Miscellaneous Release—Data 128 – Revised

Surficial Geology of Southern Ontario

Project Summary and Technical Document

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Abstract

In response to the demand for readily accessible and easily understood information on the surficial sediments of southern Ontario, the Ontario Geological Survey (OGS) has undertaken an initiative to generate a GIS-based, seamless map of the Quaternary geology for the region.

Over the past 40 years the OGS and Geological Survey of Canada (GSC) have completed Quaternary mapping, primarily at a scale of 1:50 000, for most of southern Ontario. A total of 125 maps, 36 of which belong to the GSC, were used to create the seamless coverage. These original, tiled maps existed as either digital vector or raster format. The raster images were rubber sheeted to a geographic base and digitized (heads up) according to standards established for the project. Polygonal, point and line information were captured as part of the automation process. Coverages created include geology polygons (sgu_poly), point information (sgu_point), line information (sgu_line), hummocky topography and moraines (sgu_mor), miscellaneous areas such as dunes (sgu_misc), pits and quarries (ogs_pits) and geological annotation (sgu_anno). Attribute tables were built and populated with various geological related information.

The original maps contained legends of varying detail and terminology; therefore, a single, standard legend suitable for a 1:50 000 compilation was constructed. This legend, created using Microsoft® Access® software, was used to translate all original map units to the new standard legend. Each of the map attribute tables was joined to the translation table using a unique key. A series of additional attributes, for instance, primary material and genesis were extracted from each map sheet and included in this table. By capturing these attributes a variety of derivative maps can be produced. For instance, for aggregate resource assessment studies a map of gravel resources can be derived from the primary material attribute.

Once all attribute tables were standardized and the translation table completed, coverages were appended together to create a tiled coverage for all of southern Ontario. Misaligned contacts (boundary faults) were found to exist between individual map tiles for most polygons that cross map boundaries. These discrepancies were corrected through field investigations, examination of other geoscience data sets (e.g., aggregate resource papers) and utilization of a digital elevation model (DEM), produced by the Ontario Ministry of Natural Resources (MNR) and its derivatives.

At present, the map is seamless on 4 attributes: geology, primary material, genesis and formation. Coverages are available on DVD for a fee, but may be downloaded free of charge from the GeologyOntario Web site.

The following notes provide the user with background on the Quaternary geology of southern Ontario as well as an overview of the process utilized in the project.

Introduction

Over the past 40 years the OGS and Geological Survey of Canada (GSC) have completed Quaternary mapping, primarily at a scale of 1:50 000, for most of southern Ontario. This mapping provides a wealth of information concerning the surficial materials that cover the landscape. Over the years users of these maps have been many and the uses varied. However, with increased usage of digital mapping software and demand from clients for readily accessible, user-friendly, surficial geology maps, the existing map tiles were found to have many limitations for use in an electronic world. Therefore, it was decided to convert all existing Quaternary geology maps covering southern Ontario into a seamless, attributed GIS-based map that would provide users with a flexible, easily used and understood product. The following notes outline the procedures and processes used and also provide guidelines for users of the map products.

General Quaternary Geology of Southern Ontario

The surficial deposits and landscape of southern Ontario are often related to the last glaciation, the Wisconsin Stage, which started about 115 000 years before present (BP). Although multiple glacial and interglacial stages have likely occurred during the Quaternary period (e.g., Shackleton and Opdyke 1973; Shackleton and Pisias 1985), pre-Wisconsin records are rarely preserved and, as a result, little is known about these earlier events for southern Ontario. Records of the last interglacial stage, the Sangamon Stage, have been discovered at Toronto and Woodbridge, in southern Ontario (Coleman 1894; Subcommission on North American Quaternary Stratigraphy 1993; Karrow et al. 2001). Fossils recovered from these deposits indicate a climatic condition similar to or slightly warmer than that of present day in Ontario. The Sangamon deposits are frequently underlain by till from the penultimate glaciation, the Illinois Stage (Subcommission on North American Quaternary Stratigraphy 1993).

During the Wisconsin Stage glacial advance was extensive and, at its maximum (about 20 000 to 18 000 year BP), Ontario was completely covered by the Laurentide Ice Sheet. During retreat of the ice sheet, ice lobes developed in the Great Lakes Basins and acted in response to local conditions or regional climate or both (Barnett 1992). The present landforms, as well as the associated surficial deposits that are found across southern Ontario are, to a large extent, the result of late Wisconsin glacial events (Chapman and Putnam 1984). Consequently, tills and other sediments such as glaciofluvial sand and gravel, glaciolacustrine and glaciomarine silts and clays are widespread, and glacial landforms including moraines, drumlins and eskers are commonly encountered in the field. Many of the glacially derived sediments and landforms have been modified to varying extents by postglacial geological process, i.e. erosion, slumping, etc.

The stratigraphy for the late Quaternary period in the Great Lakes Region is listed in Table 1. Please note that the recently proposed diachronic stratigraphy classification for the eastern and northern Great Lakes region is adopted in this project.

Table 1. Stratigraphy for the eastern and northern Great Lakes region *

Oxygen Isotope stage	Age (ka)	Chronostratigraphy		Diachronic Stratigraphy			^{14}C Age (ka)**
		Stage	Substage	Episode	Subepisode	Phase	
1		Holocene		Hudson			
----------10----------							
						Port Huron**	---13
						Mackinaw	---13.4
2			Late Wisconsin		Michigan	Port Bruce	---14.8
						Erie	---15.5
		Wisconsin		Wisconsin		Nissouri	---20
----------30----------							
						Farmdale	
3			Middle Wisconsin		Elgin	Brimley	
						Port Talbot	
----------60----------							
4						Guidwood	
			Early		Ontario	Willowvale	
5a -d			Wisconsin			Greenwood	
----------115----------							
5e		Sangamon		Sangamon			
----------135----------							
6		Illinois		Illinois			
----------190----------							

* Oxygen Isotope stages after Shackleton and Pisias (1985); Chronostratigraphy and diachronic stratigraphy are modified from Dreimanis and Karrow (1972) and Karrow et al. (2001); ^{14}C ages are adopted from Barnett (1992).
** The listed ages indicate the average or approximate date for the related phase. Because of the time-transgressive nature, the chrono-boundaries for a Phase change at various sites during the advance or retreat of glaciers. Interested users are advised to refer to Karrow et al. (2001) for details.
***More events or diachronic units after the Port Huron Phase have been defined but not listed in the table. Readers can find them outlined in Appendix D.

The above notes provide only a brief introduction to the surficial geology of southern Ontario. For a comprehensive review it is recommended that interested users refer to Barnett (1992). Additional detailed geological information for specific areas can be found in the reports that accompany some of the original surficial geology maps listed in Appendix A.

Data Sources

Quaternary/surficial geology maps

The seamless map was compiled from published OGS and GSC Quaternary/surficial geology maps at a scale of 1:50 000 or 1:63 360 (*see* Appendix A). Unpublished OGS and GSC maps for Owen Sound, at a scale of 1:50 000, and Toronto, at a scale of 1:50 000, were also included in the compilation.

In addition, a few smaller scale surficial geology maps were used in the compilation. These maps include GSC Map 7-1972 for Tichborne and GSC Map 8-1972 for, Kaladar, Mazinaw Lake and Bannockburn originally mapped at a scale of 1:125 000. (Appendix A).

Other data sources

Field investigations

Fieldwork was undertaken in 2001 and 2002 to collect data used in rectifying boundary fault and other problems. Data was collected from more than 1000 field stations and incorporated in the map compilation (Bajc et al. 2001; Gao et al. 2002).

Bedrock geology maps

On some of the original surficial geology maps covering areas where both Paleozoic and Precambrian bedrock exists no differentiation was made between the bedrock units. Therefore, OGS bedrock geology maps at various scales were used to delineate the Precambrian–Paleozoic boundaries. Areas where this was completed include Brockville–Mallorytown, Ganagoque–Wolfe Island, Westport and Perth areas, and the southern part of the Minden area.

Aerial photo interpretation

Aerial photographs covering southern Ontario are available through the Ontario Ministry of Natural Resources. Air photo interpretation was undertaken in some areas to assist in rectifying boundary fault and other map problems.

Aggregate resources inventory papers (ARIPs)

The OGS produces aggregate resources inventory papers (ARIPs) and maps for Ontario. Most of southern Ontario has ARIP coverage, and data from the reports and maps was utilized in the seamless compilation. Data from a number of in-progress ARIPs, including Renfrew County and the Regional Municipality of York, were also utilized.

Digital elevation models (DEMs)

Digital Elevation Models (DEMs) used in the project were generated and provided by the Ontario Ministry of Natural Resources, Geomatics Service Centre.

Water well data

Water well data was provided in digital database format (Microsoft® Access®) by the Ontario Ministry of the Environment.

Soil survey maps

Soil survey reports and maps used in the project were obtained from the Ontario Institute of Pedology, the Ontario Ministry of Agriculture and Food and Agriculture Canada.

Personal communications

Personal communications with P.J. Barnett, R.I. Kelly and C.L. Baker of the OGS provided information on unpublished maps of the OGS.

Process

Section A (Phase I and II)

Phase I – Summary: Processing Individual Maps

The first phase of this project, as set out in the initial work plan, was completed in March 2002. The software used to create the seamless Quaternary coverage in a GIS-structured format was ArcMap® 8.1 and ArcInfo® Workstation. A total of 125 maps, 36 of which belong to the GSC, were used to create the seamless coverage. These original, tiled maps existed as either digital vector or raster format. The raster images were rubber sheeted to a geographic base, and maps that required vectorization were digitized (heads up) by a contractor according to the project standards. All existing vector maps were brought in line with the RFT (Request for Tender) standards used by the above contractor via the Geomatics Service Centre in Peterborough. Once all data was delivered to the Ontario Geological Survey, the following tasks were completed:

- All required edits of attributed vector data from original maps
- Standardization of attribute tables
- Quality control/assurance. All data received from contractors were reviewed to ensure standards set for the project were met.
- All coverages were clipped to new neatline which had been created by staff of the Geomatics Service Centre, to ensure smooth migration of tiled sheets to single appended Ontario coverage
- Completion of a geological symbols library in ArcMap® 8.1
- Creation of an appended coverage for southern Ontario joined to a common legend maintaining a tiled structure for each individual map.

Task 1 – Original Map Edits

ArcInfo® coverages were created for all Quaternary maps covering southern Ontario. All efforts were made to ensure that each digital map created represented the original authors' hard copy map. That is to say, the digital maps are identical to the original map. Completed vector edits included accurate digitization, addition of missing features, proper attribution of features and polygons as well as correctness in feature location. All polygon coverages were clipped to the new provincial NTS-tile neatline created by staff of the Geomatics Service Center. These coverages included sgu_poly, sgu_mor and sgu_misc. This work was completed using ArcInfo/Arcedit command line as well as automated procedures for batch processing using AML. The "build nodups" command was used in most cases to create topology. All line work therefore was closed or snapped properly. Dangles and overshoots were not allowed. In the rare case where the clean command had to be used, a tolerance of 0.001 was used. It is important to note that it was decided to code all geological contacts as approximate (geolap-o). All map neatlines have been coded "nln" and any large areas possessing no data, such as areas where large water bodies exist, have been coded "wat". The coordinate system description for all tiled maps is as follows :

Projection : Universal Transverse Mercator:
Zone : 17 and 18
Units: metres
Geodetic Model:
Datum : North American Datum of 1983 cnt
Spheroid : Geodetic Reference System 80

Task 2 – Standardization of Attribute Tables

An important component required for the completion of the first phase of this project was the standardization of attribute tables for each coverage. Data for each map was captured in

ArcInfo® coverages as points, lines, annotation and polygons. All tables must be identical to facilitate the appending or mapjoining process required for the creation of one single coverage for all of southern Ontario. This process was required for each of the 7 coverages defined for this project. These coverages include sgu_poly (pat, aat), sgu_point, sgu_line, sgu_mor, sgu_misc, ogs_pits and sgu_anno. All table information must be identical. Features must exist and item definitions for feature attribute tables must be identical in all joined coverages (i.e., coverage names, column headings, data types, item widths). Batch processing ArcInfo® macro language (AML) scripts were written to standardize tables that were not created properly by the contractor. It was decided to add the column "map_num" to sgu_point, sgu_line, sgu_mor, sgu_misc and ogs_pits to enhance querying capabilities. Since this change was applied to 5 coverages multiplied by 125 tiles, an AML script was written to update all coverages as a batch in ArcInfo®.

Task 3 – Append each coverage to a single provincial coverage

This procedure was completed using the ArcInfo® commands mapjoin and append. As stated above, features must exist and item definitions for feature attribute tables must be identical in all joined coverages. Mapjoin was used to join all polygon coverages while the append command was used to join the point and line coverages. Mapjoin combines the append and clean processes. The fuzzy tolerance used to join the coverages is the minimum tolerance value of the input coverages. Mapjoin also creates an output coverage in the highest precision of the input coverages. These procedures were automated using an AML script. This procedure required 2 steps because the data is in UTM coordinates covering zones 17 and 18. Coverages were appended for zone 17 and zone 18, respectively. All sliver polygons were removed and the build command was used to generate topology for the zoned coverages. It was then decided to project all data located in zone 18 into zone 17 to complete the final join. The append command was used to join zone 17 and zone 18. Append was used to accommodate for boundary errors that occur along the zonal boundary. These errors were edited in ArcEdit® ensuring all nodes were snapped cleanly along the zone boundary. The build command was then used to generate topology. The sgu_poly coverage attribute table was then joined to a translation table created in Microsoft® Access®. This translation table links all the tiled Quaternary map legend units to a single common provincial legend. A series of queries were applied to the table to identify any original map units that were not translated. A few errors were identified and the legend was updated to account for these geological units.

