgeo Bank and east of Cape Breton. Structural elements are presented in the map (Fig 4). Many of the elements are spot observations only as seismic coverage is insufficient for line to line correlation. Note that where strata dip more than about 10 degrees, this cannot be resolved on the seismic profiles. Note also that strike directions are generally apparent, having only one profile intersection; the same applies to the dips such that all values are minima.

4.0 Quaternary Deposits (Overburden)

All Quaternary age deposits in the map area arise from the latest glaciation and post-glacially derived products. The Laurentian Channel is a glacially carved shelf-crossing trough which carried most material to the slope and ocean basin. It was also fed by significant ice flow from Newfoundland through Hermitage Channel. Late glacial fluctuations also supplied thick and rapidly deposited tills and glacimarine muds from the Cape Breton Trough and Magdalen Shallows (Josenhans and Lehman, 1999) but this had little influence on the map area. However glacial retreat from the Laurentian Channel left a till blanket several metres thick and much thicker at the Laurentian Moraine. This feature is the most prominent within the license area. This was followed by plume and ice-rafted (pro-glacial) deposition of stratified muds and a very thin post-glacial (Holocene age) soft mud.

The area has been mapped in its entirety originally by Fader (1982) and recompiled for GIS (Fader, 2004). More recently, Cameron and King (2010) updated the SW Grand Banks area map. However this only extends to just south of the EL 1115 wellsite license. The stratigraphic map units within the map area are summarized in terms of depositional environment, grainsize, distribution and some physical properties in Fig. 5. The map is presented in Fig. 6.

The maps were derived from high- and medium-resolution seismic-reflection profiles, side scan sonar, seabed samples and limited seafloor photographic data. Glacimarine deposits and till are the dominant sediment types. Till marks the former presence of the glacier which left a largely homogeneous diamict reflecting mixing under the glacier where it formed. Till is often scoured and pitted by icebergs at the seafloor. Glacimarine deposits are often stratified proglacial or subglacial muds found as infilling deposits in basins and shelf crossing troughs. Post-glacial sediments include the reworked component of glacial deposits derived mainly from wave and current action during a postglacial marine transgression. It comprises mainly sand and gravel lag deposits overlying all the older map units. These are largely unmapped because they are generally under 0.5 m thick, highly variable spatially. The bank tops have sand up to several meters thick.

4.1 Sediment Properties

4.1.1 Sediment Thickness

Some of the geophysical profiles crossing the map area have been examined and compiled for deriving sediment thickness. Figure 7 shows thickness of two units; the glacimarine mud and the total Quaternary overburden thickness. The moraine is highlighted by its considerable thickness, of which at least 90% is till. The total Quaternary thickness is also high in the SE area of EL1115 where the blanket of till thickens, where two stratigraphically separate tills are preserved. The overlying mud thicknesses are approximate, drawing from lower resolution profiles, because high resolution 3.5 and Huntec profiler data have not yet been compiled in the same manner.

The glacimarine muds reach 20 m thickness locally. They can be difficult to differentiate, acoustically, from the underlying till, where late-glacial iceberg scouring has turbated the muds, destroying most stratification. Such is the case on top of the moraine. This also accounts for some of the discrepancy between the two surficial geology maps.

4.1.2 Seabed Grainsize

Very few seabed samples have been analysed for grainsize. Generally the grainsize layer in Figures 6 and 7 show sandy and gravelly bank areas and mud-rich sediments below about 250 m water depth. In the deep water areas, high resolution acoustic profiler data shows near-continuous muds at the seabed, but on the Laurentian Moraine itself the soft Holocene mud thin to expose glacimarine mud which has a larger gravel component and has been turbated heavily by icebergs during calving under deglaciation. The grainsize samples might de-emphasize a gravel component at the seabed where the surficial geology map shows glacimarine sediment (green) covering the Laurentian Moraine, but this is not confirmed.

4.1.3 Sediment Core Analysis

No GSC sediment core holdings fall within the exploration license area, but several outside the site typify conditions which could be found within EL1115. Cores in the map area do not penetrate to the till surface, but have sampled the glacimarine mud, and generally the overlying very thin olive-coloured Holocene mud. Figures 9 to 12 illustrate the cores projected on very high resolution sounder profiles. Additional metadata on the cores, including locations and very brief lithologic descriptions are shown in Table 1. Note that “old” core numbers (original designations established at sea) are commonly used for identification rather than new, archive database numbers. Down-core plots of two cores are shown in Figs. 13 and 14. One core (2003033030), shown in Fig. 14, is located a distant 160 km south of the EL1115 block but near the axis of the Laurentian Channel, (outside the map area). It is included because it has rare, well-documented sediment properties for the glacial sediment.

4.1.4 Sediment Core Properties

Figure 5 presents a summary of the Quaternary stratigraphy, lithology and physical properties. Most information is not gathered from within the map area and can come from very distant cores or boreholes. Most originate from a compilation of outer and northern Grand Banks (Sonnichsen and King 2001, 2002). They are presented as a guide only, to illustrate the approximate range of these types of sediments in other areas of the Grand Banks.

Sediment properties for core 2003-030-030, noted above, is included (Fig. 14) because of the relatively complete data set (though without C-14 dating). This core may be a good proxy for the sediments in the EL1115 site because marker beds (brick red mud) are present at both sites, demonstrating that the post-glacial sequence at both sites is similar.

It penetrated to the till and physical properties measurements depict a clear increase in strength to 160 kPa in the till from under 10 kPa in the overlying glacimarine sediment. Table 2 shows an Atterberg limit summary at various depths in the core.

Table 2. Atterberg Limit summary (*from* MacRae, 2003)

Cruise	Station	Depth (cm)	Water Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Liquidity index (%)
2003033	30	50	152.7208	105.935	45.1845	60.7507	1.770124
2003033	30	374	64.944538	45.1358	25.0333	20.1025	1.985389
2003033	30	423	63.07775	47.0028	26.0929	20.9099	1.76877
2003033	30	500	34.74445	27.781	17.7658	10.0152	1.695288
2003033	30	612	23.101032	20.6729	13.6281	7.04478	1.344673

4.1.5 Seabed Photography

Though no seabed photographs are available, recent ROV observations farther south in Laurentian Channel (King, 2008) may be proxies given the broad distribution of this mud. In a setting where glacial muds occur just below the seabed, a thin and loose muddy nepheloid-type layer is present, which is easily disturbed and thrown into suspension. Sea-pens are the dominant life-form here, but corals are abundant, as are anemones and some sponges.

5.0 Potential Engineering Concerns

Geologic features of potential concern to engineering applications include shallow gas (chance of leaking on disturbance), pockmarks (for topographical reasons and potential gas leakage), buried channels (spatially variable foundation conditions), submarine sediment mass failure, heavily ice-scoured terrain (topographical seabed roughness), hard or soft sediments (drill or trench competency) and neo-tectonics. None of these factors has been studied in detail or is well understood with respect to either geologic or engineering aspects. Nor should this be construed as a complete cataloguing of features; rather their presence is noted. These are presented in Fig. 8.

The presence of assumed small quantities of shallow gas in the upper tens of metres is documented, catalogued in a geo-features GIS database. Population of the database is continuously in progress and much of the legacy data (pre 2003) have not been yet included. Pockmarks are abundant locally (Figs. 7 and 8), for example along a traverse just south of EL1115. They are generally accepted to have originated from past (and present?) shallow gas escape, recorded only where there exists a soft mud at the seabed. However, some Laurentian Channel floor features, as observed from (very limited) sidescan images may be confused with pockmarks, giving rise to uncertainty in their interpretation/recognition. Isolated areas of high acoustic backscatter may simply arise from current moats around harder, more reflective seabed or from elongated moats or even the seabed expression of buried glacial flutes. This phenomenon is more common in outer Laurentian Channel such that most features shown on Figs. 7 and 8 as pockmarks are likely correctly identified. Their present-day activity is not well known. Most pockmark occurrences are not associated with shallow gas masking or acoustic strata enhancement. ROV investigations on some small features of the channel flank were inconclusive (King, 2008).

Buried channels are rare in the map area and present only on the south flank of Burgeo Bank (Fig. 6 and 7). They can have relatively soft mud fill with very thin sand and gravel cover, cut in competent bedrock.

Though sediment mass failures are present in the general region, none are yet recognized in the map area. The closest are likely in St. Ann's Basin, to the west (King and Huppertz 2009) and clearly early post-glacial (ca. 10 000 to 11 000 yrs BP). They are likely earthquake related. Another mass failure debris deposit is recognized well to the south of the map on the St. Pierre Bank flank but this is also late glacial in age.

Relict iceberg scours attest to a dominant process affecting the seabed, mainly during deglaciation. Very dense networks of intersecting and semi-parallel (along Channel axis) iceberg scours occur both in the till surface and in overlying glacimarine muds. Commonly this process destroyed the stratification enough to render the sediment with till-like (turbated) properties. Some empirical study of the in-situ effects of scour on sediments (from cores) is presently being conducted; complete remoulding is apparent but effects on strength properties are not yet investigated. The scour process was most pervasive on the SW flank of the Channel but most areas show some evidence. Much of the turbated material has experienced partial sediment infilling. Though a relict process, it can present particularly rough micro-topography with several metres relief over tens of metres span. Some effort toward meso-scale seabed roughness (sensitive to iceberg scour-size topography) is presently being conducted but it is derived from more recently collected digital profiler data (southern Laurentian Channel coverage), too sparse in this map area to present. Present day iceberg sightings are rare, with 15 sightings from 1998 to 2009, most along the eastern flank of the channel (NSIDC 1995).

Historic earthquakes suggest moderate low magnitude activity here (Fig. 8) Five historic events of >3 magnitude occurred within 100 km (GSC earthquake On-line Bulletin). The very large1929 earthquake, 300+ km distant, caused large-scale mass sediment failure and a tsunami. Faulting associated with salt diapirism in the general area is documented. Most faulting in the map area is recognized in Carboniferous and more commonly in Cretaceous strata. It is very rare to resolve any offset in otherwise glacially planed unconformities on the bedrock surface but there are some exceptions. Neo-tectonic offset of Quaternary sediments has been suggested (Josenhans and Lehman, 1999) and protrusion of salt diapirs through otherwise glacially-planed horizons is observed. However, acoustic resolution and cross-cutting timing is generally uncertain in these relationships so direct observation of pre-historic fault activity is inconclusive.