Phase II – The Seamless Map: Methodology

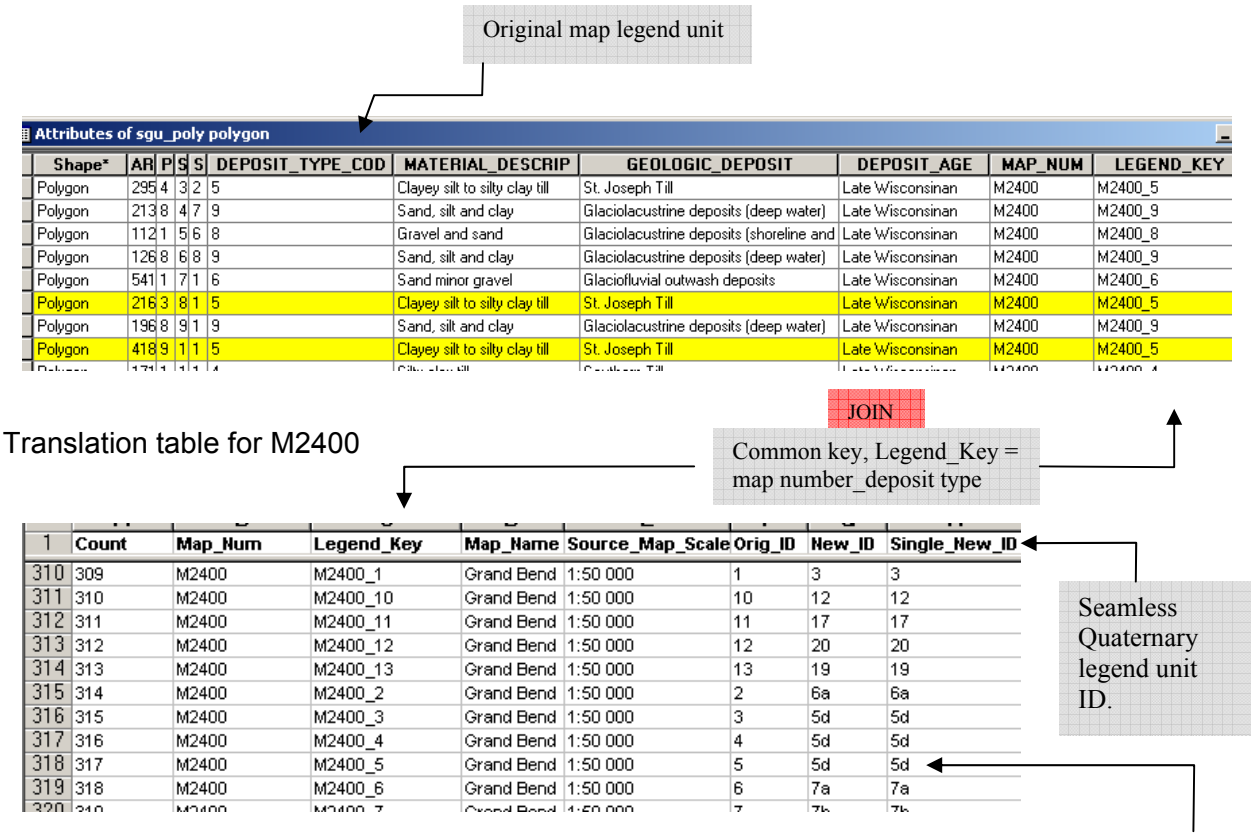
The second phase of this project involved the generation of a "seamless map" on certain attributes. All boundary faults existing between individual map sheets were corrected. Corrections were based on geologists' field investigations, review of bedrock geological maps, and aggregate resource inventory papers (ARIPs), aerial photographic interpretations, as well as a digital elevation model (DEM) and its derivatives produced by the Ontario Ministry of Natural Resources.The result of phase II is a tiled seamless map of southern Ontario. Map boundaries have been maintained through the edge matching phase. Edits were completed using workstation command line. To maintain accuracy, the build command was used to build topology rather than the clean command. This required that all nodes were snapped and that no dangles existed. It was decided that because of file size, editing would be done on the individual zone coverages first. Once each zone was seamless, zone 18 coverages were projected into zone 17. The final join and boundary fault edits were then completed along the zone boundary.

Translation table

A translation table was created by OGS geologist Dr. Andy Bajc and later maintained and modified by Dr. G. Gao and John Dodge, also of the OGS. This table was used to translate original map legend units to the new legend created for southern Ontario (Appendix B). A soft

join was used in ArcMap®, joining the geological polygons (sgu_poly.pat) attribute table to the translation table through a common key.

Figure 1. Attribute and translation tables for M2400



The example above (Figure 1) shows how original map unit 5 found on Map 2400 (Grand Bend) was translated to unit 5d in the new common legend for southern Ontario. This soft (non-permanent) join was used to allow easy editing to both the coverage attribute table as well as the translation table. Edits were applied to the original map units during the edge-matching process. The translation table was checked to ensure that all units were accounted for. If an edit required that a unit from an adjoining map be extended into the next map and it was of a unit type not existing in that map's original legend, then a new unit was added, e.g., "unit 13", to the edit map's legend (Appendix C). This new individual map unit was then translated in the translation table to the provincial legend. Therefore, the translation table was continuously updated. All new units added to any of the original map legends (dep_type_cod) were tracked and retained in a spreadsheet. Upon completion of phase II edits, a permanent join was used to complete the process. The sgu_poly coverage (Appendix D) is currently seamless on 4 of its attributes. These include single_new_id (legend), single primary material, single primary genesis and formation.

Tracking Edits

The OGS felt it was imperative to track all edits made to the original maps during the edge-matching phase. Appending 125 maps, each with different authors and different legends, was an arduous and challenging task. A total of 6821 edits were made to the arc attribute table alone. Two columns (EDIT) and (AUTHOR) were added to both the arc attribute table sgu_poly.aat and the polygon attribute table sgu_poly.pat for tracking all edits. Any arc that was altered in any way was attributed in the new 'edit' column as ADD, MOVE, or MOD. This gives the user the ability to identify all changes made to the original maps. The polygons were then tagged with the same attribute. The AUTHOR attribute was populated with the name of the

geologist who authored the edit. If a polygon code was changed, the edit column was attributed with the original unit # and the new unit #, for example 2a_3. Most edits were completed through heads up digitizing using a hillshade as a guide. Most of the errors in mapping are clearly depicted on the hillshade.

Figure 2. Editing example (linear features)

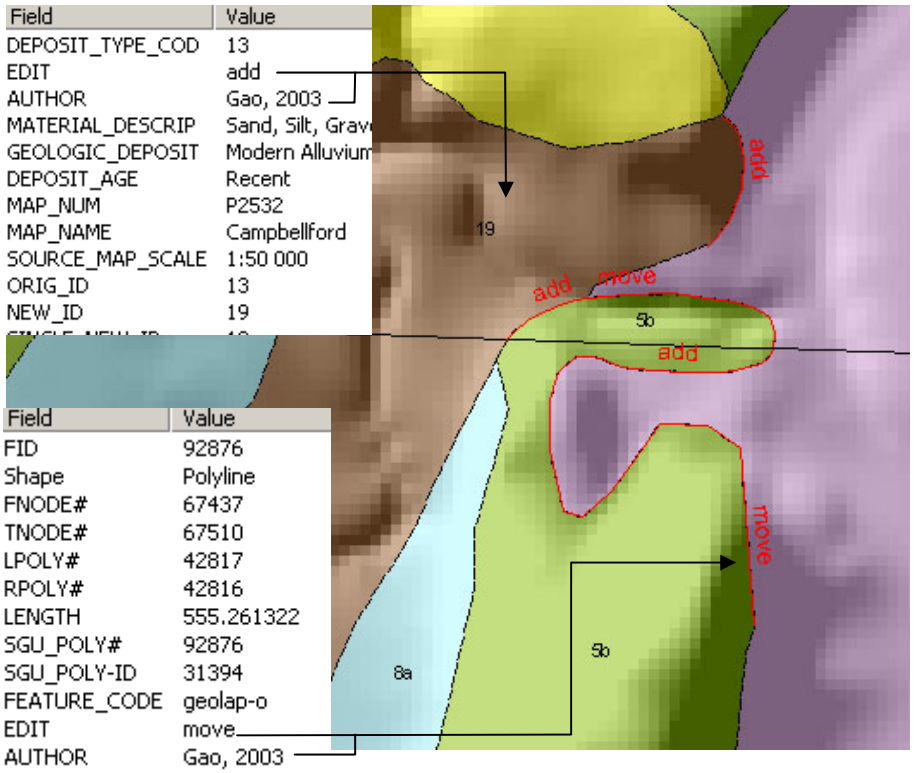
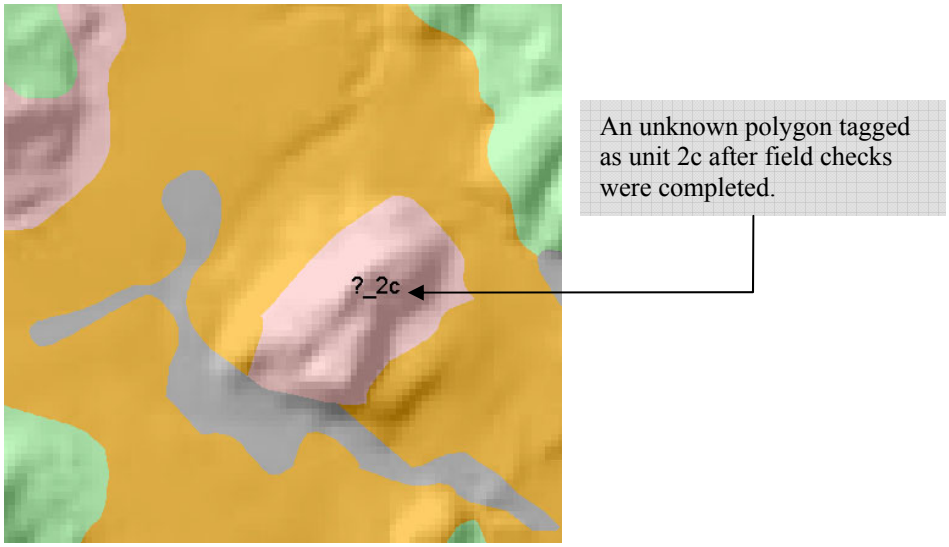


Figure 2, shows an example where geological contacts and polygons were moved or added. Both the sgu_poly.aat and sgu_poly.pat were tagged with the edit type and author name. Polygonal edits such as changes to unit numbers can also be displayed uniquely through the 'EDIT' attribute found in the sgu_poly.pat. As shown in Figure 3, an unknown unit found on the original map was found to be a unit 2c following a field visit.

Figure 3. Editing example (polygonal features)



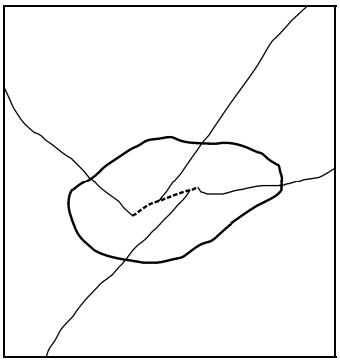
Section B (coverages and symbology)

Coverages and Attributes (Geological)

Polygonal, point and line information was captured as part of the seamless Quaternary geology map project. Coverages created include sgu_poly, sgu_point, sgu_line, sgu_mor, sgu_misc, ogs_pits and sgu_anno. Attribute tables were built and populated with various geological information.

SGU_POLY

This coverage captures all surficial geology unit polygons (sgu_poly.pat) with oriented and classified boundary lines (sgu_poly.aat). This coverage is seamless on single_new_id (legend), single primary material, primary genesis and formation. A total of 114631 polygons make up this coverage. Please note that the standards set for the creation of the seamless project stipulated that geology boundaries be extended under lakes in the NRVIS hydrology base. Arcs generally continue their heading to close against an arc drawn down the middle of the lake as in the following example:



Therefore it is very important to uses a Lake coverage to complete the geology
The polygon attribute table associated with the sgu_poly coverage is shown in Figure 4.

Figure 4. Feature Class Properties (sgu_poly.pat)

Items:

Column	Item Name	Type	Width	Output
25	DEPOSIT_TYPE_COD	Char	3	3
28	EDIT	Char	25	25
53	AUTHOR	Char	25	25
78	MATERIAL_DESCRIP	Char	320	320
398	GEOLOGIC_DEPOSIT	Char	75	75
473	DEPOSIT_AGE	Char	30	30
503	MAP_NUM	Char	10	10
513	MAP_NAME	Char	20	20
533	SOURCE_MAP_SCALE	Char	15	15
548	ORIG_ID	Char	3	3
551	NEW_ID	Char	15	15
566	SINGLE_NEW_ID	Char	3	3

Items:

Column	Item Name	Type	Width	Output
569	PRIM_MAT	Char	30	30
599	SINGLE_PRIM_MAT	Char	25	25
624	P_MAT_MOD	Char	25	25
649	SINGLE_PMAT_MOD	Char	15	15
664	SEC_MAT	Char	30	30
694	PRIM_GEN	Char	40	40
734	SINGLE_PRIM_GEN	Char	20	20
754	PRIM_GEN_MOD	Char	25	25
779	SINGLE_PGEN_MOD	Char	20	20
799	VENEER	Char	40	40
839	EPISODE	Char	15	15
854	SUBEPISODE	Char	20	20
874	PHASE	Char	15	15
889	STRAT_MOD	Char	20	20
909	PROVENANCE	Char	25	25
934	CARB_CONTENT	Char	15	15
949	FORMATION	Char	75	75
1024	PERMEABILITY	Char	15	15

Listed below are the attributes and their definitions (sgu_poly.pat).

DEPOSIT_TYPE_COD: The geological unit number taken from the original map legend.

EDIT: Any POLYGON that was altered in any way was attributed in this new 'edits' column as ADD, MOVE, or MOD. Gives the user the ability to see all edits made to the original maps.

AUTHOR: Author or person that authorized an EDIT.

MATERIAL _DESCRIP: Material or sediment description, e.g., 'sand and silty fine sand', 'silty sand and gravel' and 'silty till with low stone content'.

GEOLOGIC_DEPOSIT: This attribute shows the genetic origins or depositional environments under which the sediments were formed. Examples are 'glaciolacustrine deposits',

DEPOSIT_AGE: to show the age when the sediments were deposited, e.g., Wisconsinan, post-glacial or recent.

MAP_NUM: Original map series number, eg., 'M2402' or 'P1973'. Each polygon is tagged to its original map.

MAP_NAME: Usually NTS area where mapping was completed, e.g., 'Golden Lake'

SOURCE_MAP_SCALE: The scale at which the original map was captured, e.g., '1:50 000'

ORIG_ID: Same as dep_type_cod.

NEW_ID: This attribute will allow the user to create a traditional Quaternary geology map with a standardized provincial legend.

SINGLE_NEW_ID: Same as above except with single entries. This attribute represents the new seamless Quaternary legend for southern Ontario, geological unit number. The user is provided with the legend as a layer file, *.jpg* file and *.avl* file.

PRIM_MAT: This attribute provides the user with information regarding the most prevalent material present within a given area.

SINGLE_PRIM_MAT: Same as above except with single entries. This attribute is seamless and allows the user to create a materials map. The user is provided with a simplified legend based on material as a layer file and jpg.

PRIM_MAT_ MOD: This attribute provides the user with a more refined description of the lithological classification of the primary material.

SINGLE_PMAT_MOD: Same as above except with single entries.

SEC_MAT: This attribute provides the user with information regarding subordinate materials present within a given area.

PRIM_GEN: This attribute provides the user with an interpretation of the depositional environment within which the primary material was deposited.

SINGLE_PRIM_GEN: Same as above except with single entries. This attribute is seamless and allows the user to create a map based on genesis.

PRIM_GEN_MOD: This attribute provides the user with a refined interpretation of the primary genetic modifier.

SINGLE_PGEN_MOD: Same as above except with single entries.

VENEER: This attribute provides the user with information regarding the type of material that forms a thin, discontinuous veneer over the primary material.

EPISODE: A diachronic stratigraphic unit and the proposed late Quaternary sequence stratigraphy. Consists in descending order of Hudson, Wisconsin, Sangamon and Illinois in the Great Lakes area in late Quaternary (Johnson et al. 1997).

SUBEPISODE: A diachronic stratigraphic unit in a lower order than Episode and the proposed sequence-stratigraphic classification, consists in descending order of Michigan, Elgin and Ontario in the eastern and northern Great Lakes area in the Wisconsin Episode (Johnson et al. 1997; Karrow et al. 2000).

PHASE: A diachronic stratigraphic unit in a lower order than Subepisode, and the proposed sequence-stratigraphic classification is listed in the following table in the eastern and northern Great Lakes area (Karrow et al. 2000).

STRAT_MOD: This attribute provides the user information regarding the stratigraphic position of the mapped unit (i.e., whether the unit occurs primarily on the surface or in the subsurface).

PROVENANCE: This attribute provides the user with information regarding the provenance of a particular till unit (i.e. direction or lobe from which the till is derived).

CARB_CONTENT: This attribute provides the user with information regarding the carbonate content of till.

FORMATION: This attribute provides the user with information regarding the formation to which a given primary material belongs (e.g., Tavistock Till, Port Stanley Till, Scarborough Formation). This attribute is seamless and allows the user to create a map based on formation.

PERMEABILITY: This attribute provides the user with basic information about permeability of the sediments in a ranking of high, medium and low. (Appendix E)

The arc attribute table associated with the sgu_poly coverage is shown in Figure 5.

Figure 5. Feature Class Properties (sgu_poly.aat)

Items:

Column	Item Name	Type	Width	Output
N/A	$RIGHTPOLYGON	Binary	4	5
1	FNODE#	Binary	4	5
5	TNODE#	Binary	4	5
9	LPOLY#	Binary	4	5
13	RPOLY#	Binary	4	5
17	LENGTH	Float	8	18
25	SGU_POLY#	Binary	4	5
29	SGU_POLY-ID	Binary	4	5
33	FEATURE_CODE	Char	25	25
58	EDIT	Char	25	25
83	AUTHOR	Char	25	25

Listed below are the attributes and their definitions (sgu_poly.aat).

FEATURE_CODE: . Most of these arcs will be “geolap-o” for geological contacts.

EDIT: Any arc that was altered in any way was attributed in this new ‘edits’ column as ADD, MOVE or MOD. Gives the user the ability to see all edits made to the original maps.

AUTHOR: Author or person that authorized an EDIT.

SGU_POINT

This coverage captures all oriented point information such as drumlins and striae, and unoriented point information such as kames and bedrock locations. Please note that this coverage is not complete for all of southern Ontario. Symbols are provided for this coverage and can be viewed in the symbology section of this document. Listed below are the attributes (Figure 6) and their definitions (sgu_point.pat).

Figure 6. Feature Class Properties (sgu_point.pat).

Items:

Column	Item Name	Type	Width	Output
N/A	$ANGLE	Float	8	18
1	AREA	Float	8	18
9	PERIMETER	Float	8	18
17	SGU_POINT#	Binary	4	5
21	SGU_POINT-ID	Binary	4	5
25	FEATURE_CODE	Char	25	25
50	ORIENTATION	Number	3	3
53	PLOT_ORIENTATION	Number	3	3
56	SIZE	Number	3	3
59	FEATURE_TEXT	Char	25	25
84	MAP_NUM	Char	10	10

FEATURE_CODE: A character field containing a feature code such as drumlin or flute. (*see* symbology)

ORIENTATION: A numeric field containing each feature’s astronomic orientation. For example, for feature codes “strd”, glacial striae, direction of ice movement known, this field contains a number from 0 to 360 indicating in degrees the direction of ice movement inferred from striae observed by the geologist in the field. This direction can be measured from the published map. When the rotation field is applied, the user should select ‘geographic’ for the rotation style with 180 degrees pointing south.

SIZE: A numeric field used to denote larger-than-usual feature size. Default is 0.

PLOT_ORIENTATION: A numeric field containing a number calculated globally from orientation, and used by ArcInfo® to correctly orient its symbols.

FEATURE_TEXT: A character field of text that may be plotted with the feature. This field must be used for sample number information, relative ages of striae, and other text information which accompanies point features on the map.

MAP_NUM: Original map series number, eg., 'M2402' or 'P1973'. Each sgu_point feature is tagged to its original map.

SGU_LINE

This coverage captures all oriented line information such as eskers and beaches. Please note that this coverage is not complete for all of southern Ontario. Symbols are provided for this coverage and can be viewed in the symbology section of this document. Listed below are the attributes (Figure 7) and their definitions (sgu_line.aat).

Figure 7. Feature Class Properties (sgu_line.aat).

Items:

Column	Item Name	Type	Width	Output
N/A	$LEFTPOLYGON	Binary	4	5
N/A	$RIGHTPOLYGON	Binary	4	5
1	FNODE#	Binary	4	5
5	TNODE#	Binary	4	5
9	LPOLY#	Binary	4	5
13	RPOLY#	Binary	4	5
17	LENGTH	Float	8	18
25	SGU_LINE#	Binary	4	5
29	SGU_LINE-ID	Binary	4	5
33	FEATURE_CODE	Char	25	25
58	MAP_NUM	Char	10	10

FEATURE_CODE: A character field containing a feature code such as "eskern", esker, direction of flow known or "bluff" . The arcs must have a correct sense of digitization so that the feature will display correctly. In the esker example, digitization must be done in a downstream direction. (see symbology)

MAP_NUM: Original map series number, e.g., 'M2402' or 'P1973'. Each sgu_line feature is tagged to its original map.

SGU_MOR

This polygon coverage displays areas of hummocky topography (fhumtopo) as well as areas mapped as moraines (fmoraine). Please note that these features do not exist on all tiled maps. Symbols are provided for this coverage and can be viewed in the symbology section of this document. Listed below are the attributes (Figure 8) and their definitions. (sgu_mor.pat)

Figure 8. Feature Class Properties (sgu_mor.pat).

Items:

Column	Item Name	Type	Width	Output
N/A	FID	OID	4	5
N/A	SHAPE	Geome	4	5
1	AREA	Float	8	18
9	PERIMETER	Float	8	18
17	SGU_MOR#	Binary	4	5
21	SGU_MOR-ID	Binary	4	5
25	FEATURE_CODE	Char	25	25
50	MAP_NUM	Char	10	10

FEATURE_CODE: A character field containing a feature code such as "fhumtopo"or "fmoraine" (*see* symbology Table 3).

MAP_NUM: Original map series number, e.g., 'M2402' or 'P1973'. Each sgu_mor feature is tagged to its original map.

SGU_MISC

This polygon coverage captures all other features not previously captured. These polygon features can include areas of dunes (fdune) as well as areas containing ribbed moraines (frib). Please note that these features do not exist on all tiled maps. Symbols are provided for this coverage and can be viewed in the symbology section of this document. Listed below are the attributes (Figure 9) and their definitions. (sgu_misc.pat)

Figure 9. Feature Class Properties (sgu_misc.pat).

Items:

Column	Item Name	Type	Width	Output
N/A	FID	OID	4	5
N/A	SHAPE	Geome	4	5
1	AREA	Float	8	18
9	PERIMETER	Float	8	18
17	SGU_MISC#	Binary	4	5
21	SGU_MISC-ID	Binary	4	5
25	FEATURE_CODE	Char	25	25
50	MAP_NUM	Char	10	10

FEATURE_CODE: A character field containing a feature code such as "fdune"or "frib" (*see* symbology).

MAP_NUM: Original map series number, e.g., 'M2402' or 'P1973'. Each sgu_misc feature is tagged to its original map.

OGS_PITS

This coverage captures gravel pit and bedrock quarry locations. Other features may include clay pits, tailings as well as peat operations. These features may or may not be operational and the condition of these pits may vary from licensed, abandoned or reclaimed. Please note that this coverage is not complete for all of southern Ontario. Symbols are provided for this coverage and can be viewed in the symbology section of this document. Listed below are the attributes (Figure 10) and their definitions. (ogs_pits.pat)

Figure 10. Feature Class Properties (ogs_pits.pat).

Items:

Column	Item Name	Type	Width	Output
17	OGS_PITS#	Binary	4	5
21	OGS_PITS-ID	Binary	4	5
25	FEATURE_CODE	Char	25	25
50	MAP_NUM	Char	10	10

FEATURE_CODE: A character field containing a feature code such as “pitsg” sand and gravel pit or “quarry”. (see symbology)

MAP_NUM: Original map series number, e.g., ‘M2402’ or ‘P1973’. Each ogs_pits.pat point feature is tagged to its original map.

SGU_ANNO

This coverage captures geological annotation such as moraine, esker, or drumlin field names. Please note that this coverage is not complete for all of southern Ontario. Listed below are the attributes (Figure 11) and their definitions (sgu_anno).

Figure 11. Feature Class Properties (sgu_anno.tatgeol).

Items:

Column	Item Name	Type	Width	Output
N/A	$LEVEL	Binary	4	5
N/A	$SIZE	Float	8	18
N/A	$TEXT	Char	320	320
N/A	$OFFSETX	Float	8	18
N/A	$OFFSETY	Float	8	18
N/A	$JUSTIFY	Char	320	320
N/A	$FIT	Char	320	320
N/A	$ALIGN	Char	320	320
1	GEOL#	Binary	4	5
5	GEOL-ID	Binary	4	5
9	TEXT	Char	320	320

TEXT: a character field containing values equivalent to the annotation pseudo item $TEXT.

Coverages and Attributes (Other)

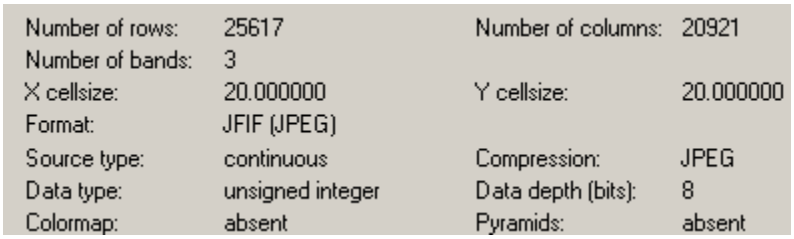
The Ontario Geological Survey felt it was important to include other coverages in this MRD that will provide the user with additional important digital information. This information includes a shaded relief raster image of southern Ontario, and an index containing information for each map tile used to create the seamless coverage. Base information is also provided on the final DVD product and includes NRVIS roads and lakes as well as upper tier municipal boundaries. The Ministry of Natural Resources (MNR) granted permission to release the NRVIS roads and lakes as vector coverages. The roads coverage provided only includes primary roads stripped of all attributes. The lakes coverage includes only those lakes having an area greater than or equal to one million square metres. The upper tier municipal boundaries data was obtained from The Ministry of Municipal Affairs and Housing.

SHADED RELIEF

The Geomatics Service Center, Ontario Ministry of Natural Resources, graciously provided the OGS permission to create and provide a seamless shaded relief map of southern Ontario. The MNR provided all digital elevation model (DEM) tiles covering the project area. The mosaic command in grid was used to append 79 tiled hillshades into one image. The image was then exported to a JFIF (JPEG) format to reduce the file size. The original 10 m resolution DEMs were resampled to 20 m cells and a vertical exaggeration of 3 times was used to create the

hillshade. The original 10 m shaded relief was 1.2 gigabytes. The JFIF (JPEG) file provided on this DVD for all of southern Ontario is 54 megabytes and its properties are shown in Figure 12.

Figure 12. Raster dataset properties



Number of rows:	25617	Number of columns:	20921
Number of bands:	3		
X cellsize:	20.000000	Y cellsize:	20.000000
Format:	JFIF (JPEG)		
Source type:	continuous	Compression:	JPEG
Data type:	unsigned integer	Data depth (bits):	8
Colormap:	absent	Pyramids:	absent

It is recommended that the user create pyramids using ArcMap® or ArcCatalog® once the data has been copied from the DVD. This will drastically reduce regeneration time.