Anthropogenic hazards are not considered here but unexploded ordinance is likely yet largely unknown in terms of distribution. Known shipwrecks (positions approximate) and communications cables (mostly abandoned) are shown in Fig. 8.

6.0 Acknowledgments

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- The GSC Geoscience for East Coast Offshore Development Project (GECOD) for framework and funding
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- G. Cameron, GSC-A, for geological discussions and review

7.0 Keywords

Laurentian Channel, Newfoundland, Nova Scotia, Scotian Shelf, St. Pierre Bank, Hermitage Channel, Burgeo Bank, St. Ann's Bank, glaciation, Quaternary stratigraphy, surficial geology, moraine, till, glacimarine sediment, glaciomarine sediment, overburden thickness, Carboniferous bedrock, geologic cross section, shallow gas, pockmark, sediment strength, sediment core

8.0 References

Cameron, G.D.M and King, E L., 2010. Quaternary geology of the Laurentian Channel and the southwestern Grand Banks of Newfoundland; Geological Survey of Canada, Open File 6451, 1 CD-ROM.

Earthquakes Canada, GSC, Earthquake Search (On-line Bulletin), http://seismo.nrcan.gc.ca/stnsdata/nedb/bull_e.php, Nat. Res. Can.

Fader, G.B., King, L.H. and Josenhans, H.W., 1982. Surficial geology of the Laurentian Channel and the western Grand Banks of Newfoundland; Geological Survey of Canada, Paper 81-22; 37 pp.

Fader, G.B.J., Lynds, T., Miller, R.O., Parrott, D.R., Hynes, S., Sherin, A., 2004. Scotian Shelf regional surficial geology compilation; Geological Survey of Canada, Open File 4671; 1 CD-ROM.

Hacquebard, P.A., 1986. The Gulf of St. Lawrence Carboniferous Basin; the largest coalfield of Eastern Canada, CIM Bulletin, 79, No.891, pp.67–78.

Josenhans, H. and Lehman, S., 1999. Late glacial stratigraphy and history of the Gulf of St. Lawrence, Canada; Canadian Journal of Earth Sciences vol. 36, no. 8, pp 1327–1345 (GSC Cont.# 1998085).

King, E.L., 2008. The Banquereau Surf Clam Dredging Impact Study "10 Years After" and Seabed Photography of Laurentian Channel. Technical Report on the CCGS Hudson Cruise: 2008-015, First Leg; Dept. of Fisheries and Oceans (DFO) and Geological Survey of Canada–Atlantic, June 10–14. Geological Survey of Canada, Open File 5911, 1 CD-ROM.

King, E.L. and Huppertz, T.J., 2009. Early post-glacial mass failures in St. Ann's Basin on the Scotian Shelf, south of Cape Breton. Abstract and poster; Atlantic Geoscience Society Colloquium, Moncton, New Brunswick, February 6–7, 2009.

MacRae, J., 2004. Analysis and Description of Core 2003033 030pc Located in the Laurentian

Channel. Student COOP term unpublished report, January 15, 2004, 24 p.

NSIDC (National Snow and Ice Data Center), 1995. International Ice Patrol (IIP) iceberg sightings database. Boulder, Colorado USA: National Snow and Ice Data Center/World Data Center for Glaciology, digital media.

Sanford, B.V. and Grant, A.C., 1990. Bedrock geological mapping and basin studies in the Gulf of St. Lawrence. Geological Survey of Canada, Paper 90-1B, p 33–42.

Sonnichsen, G.V. and King, E.L., 2001. Surficial sediments, Grand Bank, Offshore Newfoundland, PERD/CHC Report 31-27; Unpublished Technical report to National Research Council of Canada, June 2001, 30 pp.

Sonnichsen, G.V. and King E.L., 2002. Grand Bank seabed and shallow sub-bottom geology in relation to subsea engineering design. Petroleum Resources and Reservoirs of the Grand Banks *In* R. Hiscott and A. Pullham (ed.) GAC Special paper 43.

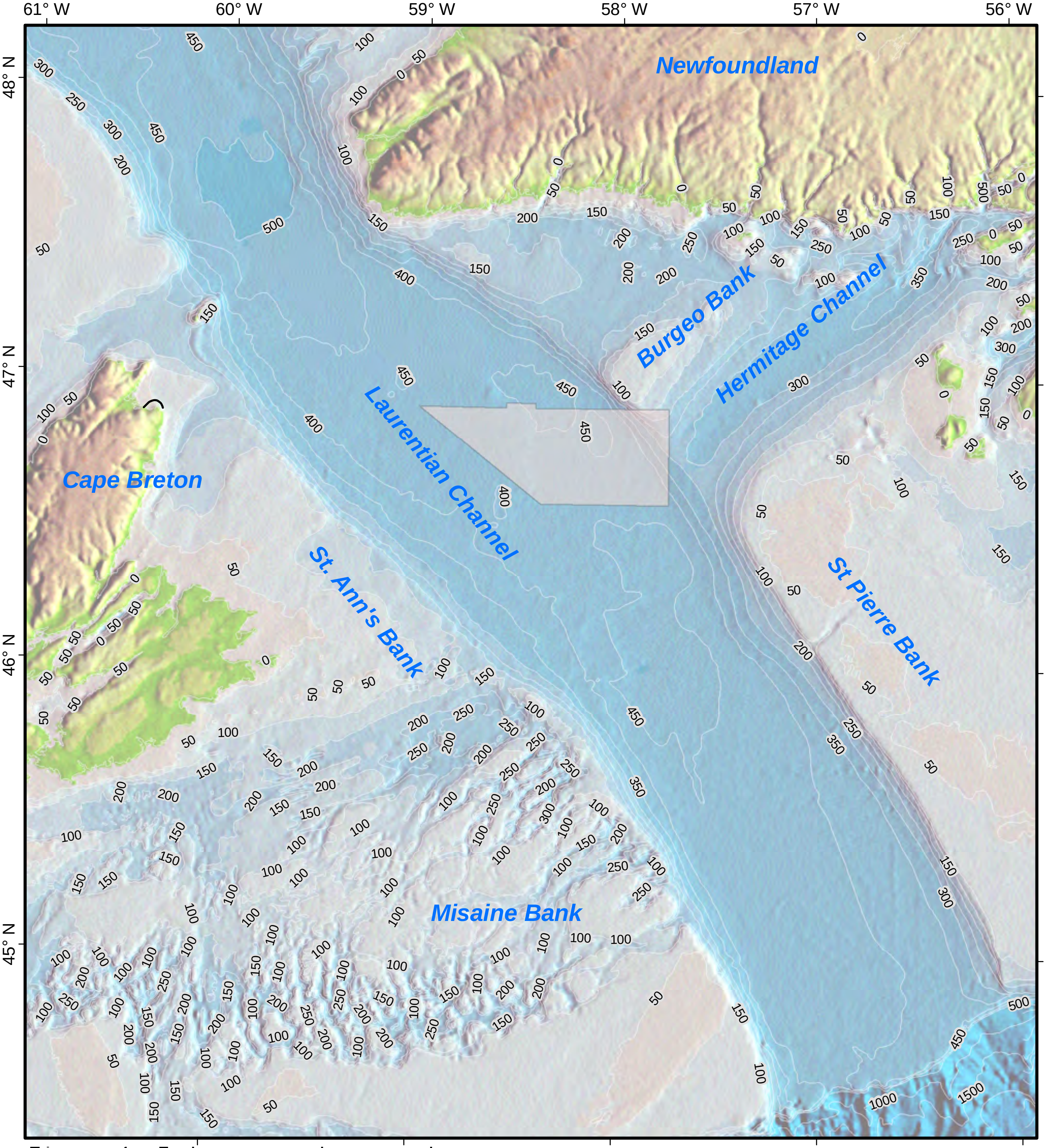


Figure 1. Index map and geography.

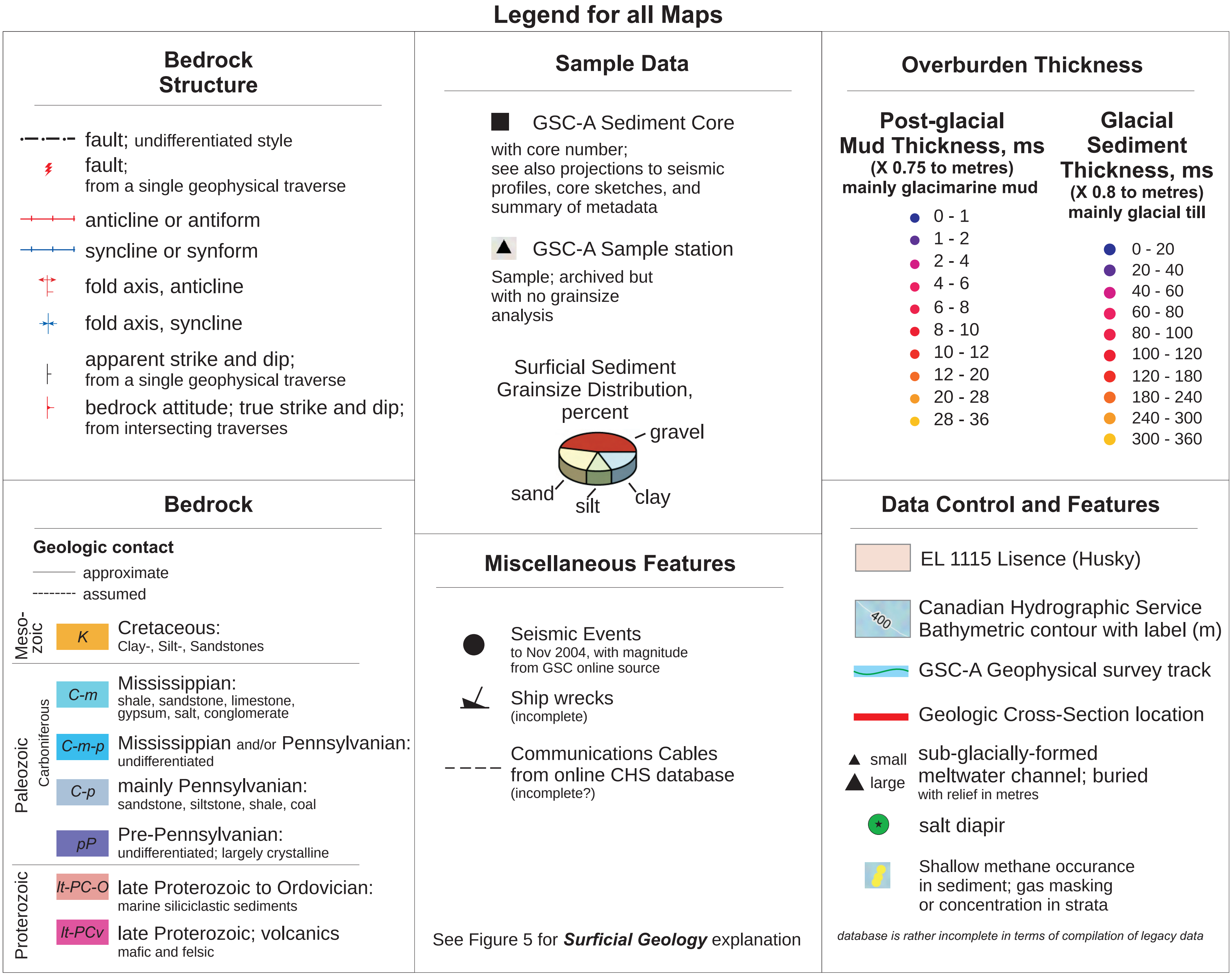
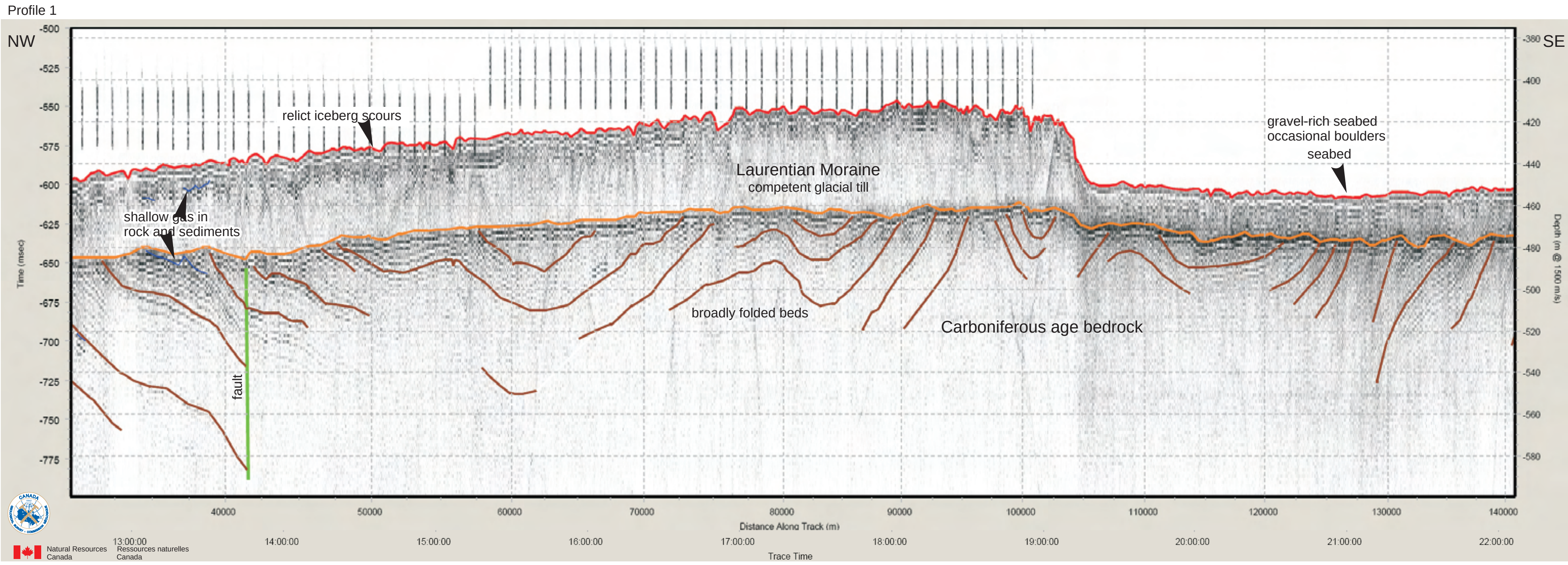
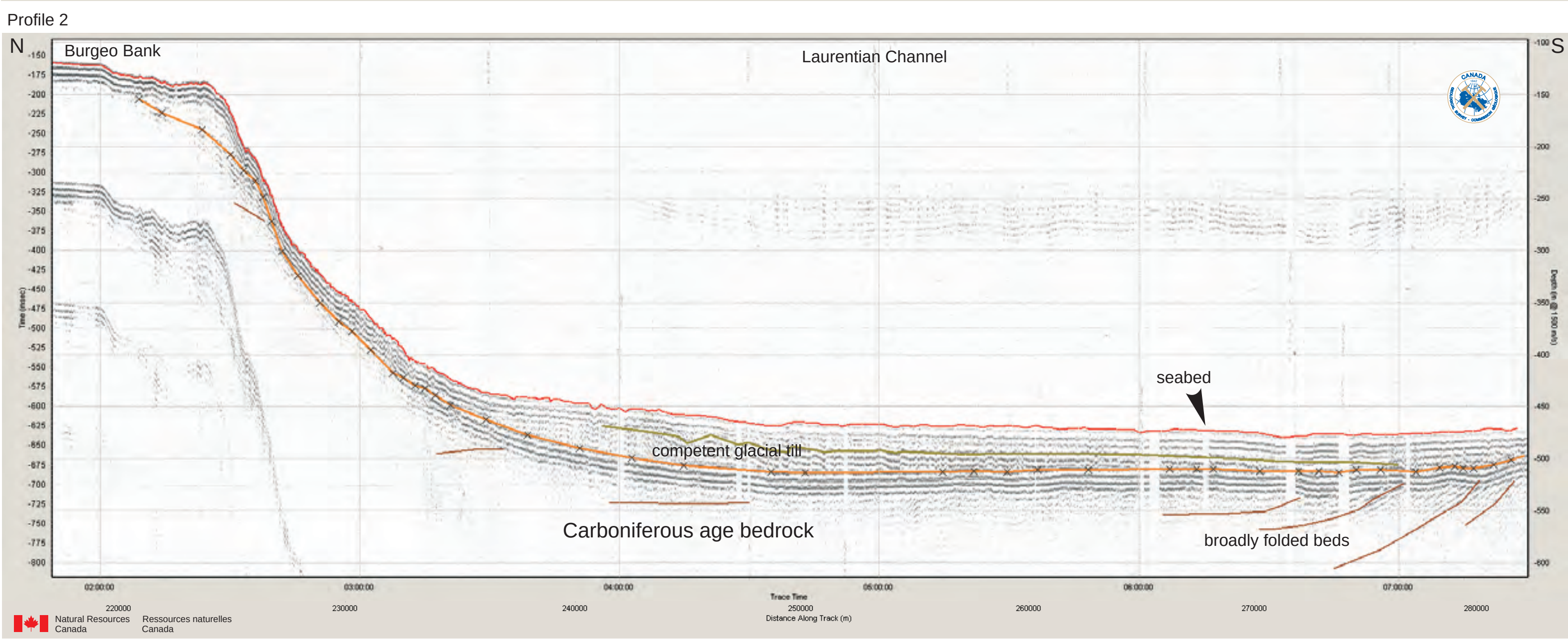
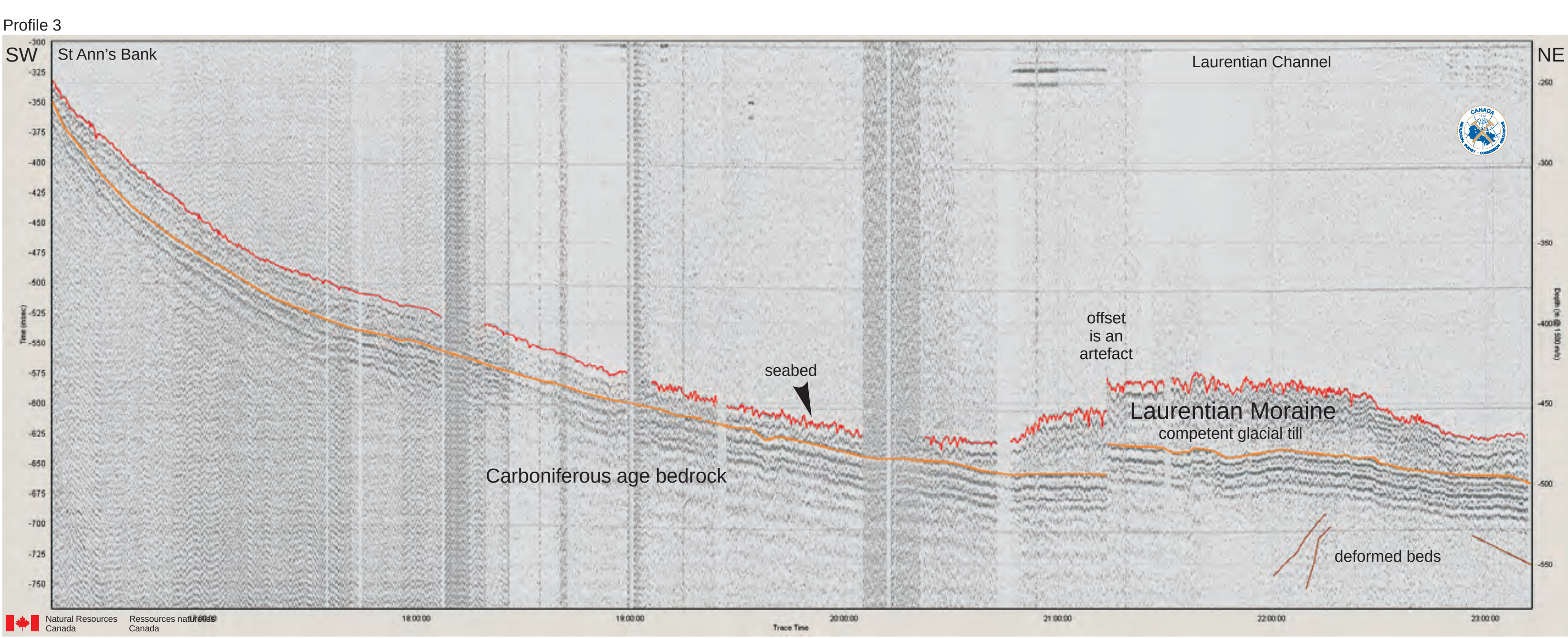
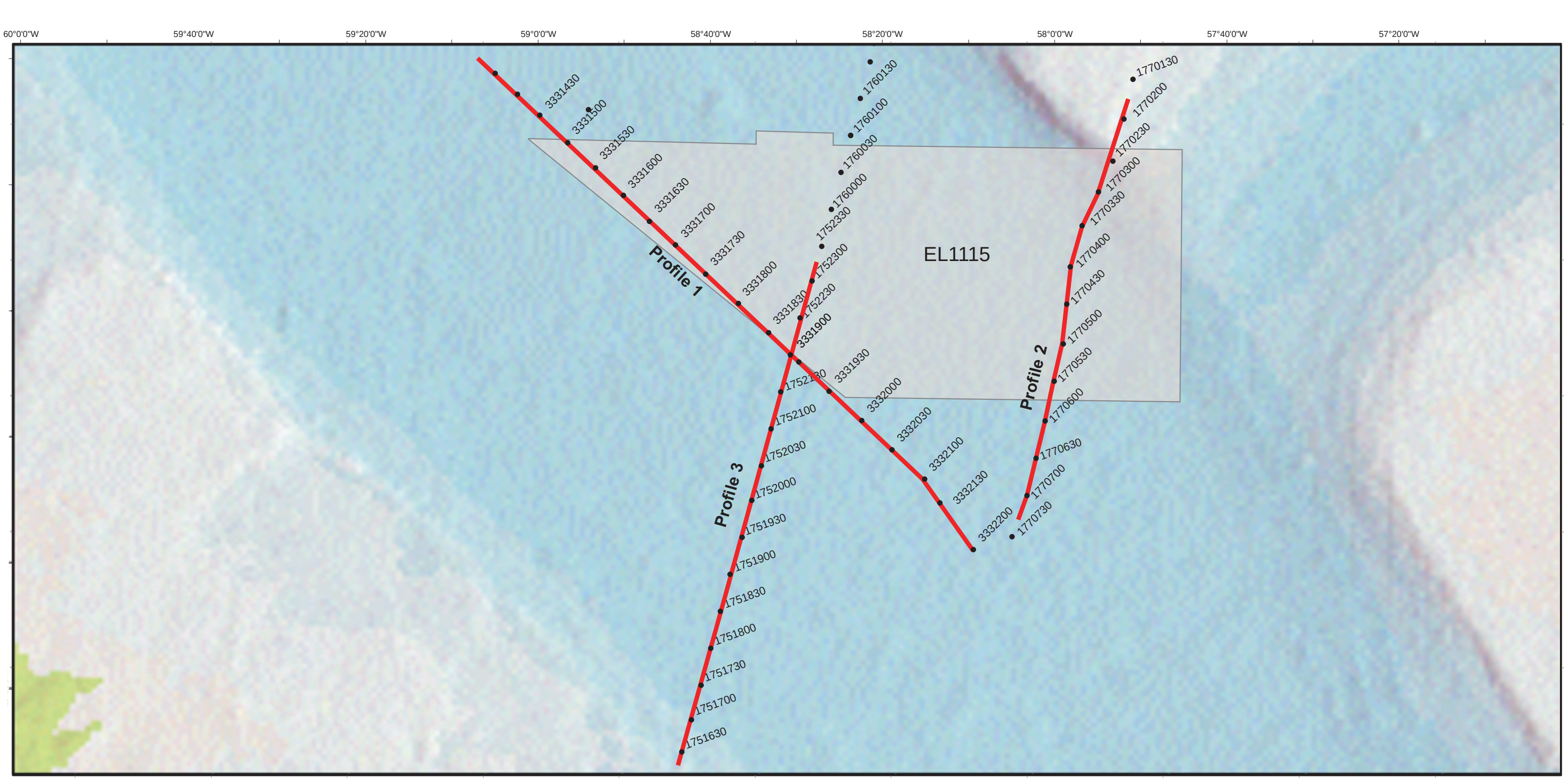