INDEX

A coverage called index was created to provide the user with information regarding the individual map tiles used to generate the seamless coverage. Some of the attributes provided include NTS sheet number, NTS name, map number, author and the name of the organization that supplied the data (OGS or GSC). Listed below are the attributes (Figure 13) and their definitions (index.pat).

Figure 13. Feature Class Properties (index.pat)

Items:

Column	Item Name	Type	Width	Output
21	INDEX-ID	Binary	4	5
25	UTM_ZONE	Char	2	2
27	NTS	Char	8	8
35	MAP_NUM	Char	15	15
50	NTS_NAME	Char	20	20
70	TITLE	Char	120	120
190	AUTHORS	Char	100	100
290	ORG_MAP	Char	110	110
400	SCALE	Char	10	10
410	ORGANIZATION	Char	30	30
440	ORG	Char	8	8

UTM_ZONE: Identifies within what zone the original tiled map originates. Southern Ontario crosses zones 17 and 18.

NTS: The National Topographic System number to which the map is located.

MAP_NUM: The original map series number (i.e., M2404 or P1048).

NTS_NAME: The National Topographic System location name (i.e., SCUGOG).

TITLE: The original map series title (ie Quaternary Geology of the Renfrew Area.).

AUTHORS: Authors of original map taken from original map reference (e.g., Barnett P.J. 1980).

ORG_MAP: Original map. Some of the GSC maps used in this compilation had been vectorized and re-released with a new digital series number and new authors. This ORG_MAP attribute lists the original paper map reference.

SCALE: The scale of the original source map.

ORGANIZATION: The Ontario Geological Survey or the Geological Survey of Canada.

ORG: OGS or GSC used as a label item for ORGANIZATION.

This coverage will be the top most layer displayed in the project file (mxd) on the DVD.

ROADS

The Ministry of Natural Resources (MNR) granted permission to release the NRVIS roads. The roads coverage provided in this dataset only includes primary roads that have been stripped of all attributes.

WATER

The Ministry of Natural Resources (MNR) granted permission to release the NRVIS lakes. The lakes coverage only includes those lakes having an area greater than or equal to one million square metres. Attributes include “IW” which defines islands as ‘0’ and lakes as ‘1’ as well as “NAME” which contains the names of the major lakes found in southern Ontario. (The Great Lakes, Lake Simcoe, Lake St. Clair)

MUNICIPAL

The upper tier municipal boundaries information was obtained from The Ministry of Municipal Affairs and Housing. This vector coverage does not provide any attribute information.

Feature Codes and Symbology

Feature Codes

Geological features are captured as point line and polygon. These features are defined in the coverage attribute table by its “feature_code”. Table 2 provides a list of standardized feature codes used by the Ontario Geological Survey. Please note that not all the features listed below appear on the seamless coverage. Appendix F contains definitions for many of the feature types listed in Table 2.

Table 2. Feature codes.

Feature Code	Feature Type	Collected As	Oriented
beach	beach ridges and near shore bars	line	
escarp	bedrock escarpment	line	yes
popup	bedrock pressure release ridge (pop-up)	line	
ridge	bedrock ridge	line	yes
karst	clint and gryke topography	line	
crevasse	crevasse filling	line	
degeer	degeer or washboard moraine trend (line)	line	
dcrest	Dune (crest)	line	
eskern	esker; direction of flow known	line	yes
eskernd	esker; direction of flow unknown	line	
terrace	fluvial terrace	line	yes
geolap-o	geological contact; approximate/assumed	line	
iceberg	iceberg scour	line	

icslope	ice-contact slope	line	yes
icewedge	ice wedge cast	line	
slidel	landslide scar (line)	line	yes
lineation	lineament observed on aerial photograph	line	
linsect	line of section	line	
megarip	megaripple	line	
fluvdl	meltwater channel, inferred direction of flow	line	yes
fluvndl	meltwater channel, direction of flow unknown	line	
mfluvdl	meltwater flow, inferred direction of flow	line	yes
mfluvndl	meltwater flow; direction of flow unknown	line	
moraine	Moraine, minor	line	
end	Moraine, major	line	
pitsg	pit, mappable edge	line	yes
quarry	pit or quarry (line)	line	yes
ribl	ribbed or Rogen moraine (line), arrows indicate direction of ice flow	line	yes
bluff	shore bluff or scarp	line	yes
slumpb	slump block, margin	line	yes
tunnel	tunnel valley	line	
washline	wash limit	line	
linfeat	linear features observed on aerial photograph	line	
archsite	archeological site	point	
clay	clay pit	point	
cres	crescentic fractures; crescentic scars; chattermarks	point	yes
cresrev	reverse crescentic fractures; reverse crescentic scars	point	yes
deform	deformation structure - arrow indicates inferred direction of ice movement	point	yes
deltagl	delta, glaciolacustrine	point	yes
hole	Drill Hole	point	
drumlin	drumlin or drumlinoid ridges (point)	point	yes
dune	Dune (point)	point	yes
fossil	fossil locality	point	
gaseep	gas seepage feature	point	
hole	geotechnical or stratigraphic borehole not reaching bedrock	point	
holerock	geotechnical or stratigraphic borehole reaching bedrock	point	
flute	glacial flute	point	yes
strd	glacial striae; direction of ice movement known	point	yes
strnd	glacial striae; direction of ice movement unknown	point	
kame	kame (point), small scale feature not requiring line work	point	
kettle	kettle (point), small scale feature not requiring line work	point	
landfill	landfill site	point	
slides	landslide scar, small (point)	point	yes
marl	marl extraction site	point	
pebbleo	observed pebble orientation in till	point	
oilgas	oil or gas well	point	
ocx	outcrop	point	
peat	peat extraction site	point	
quarry	Quarry (point)	point	
reservoir	reservoir	point	
rocmou	roche moutonee	point	
sample	sample location	point	
pitsg	sand and gravel pit	point	
lagoon	sewage lagoon	point	
karst	solution weathering feature	point	
cragtail	stoss and lee feature; crag and tail	point	yes
tailings	tailings area	point	
talus	talus	point	
testhole	testhole location	point	
karst	thermokarst	point	
waste	waste rock area	point	
well	water well not reaching bedrock	point	
wellrock	water well reaching bedrock	point	
rcdate	radiocarbon date	point	
farmour	armoured boulder pavement (pattern representing an area)	poly	
fdegeer	Degeer or washboard moraines (pattern representing an area)	poly	
fdrum	drumlins or drumlinoid ridges (pattern representing an area of drumlins or drumlinoid ridges)	poly	

fdune	Dune (pattern representing an area of dune fields)	poly	
nofdune	area within fdune with no dunes	poly	
fflooded	flooded ground (pattern representing an area)	poly	
flake	former lake bottom (pattern representing an area)	poly	
fhumtopo	hummocky topography (pattern representing an area)	poly	
nohumtopo	area within fhumtopo with no hummocky topography	poly	
fslide1	landslide scar (pattern representing an area of landslide scar)	poly	
fmoraine	pattern representing an area of moraine	poly	
frib	pattern representing an area of ribbed moraine	poly	
fscab	scab land (pattern representing an area)	poly	

Features may be as simple as a bedrock outcrop (ocx) point location or more complex such as a drumlin point symbol that requires a directional rotation. Each point feature's astronomic orientation is captured in the "orientation" attribute found in the sgu_point coverage. When the rotation field is applied, the user should select 'geographic' for the rotation style with 180 degrees pointing south as shown in Figure 14 below.

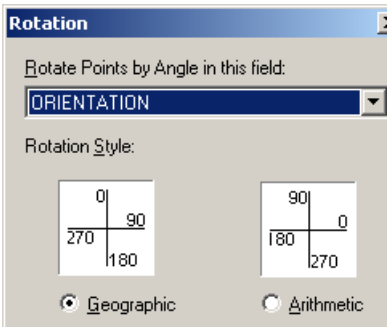


Figure 14. Rotational properties.

Some of the line features captured in sgu_line coverage also require a correct direction. For example eskers are characterized by a direction of flow. Therefore, digitization must be done in a downstream direction.

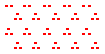
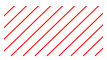
Symbology

The symbology created in ArcMap® 8.1 mimics, as closely as possible, the existing symbology developed for Microstation®, the previous standard software used by the Sedimentary Geoscience Section (SGS). All feature attribute codes for point, line and polygon feature data classes were adopted from SGS' existing standards. Within the style file created for the Quaternary symbols, symbol names match the feature codes used in each of the ArcInfo® coverages (*see* Table 2). Please note that symbols have not been created for all features listed in Table 2. Symbols have only been created for those features found on maps used in this project. It is recommended for users not using ArcMap® 8.x, when creating symbology, to match the symbology provided below.

Table 3. Symbology

ogs_pits.pat		sgu_poly.aat		sgu_mor.pat	
feature_code	symbol	feature_code	symbol	feature_code	symbol
clay	Ⓒ	geolap-o	- - - - - - - -	fhumtopo	
peat	Ⓟ	nln	————	fmoraine	
quarry	⚒			nohumtopo	
pitsg	⚔				
tailings	Ⓣ				

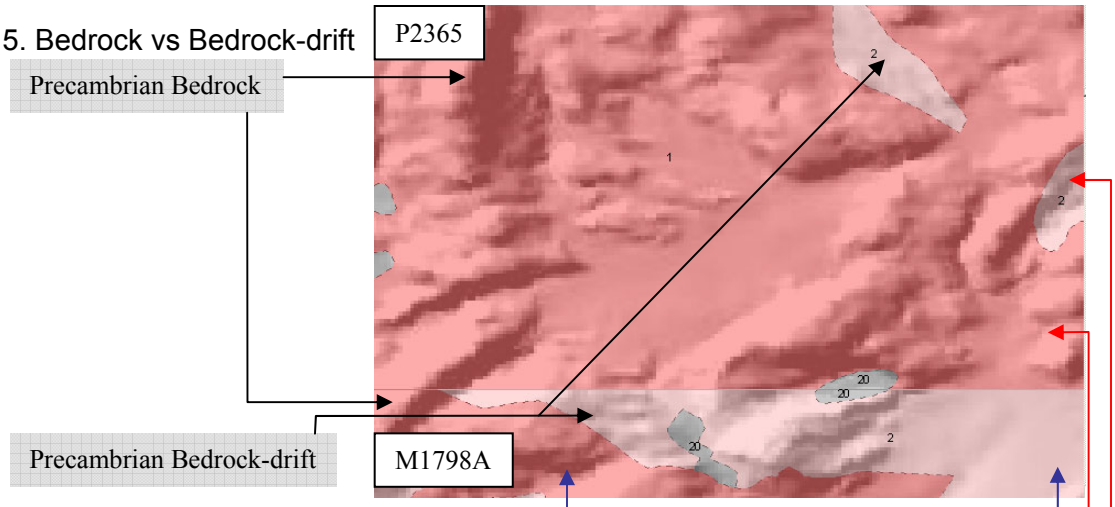
Table 3 cont'd

sgu_misc.pat		sgu_point.pat		sgu_line.aat	
feature_code	symbol	feature_code	symbol	feature_code	symbol
fdune		cragtail		beach	
flake		deltagl		bluff	
frib		drumlin		crevasse	
fscab		dune		dcrest	
fslide1		flute		end	
nofdune		fossil		escarp	
		hole		eskern	
		kame		eskernd	
		karst		fluvdl	
		kettle		fluvndl	
		ocx		iceberg	
		pebbleo		icslope	
		rcdate		karst	
		rocmou		linfeat	
		sample		megarip	
		slides		mfluvdl	
		strd		mfluvndl	
		strnd		moraine	
		talus		pitsg	
				popup	
				ribl	
				slidel	
				slumpb	
				terrace	

Legend

One major problem encountered when developing the standard legend was the issue of bedrock vs bedrock-drift map units. This issue was most notable in the northern portion of the seamless coverage area where Precambrian bedrock is extensive. Authors may have different philosophies when mapping in areas where drift thickness is 1 m or less. Generally, sediments less than 1 m thick are not indicated on standard Quaternary geology maps; however in some cases, these areas are mapped as bedrock-drift. Figure 15 illustrates one such discrepancy between 2 map boundaries.