Figure 2. Legend for maps and features in this document.









Geologic sections in vicinity of Husky EL 1115 liscence

derived from small, high resolution seismic source

Geologic Cross sections from high resolution sleeve gun profiles which cross the EL 1115 site. The top panel (A) is from 1990 and higher resolution than the two lower (B and C), from 1972. All profiles depict a broadly folded Carboniferous age sedimentary rocks. These are time related rocks of a number of (coal-bearing) siliciclastic and evaporitic formations on Cape Breton Island. Locally faults are recognized, mostly with small throws. Also, shallow gas is locally present, likely coal-gas methane. A and C cross the thick till of the Laurentian Moraine, deposited ca. 14.3 ka, C-14 (Josenhans and Lehman, 1999) with a still-stand of the glacier during overall retreat from the mouth of the Channel. These profiles do not resolve the deglaciation-related glacimarine muds which generally overly the till. They may even be present across the entire moraine, but turbated by icebergs soon after deposition. However, accompanying illustrations and nearby cores show several metres thick muds. The seabed was heavily iceberg scoured across the moraine and south of it.

Josenhans and Lehman 1999. Late glacial stratigraphy and history of the Gulf of St. Lawrence, Canada. Can. J. Earth Sci. 36: 1327–1345.

Figure 3. Geologic Cross-Sections.

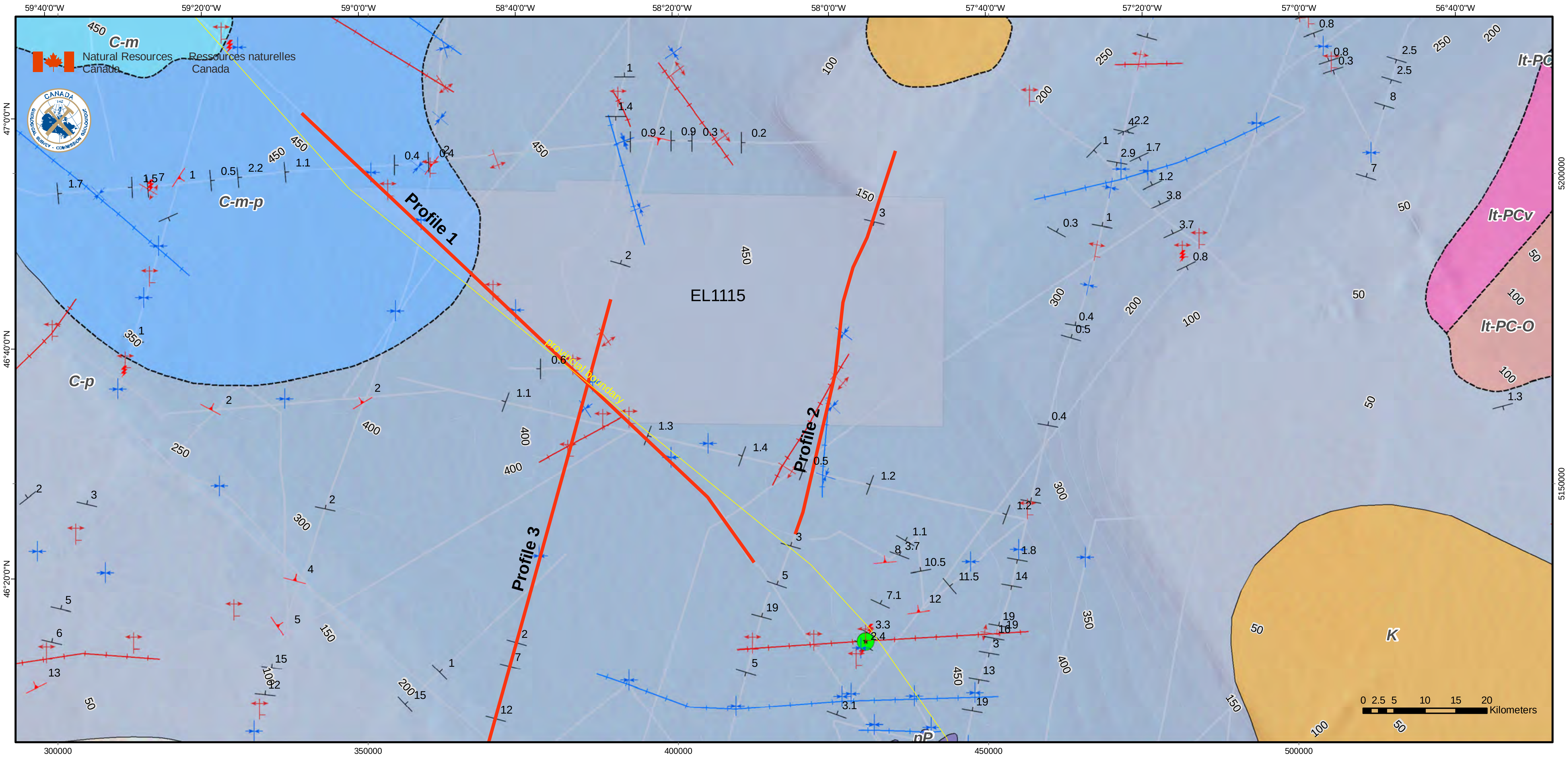


Figure 4. Bedrock sub-crop distribution and structural elements. Profiles in Fig. 3.