Figure 15. Bedrock vs Bedrock-drift



P2365

MATERIAL_DESCRIP	Abundant Bedrock Exposure With Thin Drift Cover
GEOLOGIC_DEPOSIT	Bedrock
DEPOSIT_AGE	Precambrian
MAP_NUM	P2365
MAP_NAME	Renfrew
SOURCE_MAP_SCALE	1:50 000
ORIG_ID	1a
NEW_ID	1
SINGLE_NEW_ID	1
PRIM_MAT	Precambrian Bedrock
SINGLE_PRIM_MAT	Precambrian Bedrock
P_MAT_MOD	
SINGLE_PMAT_MOD	
SEC_MAT	
PRIM_GEN	
SINGLE_PRIM_GEN	
PRIM_GEN_MOD	
SINGLE_PGEN_MOD	
VENEER	clay, silt, sand, gravel, diamicton

MATERIAL_DESCRIP	Extensive But Discontinuous Drift Cover
GEOLOGIC_DEPOSIT	Bedrock
DEPOSIT_AGE	Precambrian
MAP_NUM	P2365
MAP_NAME	Renfrew
SOURCE_MAP_SCALE	1:50 000
ORIG_ID	1b
NEW_ID	2
SINGLE_NEW_ID	2
PRIM_MAT	Precambrian Bedrock
SINGLE_PRIM_MAT	Precambrian Bedrock
P_MAT_MOD	
SINGLE_PMAT_MOD	
SEC_MAT	
PRIM_GEN	
SINGLE_PRIM_GEN	
PRIM_GEN_MOD	
SINGLE_PGEN_MOD	
VENEER	clay, silt, sand, gravel

M1798A

MATERIAL_DESCRIP	Precambrian Rock, Undivided; M
GEOLOGIC_DEPOSIT	Bedrock
DEPOSIT_AGE	Pre-Quaternary
MAP_NUM	M1798A
MAP_NAME	Clyde Forks
SOURCE_MAP_SCALE	1:50 000
ORIG_ID	R
NEW_ID	1
SINGLE_NEW_ID	1
PRIM_MAT	Precambrian Bedrock
SINGLE_PRIM_MAT	Precambrian Bedrock
P_MAT_MOD	
SINGLE_PMAT_MOD	
SEC_MAT	
PRIM_GEN	
SINGLE_PRIM_GEN	
PRIM_GEN_MOD	
SINGLE_PGEN_MOD	
VENEER	clay, silt, sand, gravel, diamictc

MATERIAL_DESCRIP	Discontinuous Cover Over Rock
GEOLOGIC_DEPOSIT	Till Veneer
DEPOSIT_AGE	Quaternary
MAP_NUM	M1798A
MAP_NAME	Clyde Forks
SOURCE_MAP_SCALE	1:50 000
ORIG_ID	1b
NEW_ID	2
SINGLE_NEW_ID	2
PRIM_MAT	Precambrian Bedrock
SINGLE_PRIM_MAT	Precambrian Bedrock
P_MAT_MOD	
SINGLE_PMAT_MOD	
SEC_MAT	
PRIM_GEN	
SINGLE_PRIM_GEN	
PRIM_GEN_MOD	
SINGLE_PGEN_MOD	
VENEER	clay, silt, sand, gravel, diamictc

The attributes for the maps are displayed on Figure 15. Specifically, the attributes for bedrock and bedrock-drift are illustrated. In the material_descrip presented above the single primary material is Precambrian bedrock (Figure 16). Other information, such as the veneer descriptor and material description, are also included. To rectify discrepancies between bedrock and bedrock-drift, it was decided to provide the user with two color schemes (layer files and avls). One scheme displays Precambrian bedrock in red, Precambrian bedrock-drift in pink, Paleozoic bedrock in purple and Paleozoic bedrock-drift in light purple (Figure 17). The second displays Precambrian bedrock and Precambrian bedrock-drift in pink and Paleozoic bedrock and Paleozoic bedrock-drift in light purple (Figure 18).

Figure 16. Materials map:Precambrian bedrock in red, Paleozoic bedrock in purple.

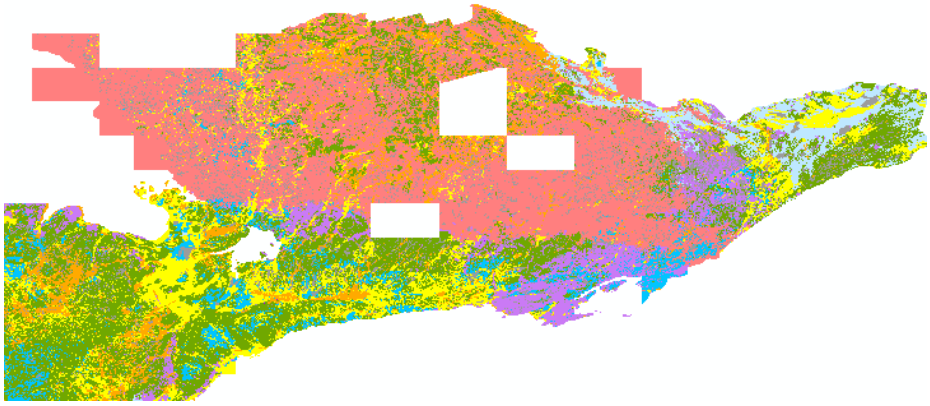


Figure 17. Legend layer file displaying bedrock and bedrock drift.

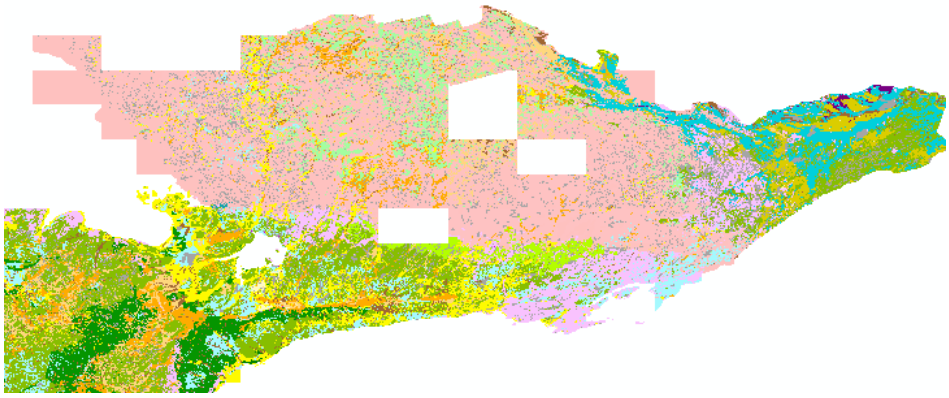
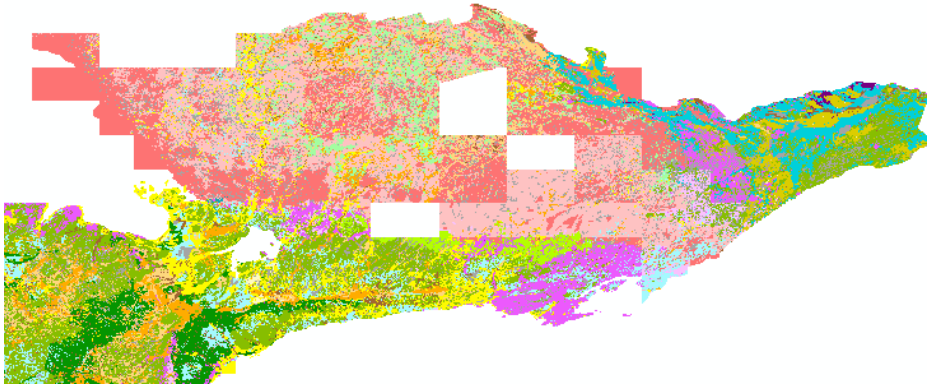
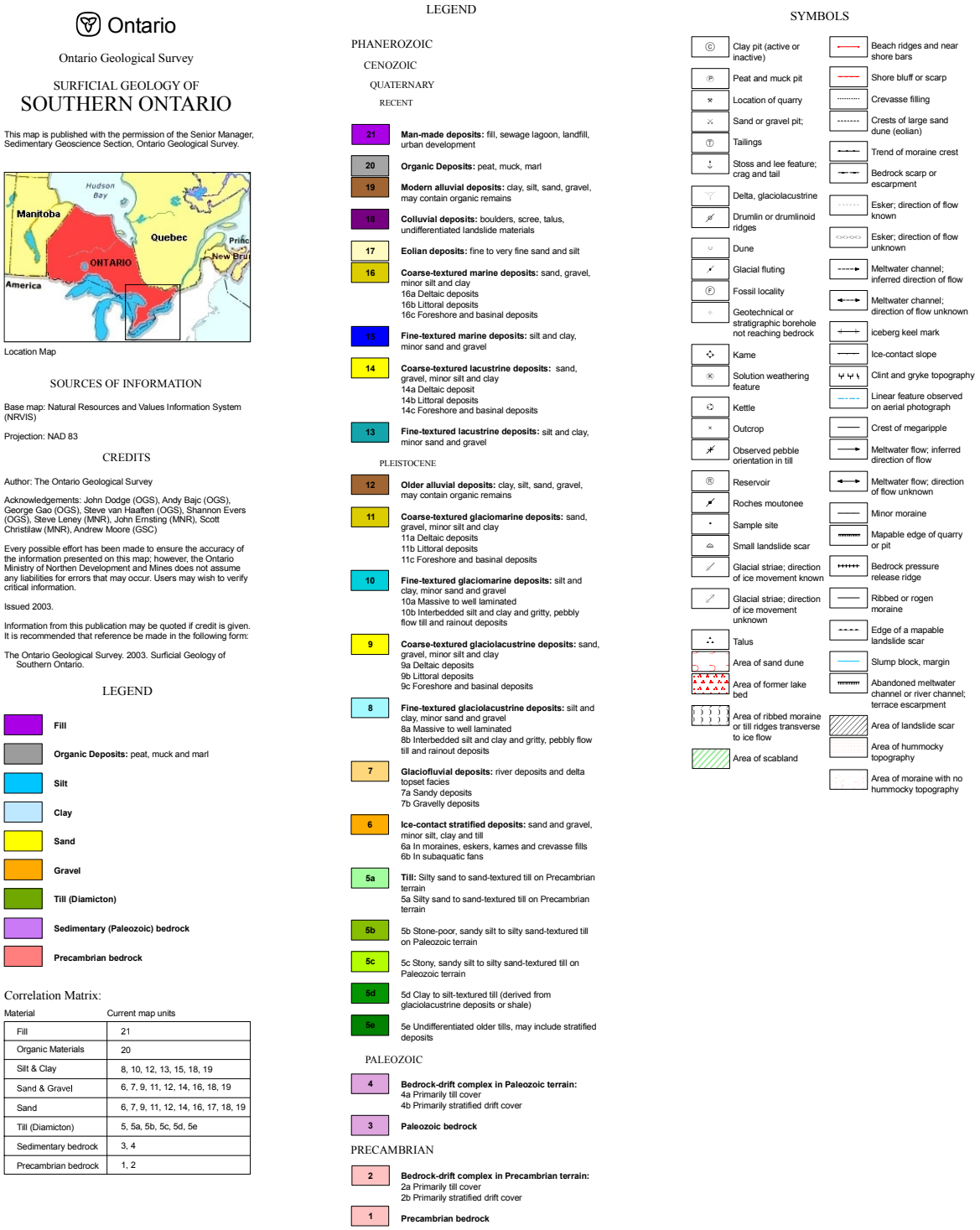


Figure 18. Legend layer file with no differentiation between bedrock and bedrock drift



The final legend shown on Figure 19 is provided to the user as a raster image. This legend includes a standard OGS Quaternary geology legend, as well as, a simplified materials based legend both of which use standard legend unit colors and descriptions.

Figure 19. Legend – Surficial Geology of Southern Ontario.



Limitations and Cautions on Map Usage

Although every possible effort has been made to ensure the information presented within the surficial geology of southern Ontario remains as accurate and as close as possible to the original map tiles, some re-interpretation has been made to varying extents, for example, in extracting single entries from composite records. Re-interpretations are founded upon the *best* judgements of the project authors, based on their experience, education and the information available at the time of compilation. Users are advised to verify critical information against the original maps or to complete their own tests in the field. It is important to bear in mind that the Permeability classification is a very generalized one, based purely on characteristics of material types. No surface relief, roughness, vegetation and other factors are considered (*see* Permeability section).

The extraction of a single entry from a multiple-entry record is a challenging task. It is suggested that in the future, should the opportunity arise, updating should take place either through field verification or acquisition of other suitable data. Some typical situations that emerged during the compilation included

- where 2 or more *New_IDs* existed, a *Single_New_ID* had to be extracted;
- where multiple primary materials (*Prim_Mat*) existed, a single entry (*Single_Prim_Mat*) had to be chosen.

In the case where a straight forward translation to a Single_New_ID was not possible, a *best estimate* as to which provincial legend map unit is most dominant within the given area was made.

In the second situation above, the entry for *Single_Prim_Mat* is the result of interpretation to indicate that a ***significant*** amount of that material is present in the given area. For instance, if *gravel* is selected as the entry of *Single_Prim_Mat* for a sand and gravel deposit it means that gravel makes up a significant amount of material, not necessarily dominant in percentage, within the area mapped as sand and gravel. The same rules also apply to other deposits such as silt and clay.

Although refining and updating of the map may occur in the future, it is strongly recommended that users check the original maps or/and other relevant data sources (e.g., Aggregate Resource Inventory Papers and maps (ARIPs)) published by OGS to obtain additional information. Users are also encouraged to contact the OGS for further information.

References

Allaby, A and Allaby, M. (editors) 1999. Oxford Dictionary of Earth Sciences 2nd edition. Oxford University Press, Oxford. 619p

Bajc, A., Leney, S., Evers, S., van Haaften, S. and Ernsting, J. 2001. A seamless Quaternary geology map of southern Ontario; *in* Summary of Fieldwork and Other Activities 2001, Ontario Geological Survey, Open File Report 6070, p.33-1 to 33-5.

Barnett, P.J. 1992. Quaternary geology of Ontario; *in* Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 2, p.1011-1090.

Benn, D.I. and Evans, D.J.A. 1998. Glaciers and glaciation; Arnold, London, 734p.

British Columbia Ministry of Environment: Surficial Geology Glossary: http://archive.ilmb.gov.bc.ca/risc/pubs/earthsci/012/012t-42.htm#p1852_128115

Chapman, L.J. and Putnam, D.F. 1984. The physiography of southern Ontario; Ontario Geological Survey, Special Volume 2, 270p. Accompanied by Map P.2715 (coloured), scale 1:600 000.

Coleman, A.P. 1894. Interglacial fossils from the Don Valley; American Geologist, v.13, p.85-95.

Dreimanis, A. 1982. Genetic classification of tills and criteria for their differentiation: Progress report on activities 1977-1982, and definitions of glacigenic terms; *in* Report on Activities 1977-1982, INQUA, Commission on Genesis and Lithology of Quaternary Deposits, ETH-Zuerich, p 12-31.

Dreimanis, A. and Karrow, P.F. 1972. Glacial history of the Great Lakes–St. Lawrence region, the classification of the Wisconsin(an) stage, and its correlatives; 24th International Geological Congress, Quaternary Geology, Section 12, 5-15.

French, H.M. 1976. The periglacial environment; Longman, London, 309p.

Gao, C., Dodge, J.E.P. and MacDonald, I.M.L. 2002. A seamless quaternary geology map of southern Ontario—2nd Phase; *in* Summary of Fieldwork and Other Activities 2001, Ontario Geological Survey, Open File Report 6100, p.28-1 to 28-2.