	Fader et al. 2004	Cameron & King 2010	Geologic Unit	Sediment Type and Geological Setting	Geotechnical Properties						
					Cone Resistance MPa	Friction Ratio R_f	Water Content %	Undrained Shear Strength kPa	Bulk Density %	Average effective cohesion kPa	Effective friction angle
Post-Glacial	LaHave Clay 9	PGm	Post-glacial mud	Acoustically weak stratification on seismic profiles. Generally with a smooth upper surface on a blanket deposit over glaciogenic sediments. Accumulations over 10 m locally. May be fluted locally, reflecting effect of currents. Shallow gas is commonly present or pockmarks on the seabed attest to former leakage of gas. Consists of soft latest glacial and Holocene age silt and clay derived from erosion and redistribution of marine glaciogenic deposits.				<10 typically <5	1.3-1.8		
Post-Glacial	Grand Banks Sand & Gravel 10	PGsg	Undifferentiated Sand and Gravel	Sand, shell hash, gravel, cobbles and boulders. Generally thin (<3-5m), variable distribution. Occurs in water depths less than 110m on banks, and considerably shallower towards southern NL coast.	<20	<1%	20				40-44
Post-Glacial	Adolphous Sand 8	present as surface modification but not mapped	Sublittoral Sand, minor gravel	Relict sub-littoral fine silty sand with gravel and shells. Locally better sorted where periodically activated			38-42 30-55	20	1.7-2.0 1.6-2.0		
Glacial	Emerald Silt 7	GMu	Glacial Marine Mud (Undifferentiated)	Acoustically stratified to non-stratified, draped across till and moraines. A silt-rich mud with significant sand and gravel component. Can be laminated or banded. An unconformable upper surface is common and generally has a thin (cm to dm) sand. Deposited by proglacial meltwater plumes in quiescent and open marine conditions. Locally heavily iceberg turbated making acoustic distinction from underlying till unclear; hence some discrepancy between maps. This remoulding likely changes the strength properties.			20-40 38-65 42	10-90 10-35 15	1.8-2.1 1.6-1.8 1.8		
Glacial	Grand Banks Drift 6	GTu	Undifferentiated Till	Silty, sandy clay matrix with gravel, cobbles and boulders. Occurs as blanket or ground moraine and terminal moraines. Rough, glacially sculpted and iceberg-scoured upper surface. Generally thin sand or mud-covered (<15m) on banks; locally thick (>100m) in Laurentian and Hermitage Channels but 10 to 50 m in the El1115 site. Overlies bedrock in most areas.			11.5 16-45 35-40 30-41 19-22	515 515 350-450 200-500 50-300+ 25-35 20-65 108-170	1.94-2.19 1.8-2.0 1.85-2.0 2.1-2.25	25-35	35-43 39-46 32-40

Figure 5. Selected stratigraphic map units of the Quaternary (overburden) across map area. Two map unid designations (colours) are presented because the newer map does not extend north into the wellsite area. Some discrepancies exist, mainly due to improved technology, data coverage, and author emphasis (surficial texture versus stratigraphic unit with post-depositional surface modification. Physical properties are mainly from Sonnichsen and King (2001), derived from short cores and boreholes and CPT measurments from areas of the Grand Banks outside the Laurentian Channel region but correlated through seismostratigraphic similarities. Multiple sediment properties values represent different locations across the banks. As they are not direct map area measurements, values should be viewed with caution.

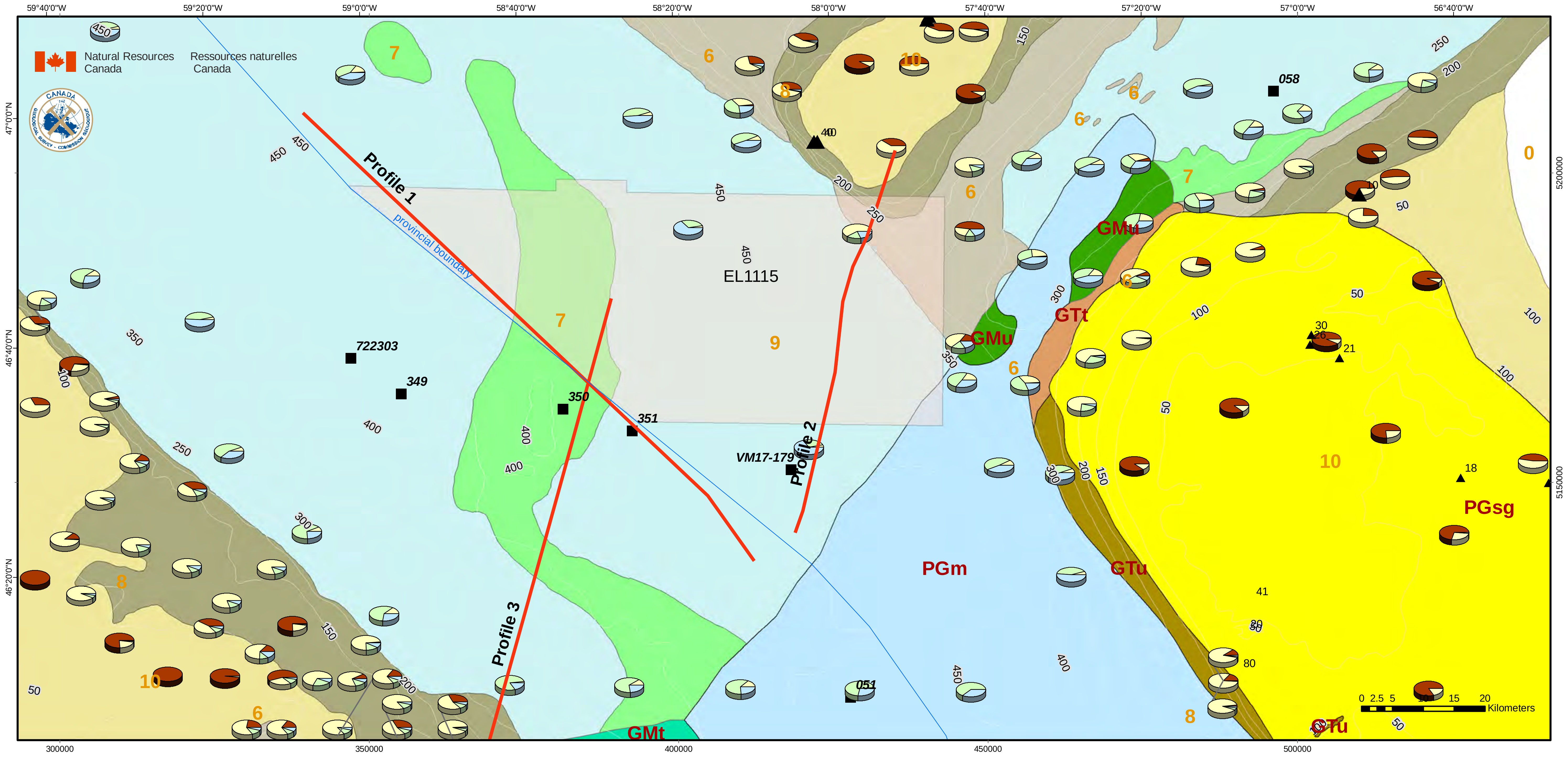


Figure 6. Surficial Geology Distribution with grainsize and core locations.

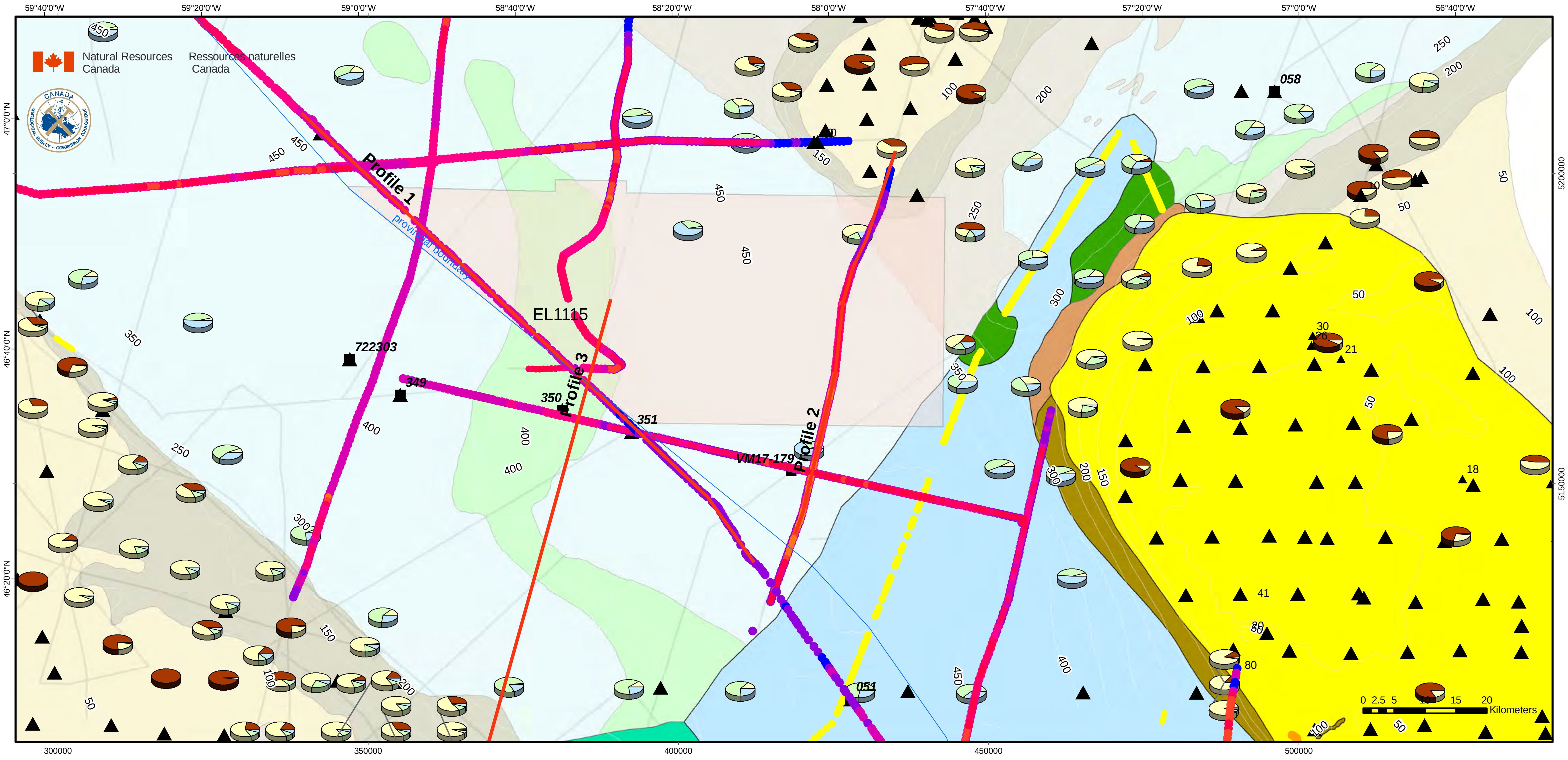


Figure 7. Elements of Quaternary overburden.