Jackson, J.A. (editor) 1997. Glossary of Geology, 4th edition; American Geological Institute, Virginia, 769p.

Johnson W.H., Hansel A.K., Bettis III, E.A. Karrow, P.F., Larson, G.J., Thomas, V.L. and Schneider, A.F. 1997. Late Quaternary temporal and event classifications, Great Lakes region, North America; Quaternary Research, v.47, p.1-12.

Karrow, P.F., Dreimanis, A and Barnett, P.J. 2000. A proposed diachronic revision of late Quaternary time-stratigraphic classification in the eastern and northern Great Lakes area; Quaternary Research, v.54, p.1-12.

Karrow, P. F., McAndrews, J. H., Miller, B. B., Morgan, A. V., Seymour, K. L. and White, O. L. 2001. Illinoian to late Wisconsinan stratigraphy at Woodbridge, Ontario; Canadian Journal of Earth Sciences, v.38, p.921-942.

Morris, T.F. 1994. Quaternary geology, Essex County (East Half), southwestern Ontario; Ontario Geological Survey, Preliminary Map P. 3252, scale 1:50 000.

National soils survey handbook (geologic terms and glossary of landform and geologic terms); URL: http://soils.usda.gov/technical/handbook/ <Accessed February 27, 2010>.

North American Commission on Stratigraphic Nomenclature 1983. North American stratigraphic code; The American Association of Petroleum Geologists Bulletin, v.67, p.841-875.

Shackleton, N.J. and Opdyke, N.D. 1973.Oxygen isotope and palaeomagnetic stratigraphy of equatorial Pacific core V38-238: Oxygen isotope temperatures and ice volumes on a 105 and 106 year scale; Quaternary Research, v.3, p.39-55.

Shackleton, N.J. and Pisias, N.G. 1985. Atmospheric carbon, orbital forcing and climate; *in* The Carbon Cycle and Atmospheric CO_2: Natural Variations Archean to Present, Geophysical Monographs, v.32, p.303-317.

Soil Survey Committee, 1978. Canadian system of soil classification 3rd edition; Canada Department of Agriculture, 164p.

Soil Survey Staff 1951. Soil survey manual, U.S. Department of Agriculture Handbook, no.18.

Soil Classification Working Group 1998. The Canadian system of soil classification, 3rd ed. Agriculture and Agri-Food Canada Publication.

Subcommission on North American Quaternary Stratigraphy 1993. Quaternary stratotypes of North America. Revised edition. Edited by P.F. Karrow. The Subcommission on North American Quaternary Stratigraphy of International Union for Quaternary Research (INQUA). University of Waterloo, Waterloo.

Wentworth, C.K. 1922. A scale of grade and class terms for clastic sediments; Journal of Geology, v.30, p.377-392.

Appendix A: Map Sources and References

The original map tiles utilized in the project and their source and reference information are listed below.

Bajc, A.F. and Henry, A.P. 1991. Quaternary geology of the Huntsville-Bracebridge area, southern Ontario; Ontario Geological Survey, Open File Map 161, scale 1:50 000.

Bajc, A.F. and Paterson, J.T. 1992a. Quaternary geology of the Gravenhurst area, southern Ontario; Ontario Geological Survey, Open File Map 195, scale 1:50 000.

Bajc, A.F. and Paterson, J.T. 1992b. Quaternary geology of the Penetanguishene and Christian Island areas, southern Ontario; Ontario Geological Survey, Open File Map 194, scale 1:50 000.

Barnett, P.J. 1980. Quaternary geology of the Fort Coulonge area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2367, scale 1:50 000.

Barnett, P.J. 1985. Quaternary geology of the Bancroft area, southern Ontario; Ontario Geological Survey, Map 2500, scale 1:50 000.

Barnett, P.J. 1997. Quaternary geology, eastern half of the Barrie and Elmvale areas; Ontario Geological Survey, Map 2645, scale 1:50 000.

Barnett, P.J. 1998, Quaternary geology of the Port Burwell area, southern Ontario; Ontario Geological Survey, Map 2601, scale 1:50 000.

Barnett, P.J. and Ainsworth, B. 1982. Quaternary geology of the Brudenell area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2558, scale 1:50 000.

Barnett, P.J. and Ainsworth, B. 1989. Quaternary geology of the Golden Lake area, Renfrew County; Ontario Geological Survey, Preliminary Map P. 3125, scale 1:50 000.

Barnett, P.J. and Clarke, W.S. 1980a. Quaternary geology of the Cobden area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2366, scale 1:50 000.

Barnett, P.J. and Clarke, W.S. 1980b. Quaternary geology of the Renfrew area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2365, scale 1:50 000.

Barnett, P.J., Dodge, J.E.P. and Henderson, I.G. 1996. Quaternary geology, Scugog area, Ontario; Ontario Geological Survey, Map 2644, scale 1:50 000.

Barnett, P.J., Dodge, J.E.P., McCrae, M.K. and Stuart, A. 1999. Quaternary geology, Newmarket area, Ontario; Ontario Geological Survey, Map 2562, scale 1:50 000.

Barnett, P.J. and Girard, C.K. 1982. Quaternary geology of the Tillsonburg area, southern Ontario; Ontario Geological Survey, Map 2473, scale 1:50 000.

Barnett, P .J., Girard, C.K. and Watt, A.K. 1976. Quaternary geology of the Simcoe area, southern Ontario; Ontario Geological Survey, Map 2369, scale 1:50 000.

Barnett, P.J. and Leyland, J.G. 1988. Quaternary geology of the Pembroke area, Renfrew County; Ontario Geological Survey, Preliminary Map P. 3124, scale 1:50 000.

Barnett, P.J. and Mate, D.J. 1998. Quaternary geology of the Beaverton area, Ontario; Ontario Geological Survey, Map 2560, scale 1:50 000.

Barnett, P.J. and Zilans, A. 1998. Quaternary geology of the Long Point area, southern Ontario; Ontario Geological Survey, Map 2600, scale 1:50 000.

Bélanger, J R, Moore, A and Prégent, A, 1997. Surficial geology, digital map, Huntingdon, Quebec-Ontario (31G/1), Open File 3480, scale 1:50 000.

Brennand, T.A. 1997a. Surficial geology of the Oshawa area, NTS 30M/15, southern Ontario; Geological Survey of Canada, Open File 3331, scale 1:50 000.

Brennand, T.A. 1997b. Surficial geology of the Port Hope area, NTS 30M/16, southern Ontario; Geological Survey of Canada, Open File 3298, scale 1:50 000.

Burwasser, G.J. 1974. Quaternary geology of the Collingwood-Nottawasaga area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 0919, scale 1:50 000.

Burwasser, G.J. and Boyd, S.T. 1974. Quaternary geology of the Orr Lake area (western half)-Nottawasaga area (eastern half), southern Ontario; Ontario Geological Survey, Preliminary Map P. 0975, scale 1:50 000.

Burwasser, G.J. and Cairns, B.D. 1974. Quaternary geology of the Barrie area (western half), southern Ontario; Ontario Geological Survey, Preliminary Map P. 0978, scale 1:50 000.

Cooper, A.J. 1977a. Quaternary geology of the Parkhill area, southern Ontario; Ontario Geological Survey, Map 2402, scale 1:50 000.

Cooper, A.J. 1977b. Quaternary geology of the Grand Bend area, southern Ontario; Ontario Geological Survey, Map 2400, scale 1:50 000.

Cooper, A.J. and Baker, C.L. 1978. Quaternary geology of the Bothwell-Ridgetown area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 1973, scale 1:50 000.

Cooper, A.J., Baker, C.L. and Fitzgerald, W.D. 1978. Quaternary geology of the Strathroy area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 1972, scale 1:50 000.

Cooper, A.J. and Fitzgerald, W.D. 1977. Quaternary geology of the Goderich area, southern Ontario; Ontario Geological Survey, Preliminary Map P.1232, scale 1:50 000.

Cooper, A.J., Fitzgerald, W.D. and Clue, J. 1977. Quaternary geology of the Seaforth area, southern Ontario; Ontario Geological Survey, Preliminary Map P.1233, scale 1:50 000.

Cowan, W.R. 1972. Pleistocene geology of the Brantford area, southern Ontario; Ontario Geological Survey, Map 2240, scale 1:63 360.

Cowan, W.R. 1973. Quaternary geology of the Woodstock area, southern Ontario; Ontario Geological Survey, Map 2281, scale 1:63 360.

Cowan, W.R. 1979. Quaternary geology of the Palmerston area, southern Ontario; Ontario Geological Survey, Report 187, 64p; With Map 2383, scale 1:50 000.

Cowan, W.R., Cooper, A.J. and Pinch, J.J. 1986. Quaternary geology of the Wingham-Lucknow area, Southern Ontario; Ontario Geological Survey, Preliminary Map P.2957, scale 1:50 000.

Cowan, W.R. and Pinch, J.J. 1986. Quaternary geology of the Walkerton-Kincardine area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2956, scale 1:50 000.

Cowan, W.R. and Sharpe, D.R. 2007. Surficial geology, Bruce Peninsula, southern Ontario; Ontario Geological Survey, Map 2679, scale 1:100 000.

Cowan, W.R., and Sharpe, D.R. 1976. Quaternary geology of the Orangeville area, southern Ontario; Ontario Geological Survey, Map 2326, scale 1:50 000.

Dreimanis, A. 1964. Pleistocene geology of the St. Thomas area (west half), southern Ontario; Ontario Geological Survey, Preliminary Map P.0238, scale 1:50 000.

Dreimanis, A. 1970. Pleistocene geology of the St. Thomas area (east half), southern Ontario; Ontario Geological Survey, Preliminary Map P.0606, scale 1:50 000.

Dreimanis, A. and Barnett, P.J. 1985. Quaternary geology of the Port Stanley area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2827, scale 1:50 000.

Feenstra, B.H. 1974. Quaternary geology of the Dunnville area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 0981, scale 1:50 000.

Feenstra, B.H. 1975. Quaternary geology of the Grimsby area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 0993, scale 1:50 000.

Feenstra, B.H. 1984. Quaternary geology of the Niagara-Welland areas, southern Ontario; Ontario Geological Survey, Map 2496, scale 1:50 000.

Feenstra, B.H. 1994. Quaternary geology of the Markdale area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 3251, scale 1:50 000.

Feenstra, B.H. Quaternary geology of the Owen Sound area, Ontario; Ontario Geological Survey, Unpublished map, scale 1:50 000.

Finamore, P.F. and Bajc, A.F. 1983. Quaternary geology of the Fenelon Falls area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2596, scale 1:50 000.

Finamore, P.F. and Bajc, A.F. 1984. Quaternary geology of the Orillia area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2697, scale 1:50 000.

Finamore, P.F. and Courtney, S.J. 1982. Quaternary geology of the Coe Hill area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2536, scale 1:50 000.

Fitzgerald, W.D. and Hradsky, M. 1980. Quaternary geology of the Wallaceburg-St. Clair Flats area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2368, scale 1:50 000.

Fitzgerald, W.D., Janicki, E. and Storrison, D.J. 1979. Quaternary geology of the Sarnia-Brights Grove area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2222, scale 1:50 000.

Ford, M.J. and Bajc, A.F. 1984a. Quaternary geology of the Opeongo Lake area, Nipissing District and Haliburton County; Ontario Geological Survey, Preliminary Map P. 2704, scale 1:50 000.

Ford, M.J. and Bajc, A.F. 1984b. Geological series, Quaternary geology, Whitney area, Nipissing District and Haliburton and Hastings counties; Ontario Geological Survey, Preliminary Map P. 2706, scale 1:50 000.

Ford, M.J. and Lall, R.A. 1983. Quaternary geology, Algonquin Park, northeastern part, Nipissing District and Renfrew County; Ontario Geological Survey, Preliminary Map P. 2609, scale 1:50 000.

Ford, M.J., Lall, R.A. and Bajc, A.F. 1984. Quaternary geology, Algonquin Park, north central part, Nipissing District; Ontario Geological Survey, Preliminary Map P. 2703, scale 1:50 000.

Gadd, N.R. 1963. Surficial Geology, Chalk River, Ontario-Quebec; Geological Survey of Canada, Map 1132A, scale 1:63 360.

Geddes, R.S. and McClenaghan, M.B. 1983. Quaternary geology, Algonquin Park, northwestern part, Nipissing District; Ontario Geological Survey, Preliminary Map P. 2608, scale 1:50 000.

Geddes, R.S. and McClenaghan, M.B. 1984a. Quaternary geology, Algonquin map sheet, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2698, scale 1:50 000.

Geddes, R.S. and McClenaghan, M.B. 1984b. Quaternary geology of the Kawagama Lake area, Nipissing and Muskoka districts and Haliburton County; Ontario Geological Survey, Preliminary Map P. 2705, scale 1:50 000.

Geological Survey of Canada (GSC). Surficial geology of Toronto, Ontario, digital map, Open File 3336 (in process).

Gorrell, G. and Brennand, T.A. 1997. Surficial geology of the Rice Lake area, NTS 31D/1, southern Ontario; Geological Survey of Canada, Open File 3332, scale 1:50 000.

Gravenor, C.P. 1952. Glacial Geology of the Peterborough area (Victoria, Durham and Northumberland Counties), Ontario; Geological Survey of Canada, Preliminary Map 52-14A, scale 1:63 360.

Gravenor, C.P. 1955. Surficial Geology of the Lindsay area (Victoria, Durham, Ontario and Peterborough Counties), Ontario; Geological Survey of Canada, Preliminary Map 54-21, scale 1:63 360.

Gwyn, Q.H.J. 1972. Quaternary geology of the Dundalk area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 0727, scale 1:50 000.

Gwyn, Q.H.J. and Lohse, H. 1973. Quaternary geology of the Alexandria area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 0906, scale 1:50 000.

Henderson, E.P. 1965. Surficial Geology of the Brockville and Mallorytown area, Ontario; Geological Survey of Canada, Map 6-1970, scale 1:63 360.