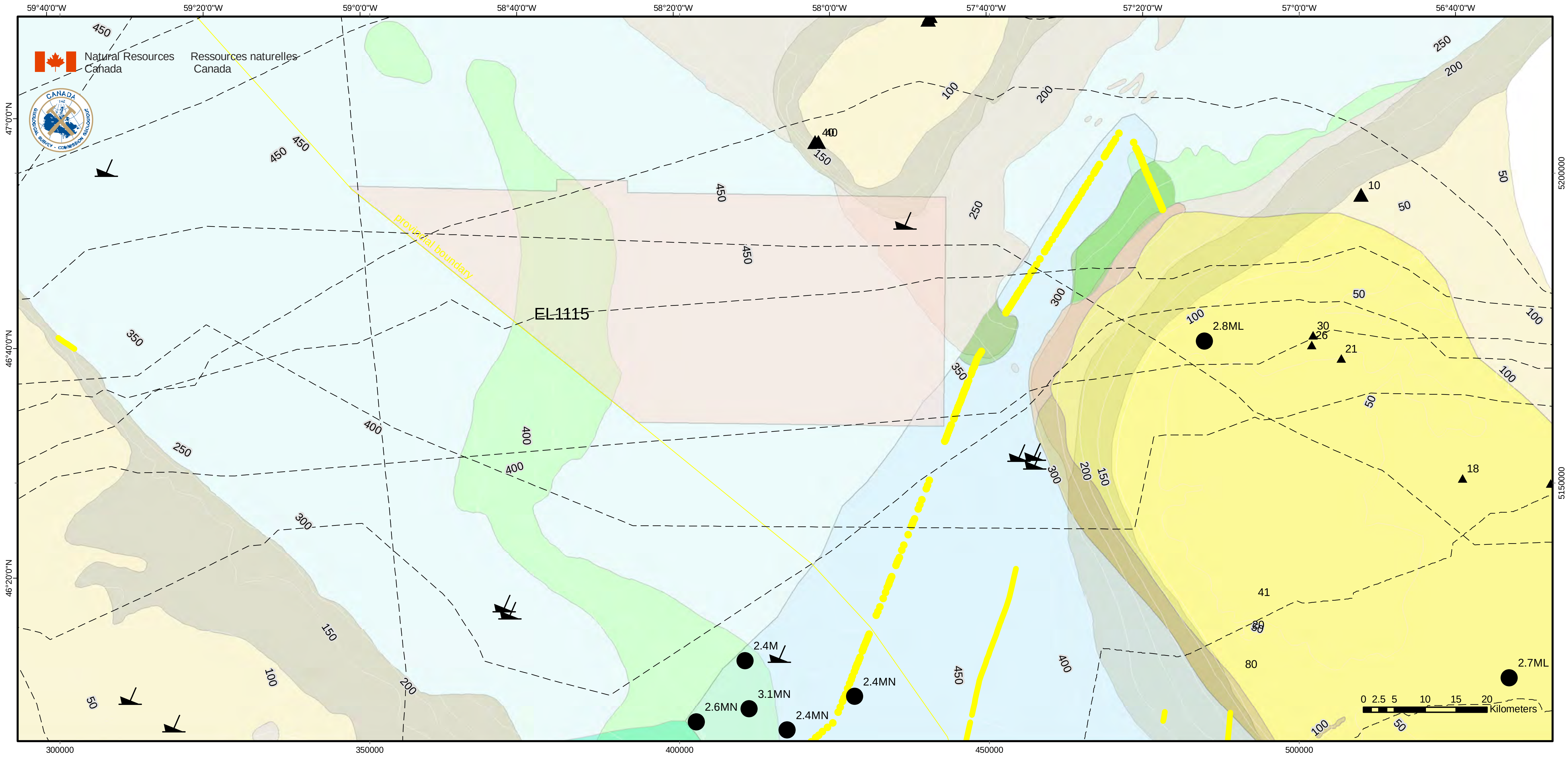


Figure 8. Potential features of engineering concern. (not intended as an exaustive cataloguing)

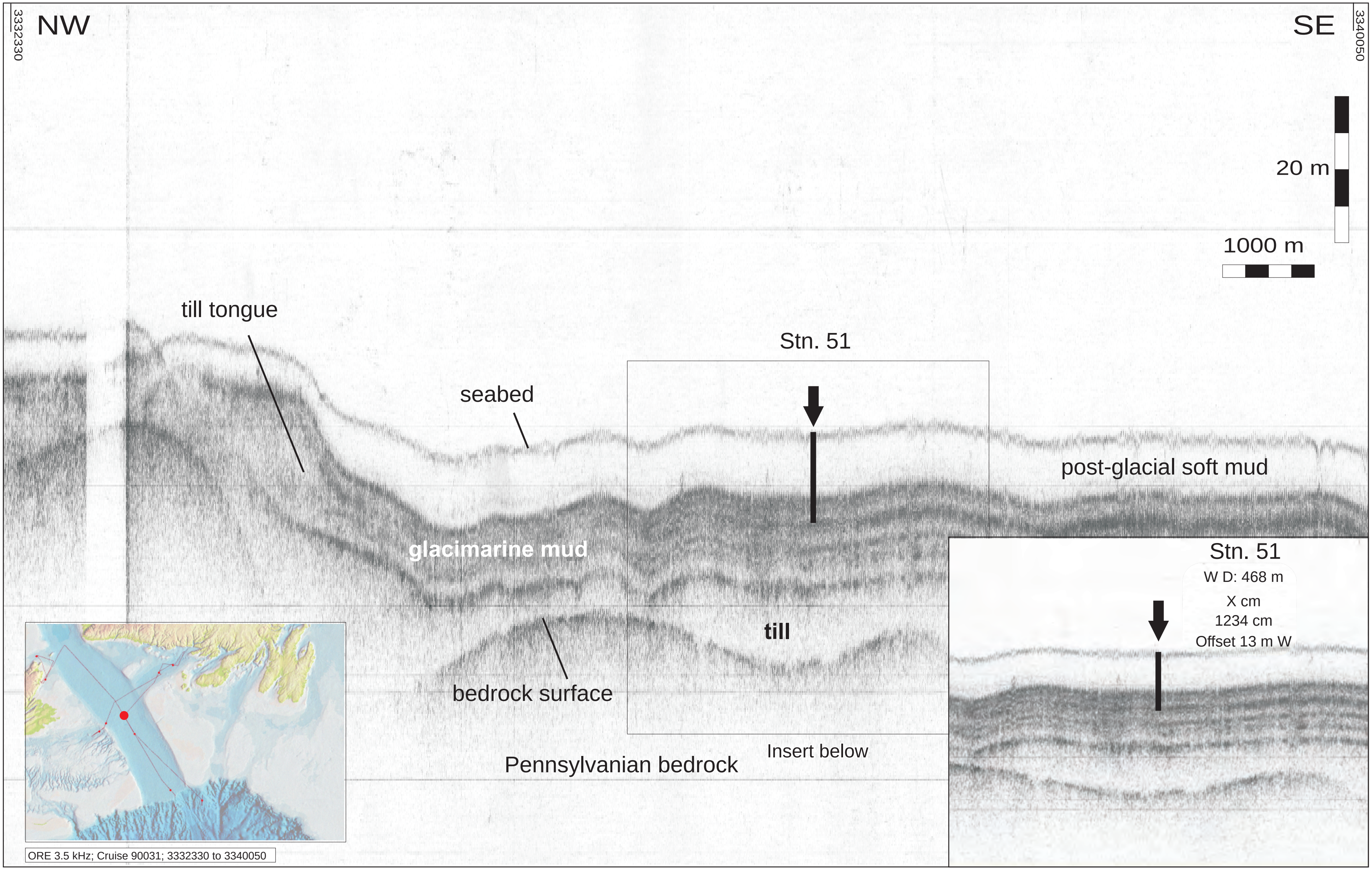


Figure 9. Expedition 90031; 3.5 kHz sounder profile from western Laurentian Channel with superimposed piston core 90031-051.

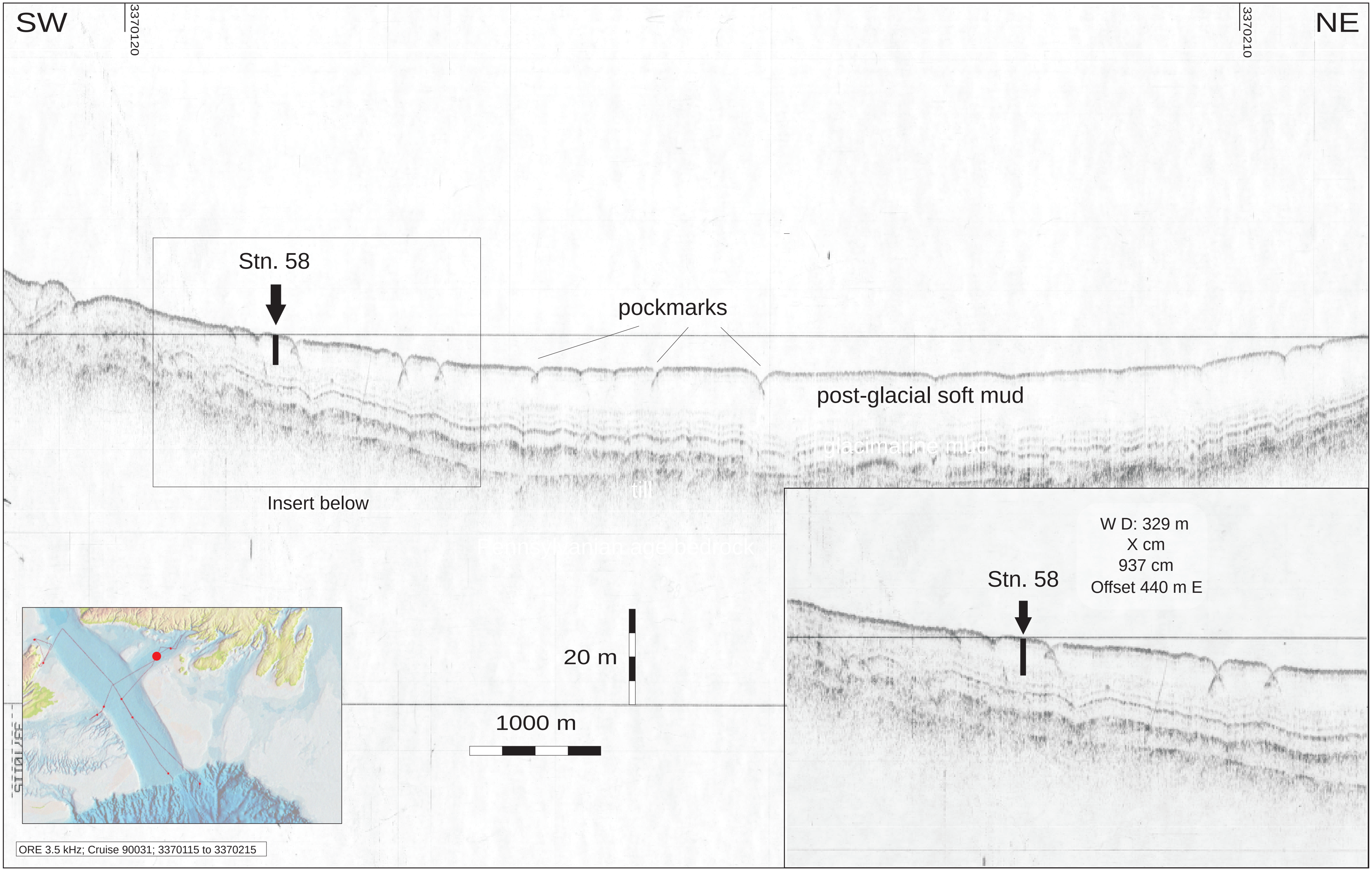


Figure 10. 90031 3.5 kHz from Hermitage Channel with superimposed site of Core 90-031-058. It penetrates only into soft surficial Holocene age mud (with pockmarks).

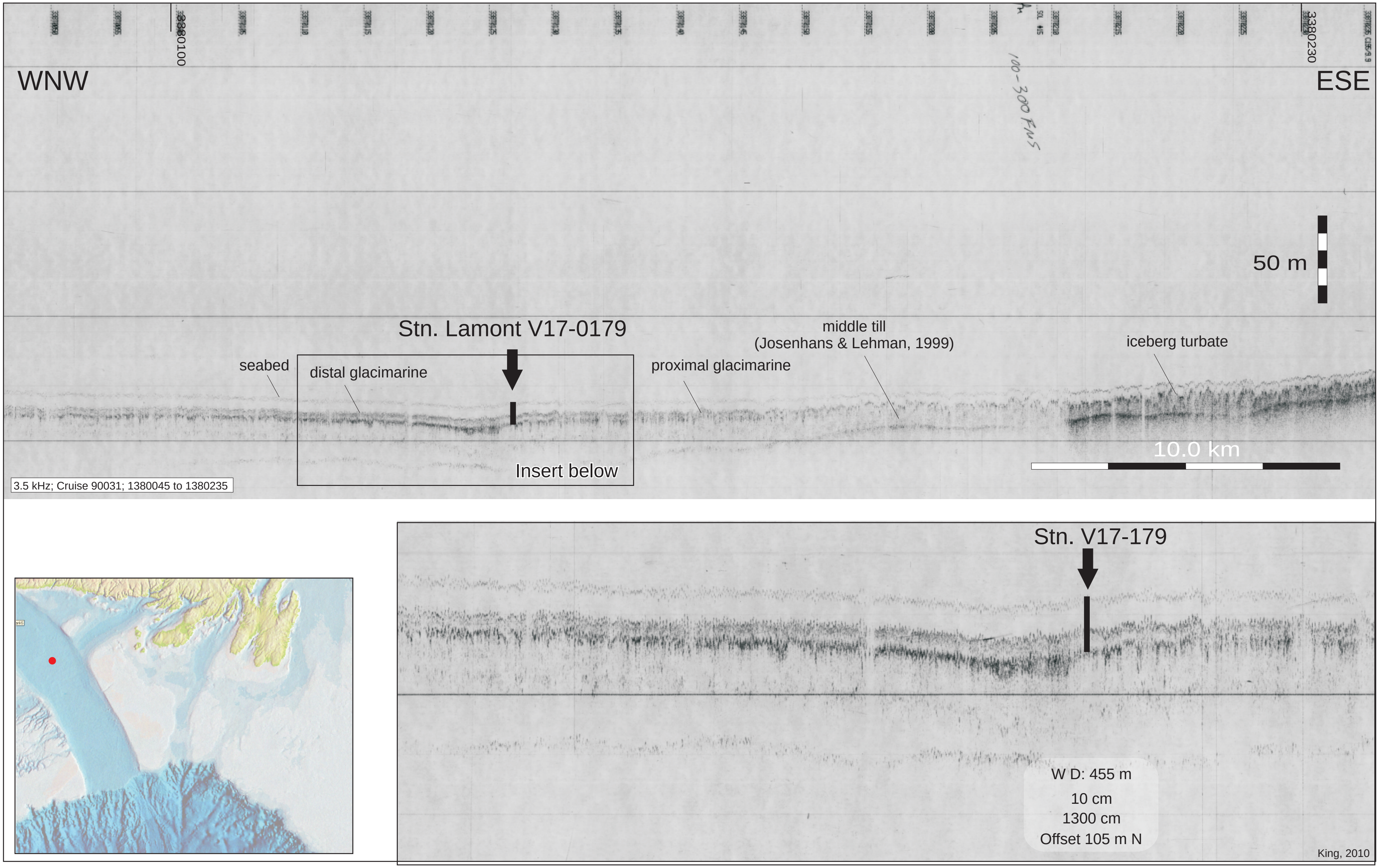


Figure 11. Expedition 90030; 3.5 kHz sounder profile with superimposed Lamont core. See accompanying core description and analysis, including C-14 dating.