Henderson, E.P. 1970. Surficial Geology of the Ganonoque-Wolfe Island area, Ontario; Geological Survey of Canada, Map 13-1965, scale 1:63 360.

Henderson, E.P. 1973a. Surficial Geology of the Kingston area (northeast sheet), Ontario; Geological Survey of Canada, Map 7-1972, scale 1:125 000.

Henderson, E.P. 1973b. Surficial Geology of the Kingston area (northwest sheet), Ontario; Geological Survey of Canada, Map 8-1972, scale 1:125 000.

Henderson, P.J. and Kettles, I.M. 1992. Surficial Geology of the Sharbot Lake area, Ontario; Geological Survey of Canada, Map 1799A, scale 1:50 000.

Karrow, P.F. 1968. Pleistocene geology of the Guelph area, southern Ontario; Ontario Geological Survey, Map 2153, scale 1: 63 360.

Karrow, P.F. 1976. Quaternary geology of the St. Mary's area, southern Ontario; Ontario Geological Survey, Map 2366, scale 1:50 000.

Karrow, P.F. 1987a. Quaternary geology of the Cambridge area, southern Ontario; Ontario Geological Survey, Map 2508, scale 1:50 000.

Karrow, P.F. 1987b. Quaternary geology of the Hamilton area, southern Ontario; Ontario Geological Survey, Map 2509, scale 1:50 000.

Karrow, P.F. 1993a. Quaternary geology of the Conestogo area; southern Ontario; Ontario Geological Survey, Map 2558, scale 1:50 000.

Karrow, P.F. 1993b. Quaternary geology of the Stratford area, southern Ontario; Ontario Geological Survey, Map 2559, scale 1:50 000

Karrow, P.F, Easton, J. and Turnbull, D.S. 1990. Quaternary geology of the Brampton area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 3171, scale 1:50 000.

Kaszycki, C.A. 2001a. Surficial Geology, Preliminary Map Gooderham, Ontario; Geological Survey of Canada, Open File 3964, scale 1:50 000.

Kaszycki, C.A. 2001b. Surficial Geology, Preliminary Map Haliburton, Ontario; Geological Survey of Canada, Open File 3966, scale 1:50 000.

Kaszycki, C.A. 2001c. Surficial Geology, Preliminary Map Minden, Ontario; Geological Survey of Canada, Open File 3963, scale 1:50 000.

Kaszycki, C.A. 2001d. Surficial Geology, Preliminary Map Wilberforce, Ontario; Geological Survey of Canada, Open File 3965, scale 1:50 000.

Kelly, R.I. 1998. Quaternary geology of the Chatham-Wheatley areas, southwestern Ontario; Ontario Geological Survey, Map 2557, scale 1:50 000.

Kettles, I.M. 1992a. Surficial Geology, Clyde Forks, Ontario; Geological Survey of Canada, Map 1798A, scale 1:50 000.

Kettles, I.M. 1992b. Surficial Geology, Perth, Ontario; Geological Survey of Canada, Map 1800A, scale 1:50 000.

Kettles, I.M., Henderson, P.J. and Henderson, E.P. 1992. Surficial Geology, Westport, Ontario; Geological Survey of Canada, Map 1801A, scale 1:50 000.

Kor, P.S.G. and Delorme, R.J. 1989a. Quaternary geology of the Key Harbour area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 3145, scale 1:50 000.

Kor, P.S.G. and Delorme, R.J. 1989b.Quaternary geology of the Magnetawan area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 3135, scale 1:50 000.

Kor, P.S.G. and Delorme, R.J. 1989c. Quaternary geology of the Orrville area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 3134, scale 1:50 000.

Kor, P.S.G. and Delorme, R.J. 1989d. Quaternary geology of the Pointe-au-Baril station-Naiscoot River area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 3142, scale 1:50 000.

Kor, P.S.G. and Delorme, R.J. 1990a. Quaternary geology of the Burk's Falls area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 3161, scale 1:50 000.

Kor, P.S.G. and Delorme, R.J. 1990b. Quaternary geology of the South River area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 3160, scale 1:50 000.

Kor, P.S.G. and Miller, M.J. 1987a. Quaternary geology of the Lake Joseph-Sans Souci area, District of Parry Sound and District Municipality of Muskoka; Ontario Geological Survey, Preliminary Map P. 3103, scale 1:50 000.

Kor, P.S.G. and Miller, M.J. 1987b. Quaternary geology of the Parry Sound area, District of Parry Sound; Ontario Geological Survey, Preliminary Map P. 3102, scale 1:50 000.

Leyland, J.G. 1982a. Quaternary geology of the Belleville area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2540, scale 1:50 000.

Leyland, J.G. 1982b. Quaternary geology of the Wellington area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2541, scale 1:50 000.

Leyland, J.G. and Mihychuk, M. 1983. Quaternary geology of the Tweed area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2615, scale 1:50 000.

Leyland, J.G. and Mihychuk, M. 1984a. Quaternary geology of the Campbellford area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2532, scale 1:50 000.

Leyland, J.G. and Mihychuk, M. 1984b. Quaternary geology of the Trenton-Consecon area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2586, scale 1:50 000.

Leyland, J.G. and Russell, T.S. 1983. Quaternary geology of the Bath-Yorkshire Island area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2588, scale 1:50 000.

Leyland, J.G. and Russell, T.S. 1984. Quaternary geology of the Sydenham area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2587, scale 1:50 000.

MacDonald, B.C. 1969. Glacial and interglacial stratigraphy, Hudson Bay Lowland; in Earth Science Symposium on Hudson Bay, Geological Survey of Canada, Paper 68-53, 78-99.

Morris, T.F. 1994a. Quaternary geology, Essex County (East Half), southwestern Ontario; Ontario Geological Survey, Preliminary Map P. 3252, scale 1:50 000.

Morris, T.F. 1994b. Quaternary geology, Essex County (West Half), southwestern Ontario; Ontario Geological Survey, Preliminary Map P. 3253, scale 1:50 000.

Richard, S.H. 1982a. Surficial Geology, Huntingdon, Quebec-Ontario; Geological Survey of Canada, Map 1489A, scale 1:50 000.

Richard, S.H. 1982b. Surficial Geology, Kemptville, Ontario; Geological Survey of Canada, Map 1492A, scale 1:50 000.

Richard, S.H. 1982c. Surficial Geology, Morrisburg, Ontario-New York; Geological Survey of Canada, Map 1493A, scale 1:50 000.

Richard, S.H. 1982d. Surficial Geology, Ottawa, Ontario; Geological Survey of Canada, Map 1506A, scale 1:50 000.

Richard, S.H. 1982e. Surficial Geology, Russell, Ontario; Geological Survey of Canada, Map 1507A, scale 1:50 000.

Richard, S.H. 1982f. Surficial Geology, Vaudreuil, Quebec-Ontario; Geological Survey of Canada, Map 1488A, scale 1:50 000.

Richard, S.H. 1982g. Surficial Geology, Winchester, Ontario; Geological Survey of Canada, Map 1491A, scale 1:50 000.

Richard, S.H. 1984a. Surficial Geology, Arnprior, Ontario-Quebec; Geological Survey of Canada, Map 1599A, scale 1:50 000.

Richard, S.H. 1984b. Surficial Geology, Lachute-Arundel, Quebec-Ontario; Geological Survey of Canada, Map 1577A, scale 1:100 000.

Richard, S.H. 1990. Surficial Geology, Carleton Place, Ontario; Geological Survey of Canada, Map 1681A, scale 1:50 000.

Richard, S.H. 1991. Surficial Geology, Buckingham, Quebec-Ontario; Geological Survey of Canada, Map 1670A, scale 1:100 000.

Russell, H.A. and Dumas, S. 1997. Surficial geology of the Alliston area, NTS 31D/4, southern Ontario; Geological Survey of Canada, Open File 3334, Scale 1:50 000.

Sado, E.V. and Vagners, U.J. 1975. Quaternary geology of the Lucan area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 1048, scale 1:50 000.

Sharpe, D.R. 1977. Quaternary geology of the Merrickville area, southern Ontario; Ontario Geological Survey, Map 2387, scale 1:50 000.

Sharpe, D.R. and Barnett, P.J. 1997. Surficial geology of the Markham area, NTS 30M/14, southern Ontario; Geological Survey of Canada, Open File 3300, Scale 1:50 000.

Sharpe, D.R. and Broster, B.E. 1977. Quaternary geology of the Durham area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 1556, scale 1:50 000.

Sharpe, D.R. and Edwards, W.A.D. 1979. Quaternary geology of the Chelsey-Tiverton area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2314, scale 1:50 000.

Sharpe, D.R. and Jamieson, G.R. 1982. Quaternary geology of the Wiarton area, southern Ontario; Ontario Geological Survey, Preliminary Map P. 2559, scale 1:50 000.

White, O.L. and Karrow, P.F. 1973. Quaternary geology of the Bolton area, southern Ontario; Ontario Geological Survey, Map 2275, scale 1:63 360.

Appendix B: Provincial legend

21 Man-made deposits: fill, sewage lagoon, landfill, urban development
20 Organic deposits: peat, muck, marl
19 Modern alluvial deposits: clay, silt, sand, gravel, may contain organic remains
18 Colluvial deposits: boulders, scree, talus, undifferentiated landslide materials
17 Eolian deposits: fine to very fine sand and silt (loess)
16 Coarse-textured marine deposits: sand, gravel, minor silt and clay
- 16a Deltaic deposits
- 16b Littoral deposits
- 16c Foreshore and basinal deposits

15 Fine-textured marine deposits: silt and clay, minor sand and gravel
14 Coarse-textured lacustrine deposits: sand, gravel, minor silt and clay
- 14a Deltaic deposits
- 14b Littoral deposits
- 14c Foreshore and basinal deposits

13 Fine-textured lacustrine deposits: silt and clay, minor sand and gravel
12 Older alluvial deposits: clay, silt, sand, gravel, may contain organic remains
11 Coarse-textured glaciomarine deposits: sand, gravel, minor silt and clay
- 11a Deltaic deposits
- 11b Littoral deposits
- 11c Foreshore and basinal deposits

10 Fine-textured glaciomarine deposits: silt and clay, minor sand and gravel
- 10a Massive to well laminated
- 10b Interbedded silt and clay and gritty, pebbly flow till and rainout deposits

9 Coarse-textured glaciolacustrine deposits: sand, gravel, minor silt and clay
- 9a Deltaic deposits
- 9b Littoral deposits
- 9c Foreshore and basinal deposits

8 Fine-textured glaciolacustrine deposits: silt and clay, minor sand and gravel
- 8a Massive to well laminated
- 8b Interbedded silt and clay and gritty, pebbly flow till and rainout deposits

7 Glaciofluvial deposits: river deposits and delta topset facies
- 7a Sandy deposits
- 7b Gravelly deposits

6 Ice-contact stratified deposits: sand and gravel, minor silt, clay and till
- 6a In moraines, eskers, kames and crevasse fills
- 6b In subaquatic fans

5 Till:
- 5a Silty sand to sand-textured till on Precambrian terrain
- 5b Stone-poor, sandy silt to silty sand-textured till on Paleozoic terrain
- 5c Stony, sandy silt to silty sand-textured till on Paleozoic terrain
- 5d Clay to silt-textured till (derived from glaciolacustrine deposits or shale)
- 5e Undifferentiated older tills, may include stratified deposits

4 Bedrock-drift complex in Paleozoic terrain:
- 4a Primarily till cover
- 4b Primarily stratified drift cover

3 Paleozoic bedrock:
2 Bedrock-drift complex in Precambrian terrain:
- 2a Primarily till cover
- 2b Primarily stratified drift cover

1 Precambrian bedrock:

Appendix C: Original map legend edits

MAP	DATE	EDIT
P1973	Oct. 25/02	Some small dune ORIG ID-9 change dep_type_code to 9a translate to 17 (Eolian). Edgematch to M2557 & P2368
P2368	Oct. 28/02	Add a unit 8a (Eolian) translates to unit 17 (Eolian). Edgematch with M2557 & P1973
P1973	Oct. 28/02	Add new unit 10a (Edgematch P2368_6 translate to unit 14c). Add 10b, match P2368_7, translate to 12
P0238	Nov. 12/02	Add a unit 6f to legend translate to 6a (provincial) to accommodate ice-contact glaciofluvial unit 4 on adjoining map P2827
P0606	Nov. 12/02	Removed two small polygons unit 6 & 1 unit 3 SW corner. (Field Checked)
P2827	Nov. 13/02	Removed small unit 8 NE corner. (Field Checked)
P0606	Nov. 14/02	Add a unit 6f to legend & translates to 6a (Provincial) to accommodate ice contact glaciofluvial unit 4 on adjoinning map P2827 => P1048
M2473	Nov. 20/02	Add unit 9c (Eolian) to original legend (Prov) translate to unit 17
M2366	Nov. 22/02	Removed a unit 13 to match south edge P1048 Field checked. Removed a unit 13.
P1048	Nov. 22/02	Removed a unit 4.
M2509	Dec. 9/02	Add unit 11a and translate to 8b edgematch P3171
M2558	Dec. 19/02	Add unit 14a (Lacustrine fine sand) translate to 9c edgematch M2383
P1233	Dec. 20/02	Add unit 9a (Lacustrine sd) translate to 9c
P0727	Dec. 23/02	Add unit 6a (Lacustrine silt & clay) translate to 8a match M2326
P2559	Jan. 6/03	Add unit 12 (man-made) translate to unit 21
M2326	Jan. 10/03	Add unit 2 Paleozoic Drift-Complex to match M2275 translate to unit 4
P3171	Jan. 13/03	Add unit 3a Newmarket Till translate to 5b (Newmarket Till) to match M2275 & ORM
P0727	Jan. 14/03	Add unit 1a (Paleozoic Drift Complex) translate to unit 4, Match ORM_1a
P2697	Jan. 20/03	Add unit 10a (Older Alluvium) translate to unit 12, Match M2645_15
M2645	Jan. 20/03	Add unit 1a (Precambrian bedrock drift complex) translate to unit 2, Match OFM194_2 Add unit 2a (Paleozic Bedrock drift complex) translate to unit 4 match P2697_2a
P2697	Jan. 20/03	Add unit 12 (Lacustrine silt & sand) translate to 14c match M2560_11
M2560	Jan. 20/03	Add unit 1b (Paleozoic Bedrock drift) translate to 4 match P2697_2a
OFM195	Jan. 22/03	Add unit 3b (Paleozoic Bedrock drift) translate to 4 match P2697_2a
M5421	Jan. 28/03	Add unit 10 (modern alluvium) translate to unit 19, match M2644_21
M5214	Jan. 28/03	Add unit 7c (glaciolacustrine sand) translate to 9c, match M5421_8a
M5421	Jan. 29/03	Edit translation table, M5421_2rd not used, so changed to 2Li (Paleozoic Bedrock drift) translate to unit 4, match P2596_2a
M5421	Jan. 29/03	Add unit 2Ld (Till over Pa Rock) translate to 4a match P2596_2d
M5421	Jan. 29/03	Add unit 2a (Dummer Till) translate to 5a, match P2596_3b
M131965	Jan. 30/03	Add unit 1g to accomadate till changes (E Ont) Andy
P2367	Jan. 30/03	Add unit 3c to accomadate till changes (Andy)
M131965	Feb. 8/03	Add units 1f (Pre Bedrock drift) ,1e (Paleozoic Bedrock drift) 1f translate tounit 2, 1c translate tounit 4 Paleozoic Bedrock drift
P0975	Feb. 14/03	Add unit 11c (Lacustrine Beach) and translate to 14c to alter 3 polygons to match (original 11b translate to unit 14b) OFM194_13
M5214	Feb. 14/03	Add unit 10a (alluvium) translate to 19 match ORM_10a Add unit 10b (older alluvium) translate to 12 match ORM_10b Add unit 2Li (Paleozoic Bedrock drift) translate tounit 4
HAL	Feb. 21/03	Add unit 2d (paleozoic Bedrock) translate to 3, match P2596_1a.