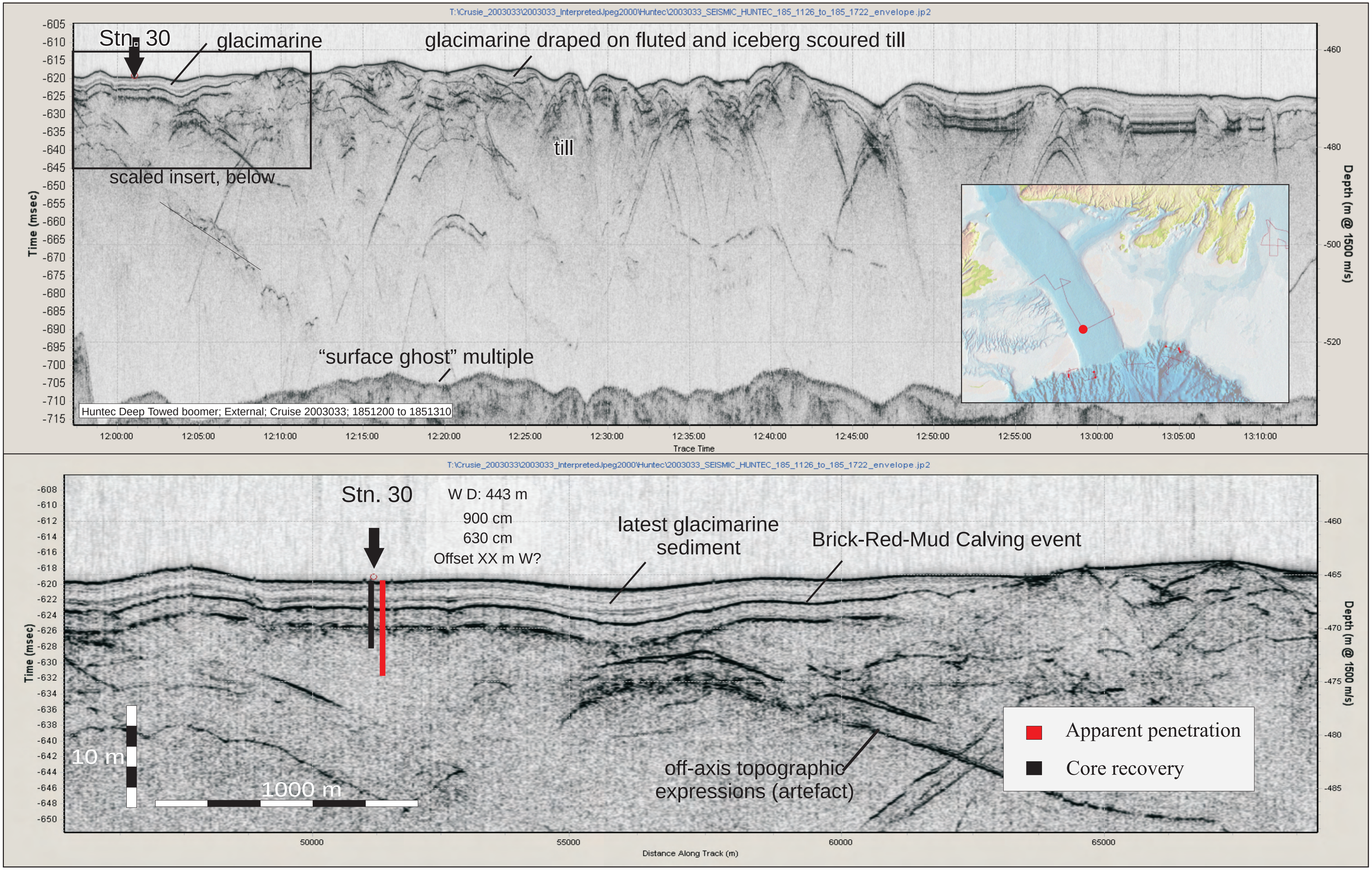


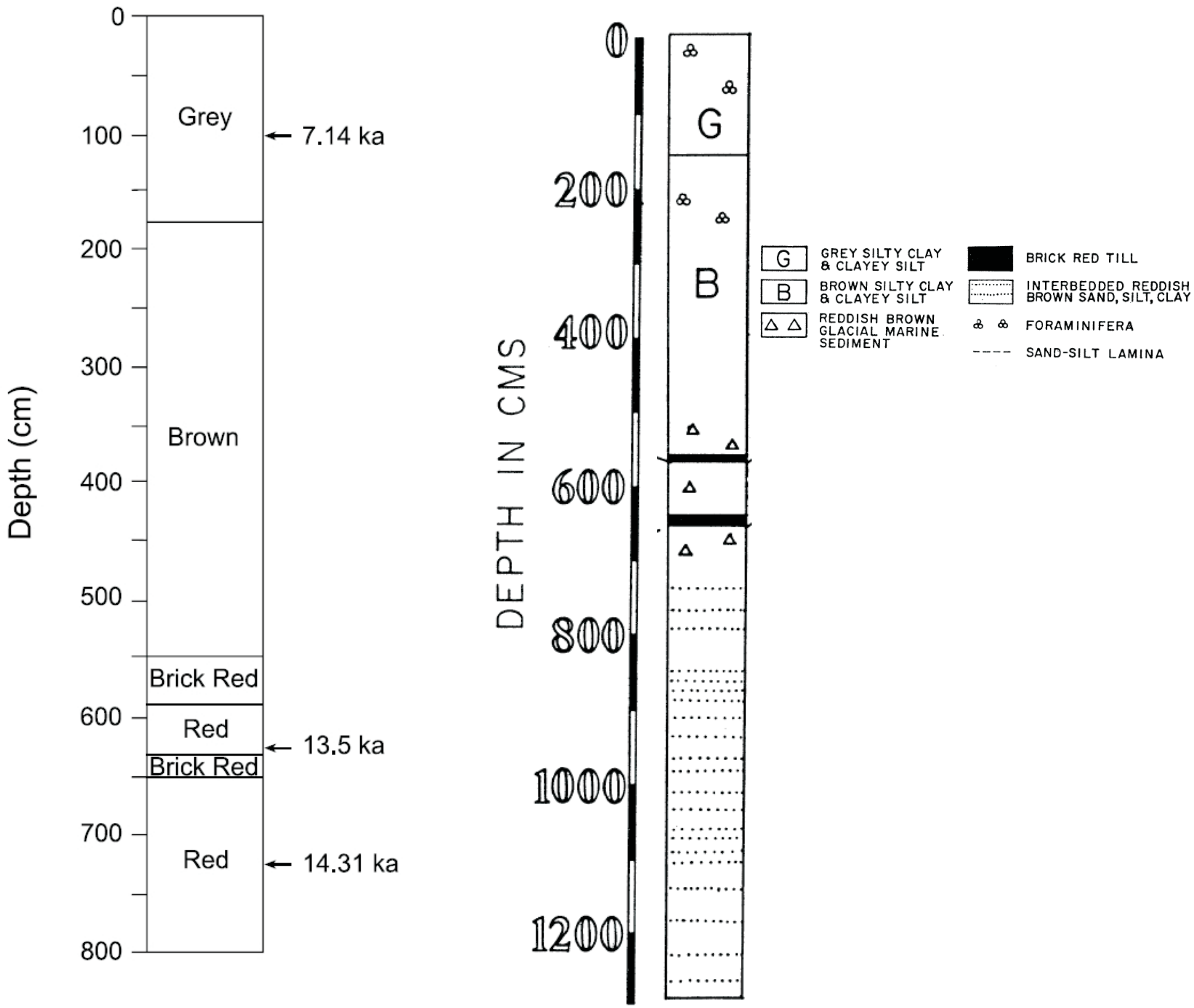
Figure 12. Expedition 2003033 Huntec boomer profile across Station 30. This core penetrated the glacimarine section and into the till. This contact is depicted the core physical properties plots as is the strong reflector which coincides with a thin brick-red mud in the core.

Table 1: GSC-A core sample metadata

EXPEDITION	STATION NUMBER	OLD STATION NUMBER	STATION TYPE	JULIAN DAY	LATITUDE	LONGITUDE	WATER DEPTH, M	COMMENTS	CORE LENGTH, CM	ANALYSIS
90031	3336	58	Piston AGC Large	337	47.072830	-57.051170	329.00	No Comment; many (106) micropaleontology samples taken; no info on status	1060	Micropaleontology
90031	4133	51	Piston AGC Large	336	46.187000	-57.935670	468.00	C -> D LINER BROKEN AT ABOUT 30 CM. E -> F LINER SHATTERED 0 - 10 CM. C -> C IN CORE CAP. CATCHER IN BAG; many (133) micropaleontology samples taken; no info on status; 3 age subsamples	1234	Micropaleontology
73006	7783	351	Piston Benthos	195	46.570000	-58.403330	454.00	CLAY IN FRONT OF MORAINE. LIGHT REDDISH GREY.	914	
73006	1078	350	Piston Benthos	195	46.600000	-58.550000	420.00	ON TOP OF MORAINE.	457	
72019	6861	722303	Gravity Gravity	178	46.666670	-59.000000	417.00	No Comment; no recovery	0	
73006	7780	349	Piston Benthos	195	46.616670	-58.891670	400.00	GREY CLAY OVERLYING AN ASSUMED MORAINE (CORE STOPPED BY TILL). GREY CLAY ON CORE CATCHER AND OUTER BARREL.; 11 micropalentology analysis and 6 grainsize in upper 3 m in ED	610	
Lamont" VEMA" 1961 cruise	0179	VM17-179	Piston	0	0.000000	0.000000	0.00	includes upper and lower brick red mud constrained by c-14 dates (Josenhans and Lehman 1999)	1300	grainsize; mineralogy; rock frag ;O isotope; C-14
2003033	0030	None	Piston AGC Large	185	45.212606	-57.216480	442.60	core length 708 cm: ED shows many index analyses; PC cutter/catcher = 24cm	708	

Figure 13

Lamont V17-079 PC

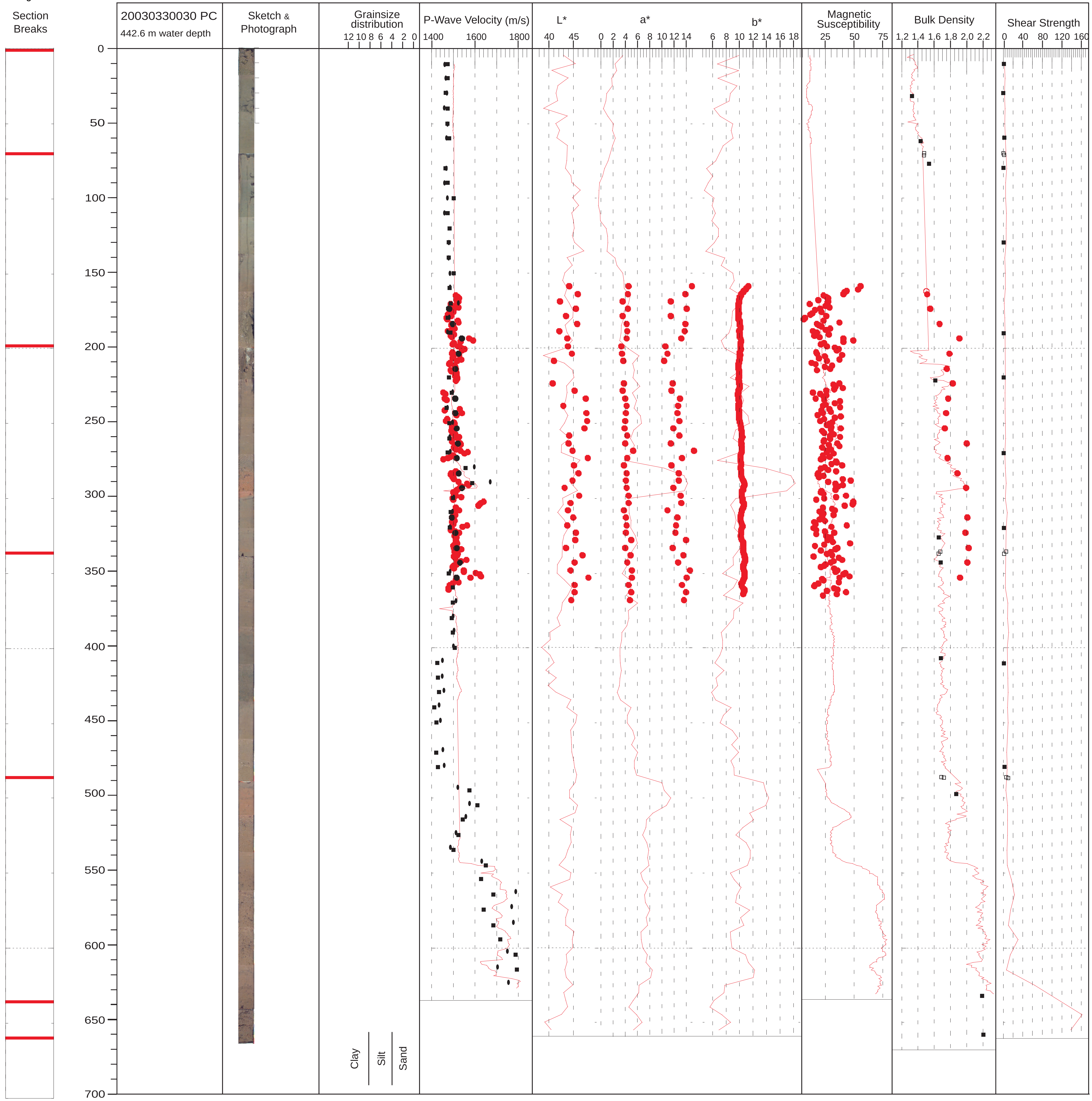


Core V17-179, reported in two publications: First (right) Conolly and Heezen (1967). Secondly (left) Josenhans & Lehman (1999) but this display is slightly modified.

J. R. Conolly, H. D. Needham and Bruce C. Heezen. 1967: Late Pleistocene and Holocene Sedimentation in the Laurentian Channel. The Journal of Geology, Vol. 75, No. 2 (Mar., 1967), pp. 131-147.

H. Josenhans & S. Lehman 1999: Late glacial stratigraphy and history of the Gulf of St. Lawrence, Canada Can. J. Earth Sci. Vol. 36, 1327-1345.

Figure 14


Section Breaks
20030330030 PC
442.6 m water depth
Sketch & Photograph
Grainsize distribution
12 10 8 6 4 2 0
Clay
Silt
Sand
P-Wave Velocity (m/s)
1400 1600 1800
L*
40 45
a*
0 2 4 6 8 10 12 14
b*
6 8 10 12 14 16 18
Magnetic Susceptibility
25 50 75
Bulk Density
1.2 1.4 1.6 1.8 2.0 2.2
Shear Strength
0 40 80 120 160
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700