		Add unit 8 (Till silty sand) translate to 5b match P2596_3a. Add unit 9 (Glaciolacustrine) translate to 8a Match P2596_6a
P2705	March 13/03	Add unit 7a (older Alluvium) translate to 12 match OFM161_8
P3161	March 13/03	Add unit 5a (Glaciolacustrine deltaic) translate to 7a match OFM161_5a
OFM161	March 13/03	Add unit 4c translate to 6a match P3161_4c
P2366	March 24/03	Add unit 10b translate to14c match P2367_10b
EONT	April 5/03	Add unit 2d translate to 6
EONT	April 5/03	Add unit 12a translate to 9a, match M1800A_4b
M2387	April 5/03	Add unit 5a, translate to 11a, match M1800A_5b
M2402	April 10/03	Add unit 14 translate to 14b, match P2222_4e
M1801A	April 11/03	Add unit 4c translate to 9c match M131965_6
P2368	April 15/03	Add unit 6a translate to 14b match M2557_10
P1973	April 15/03	Add 10b, older alluvium translate to 12, mtach P2368_7
P0238	April 15/03	Add unit 6a1 translate to 7a, match P1972_6
P0606	April 15/03	Add unit 6a1 translate to 7a match M2473_5
P1048	April 15/03	Add unit 5b translate to 6a match P0606_6a & P0238_6a
M2281	April 16/03	Add 9c translate to 7b match M2559_12
M2559	April 17/03	Add 12a translate to 7 match M2281_8
M2558	April 17/03	Add 12a. translate to 7 match M2383_7
M2508	April 22/03	Add 7a translate to 7 match M2240_7
M2153	April 22/03	Add 7a translate to 7 match M2326_10
M2326	April 22/03	Add 10a translate to 7b match M2153_7
P3171	April 22/03	Add 2a translate to 4 match M2275_2
P0727	April 22/03	Add 4a translate to 7 match M2326_10
of3334	April 22/03	Add 6c translate to 7a match P0727_5
P2314	April 22/03	Add 6a translate 7 match P2956_7
M5421	April 23/03	Add 7a translate 7 match P2596_5a
OFM195	April 24/03	Add unit 7 translate to 7 match OFM161_5
of3966	April 24/03	Add unit 4a translate to 7a match OFM161_5a
M1801A	April 25/03	Add unit 2a translate to 6a match M131965_3 Add unit 3 translate to 7 match M61970_2
M61970	April 25/03	Add unit 3b translate to 10 match M2387_3
M1800A	April 25/03	Add unit 5 translate to 10 Match M2387_3
M1798A	April 25/03	Add unit 2a translate to 6a match P2365_4
P2586	May 1/03	Add unit 5a translate to 6 match of3332_5
M5214	May 1/03	Add 4a translate to 7b match P2532_6a
P2532	May 1/03	Add 6 translate to 7 match M5214_4 Add 5a translate to 6 match M5214_6
P2536	May 2/03	Add 8 translate to 19 match of3964_7
M2500	May 2/03	Add 4a translate to 6 match of 3965_3b
M2240	May 6/03	Add 10a translate to 8a (Silt) match 5PM of M2369_9
P3252	May 6/03	Add 4a translate to 9b (gravel) match 5PM of M2557_7
M81972	June 2/03	Add Rpa (Paleozoic Rock) translate to unit 3 match P2532_2
M71972	June 5/03	Add Rpa (Paleozoic Rock) translate to unit 3
M81972	June 2/03	Add pa1 (paloezoic bedrock drift) translate to 4
M71972	June 5/03	Add 12 translate to 7b match P2587_6a SPM gravel
M1799A	June 5/03	Add 2a translate to 6a match M71972_3
M81972	June 6/03	Add 12 translate to 7 match

Appendix D: Attributes (sgu_poly)

1. **New_ID:** this attribute will allow the user to create a traditional Quaternary geology map with a standardized provincial legend.

2. **Single_New_ID:** same as above except with single entries.

3. **Prim_Mat:** this attribute provides the user with information regarding the most prevalent material present within a given area and allows the user to create a materials map with no information concerning age, genesis or provenance.

4. **Single_Prim_Mat:** same as above except with single entries.

5. **Prim_Mat_ Mod:** this attribute provides the user with a more refined description of the lithological classification of the primary material.

6. **Single_Pmat_Mod:** same as above except with single entries.

7. **Sec_Mat:** this attribute provides the user information regarding subordinate materials present within a given area.

8. **Prim_Gen:** this attribute provides the user with an interpretation of the depositional environment within which the primary material was deposited.

9. **Single_Prim_Gen:** same as above except with single entries.

10. **Prim_Gen_Mod:** this attribute provides the user with a refined interpretation of the primary genetic modifier.

11. **Single_PGen_Mod:** same as above except with single entries.

12. **Veneer:** this attribute provides the user with information regarding the type of material that forms a thin, discontinuous veneer over the primary material.

13. **Age:** this series of attributes provide the user with information regarding the age of the primary material (Episode/Subepisode/Phase).

    - Episode: A diachronic stratigraphic unit and the proposed late Quaternary sequence stratigraphy consists in a descending order of Hudson, Wisconsin, Sangamon and Illinois in the Great Lakes area in late Quaternary (Johnson et al. 1997).
    - Subepisode: A diachronic stratigraphic unit in a lower order than Episode and the proposed sequence-stratigraphic classification, consists in a descending order of Michigan, Elgin and Ontario in the eastern and northern Great Lakes area in the Wisconsin Episode (Johnson et al. 1997; Karrow et al. 2000).
    - Phase: A diachronic stratigraphic unit in a lower order than Subepisode, and the proposed sequence-stratigraphic classification is listed in the following table in the eastern and northern Great Lakes area (Karrow et al. 2000).

Episode	Subepisode	Phase
Hudson		
Wisconsin	Michigan	Driftwood Abitibi Marquette Gribben Onaway Two Creeks Port Huron Mackinaw Port Bruce Erie Nissouri
	Elgin	Farmdale Brimley
	Ontario	Port Talbot Guidwood Willowvale Greenwood
Sangamon		
Illinois		

14. **Strat_Mod:** this attribute provides the user information regarding the stratigraphic position of the mapped unit. i.e., does the unit occur primarily on the surface or in the subsurface.

15. **Provenance:** this attribute provides the user with information regarding the provenance of a particular till unit (i.e. direction or lobe from which the till is derived).

16. **Carb_Content:** this attribute provides the user with information regarding the carbonate content of till.

Rank	Carbonate percentages
high	>35% matrix carbonate
low	2-10% matrix carbonate
medium	10-35% matrix carbonate
medium-high	>10% matrix carbonate
variable	0-100% matrix carbonate

17. **Formation:** this attribute provides the user with information regarding the formation to which a given primary material belongs (e.g. Tavistock Till, Port Stanley Till, Scarborough Formation).

18. **Permeability:** this attribute provides the user with information about permeability of the sediments in a rank from high, medium to low (see Appendix F).

Appendix E: Permeability ranking system

21 Man-made deposits.....Variable
20 Organic deposits.....High
19 Modern Alluvial deposits.....Variable
18 Colluvial deposits.....Variable
17 Eolian deposits.....Medium-High
16 Coarse-textured marine deposits.....High
16a Deltaic deposits.....High
16b Littoral deposits.....High
16c Foreshore and basinal deposits.....High
15 Fine-textured marine deposits.....Low
14 Coarse-textured lacustrine deposits.....High
14a Deltaic deposits.....High
14b Littoral deposits.....High
14c Foreshore and basinal deposits.....High
13 Fine-textured lacustrine deposits.....Low
12 Older alluvial deposits.....Variable
11 Coarse-textured glaciomarine deposits.....High
11a Deltaic deposits.....High
11b Littoral deposits.....High
11c Foreshore and basinal deposits.....High
10 Fine-textured glaciomarine deposits.....Low
10a Massive-well laminated.....Low
10b Interbedded silt and clay, flow till and rainout deposits.....Low
9 Coarse-textured glaciolacustrine deposits.....High
9a Deltaic deposits.....High
9b Littoral deposits.....High
9c Foreshore and basinal deposits.....High
8 Fine-textured glaciolacustrine deposits.....Low
8a Massive-well laminated.....Low
8b Interbedded silt and clay, flow till and rainout deposits.....Low
7 Glaciofluvial deposits.....High
7a Sandy deposits.....High
7b Gravelly deposits.....High
6 Ice-contact stratified deposits.....High
6a In moraines, eskers, kames and crevasse fills.....High
6b In subaquatic fans.....High
5 Till.....Medium-Low
5a Silty sand-sand-textured till on Precambrian terrain.....Medium
5b Stone-poor, sandy silt to silty sand-textured till on Paleozoic terrain.....Medium-Low
5c Stony, sandy silt to silty sand-textured till on Paleozoic terrain.....Medium
5d Clay to silt-textured till (derived from glaciolacustrine deposits or shale).....Low
5e Undifferentiated older tills, may include stratified deposits.....Variable
4 Bedrock-drift complex in Paleozoic terrane.....Variable
4a Primarily till cover.....Variable
4b Primarily stratified cover.....Variable
3 Paleozoic bedrock.....Variable
2 Bedrock-drift complex in Precambrian terrane.....Variable
2a Primarily till cover.....Variable
2b Primarily stratified cover.....Variable
1 Precambrian bedrock.....Variable

Appendix F: Glossary

abandoned cliff – a sea cliff that is no longer undergoing wave attack, as a result of a relative drop of sea level or progradation at the cliff base. Source: Glossary of Geology, 4th ed.

abandoned channel – (a) a drainage channel along which runoff no longer occurs (b) oxbow. *Source*: *Glossary of Geology, 4th ed.*

abandoned floodplain: a surface or strip of relatively smooth land adjacent to a previously occupied river channel, covered with water when the river overflowed its banks. It is built of alluvium carried by the river during floods and deposited in the sluggish water beyond the influence of the swiftest current. *Source: Glossary of Geology, 4th ed.*

alluvial: pertaining to or composed of alluvium (clay, silt, sand, gravel, organic) or deposited by a stream or running water. *Source: Glossary of Geology, 4th ed.*

anthropogenic: applied to substances, processes, etc. of human origin or that result from human activity. *Source: Oxford Dictionary of Earth Sciences, 2nd ed.*

beach ridge: a low, essentially continuous mound of beach or beach-and-dune material heaped up by the action of waves and currents on the backshore of a beach. It occurs either singly or as one of a series of ridges that roughly parallel the shoreline. *Modified from Glossary of Geology, 4th ed. and National Soil Survey*

bedrock – a general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material. *Source: Glossary of Geology, 4th ed.*

bedrock pressure release ridge: also called *pop-up.* A mass of rock uplifted by reverse slip on two faults that dip toward a common point beneath the rock mass. In fold-thrust belts, pop ups occur where synthetic and antithetic splays together lift part of a thrust hanging wall. *Source: Glossary of Geology, 4th ed.*

bedrock ridge: a long, narrow elevation of the bedrock surface, usually sharp crested with steep sides and forming an extended upland between valleys. The term is used in areas of both hill and mountain relief. *Modified from Glossary of Geology, 4th ed.*

biogenic: a material produced directly by the physiological activities of organisms. *Source: Glossary of Geology, 4th ed.*

blowout: a general term for a small saucer- or cup- or trough-shaped hollow or depression formed by wind erosion on a pre-existing dune or other sand deposit, especially in an area of shifting sand or loose soil, or where protective vegetation is disturbed or destroyed; the adjoining accumulation of sand derived from the depression, where recognizable, is commonly included. *Source: Glossary of Geology, 4th ed.*

bluff: (a) a high bank or bold headland with a broad, precipitous sometimes rounded cliff face overlooking a plain or a body of water; especially on the outside of a stream meander; a river bluff (b) any cliff with a steep broad face. *Source: Glossary of Geology, 4th ed.*

bog: deposits consisting of sphagnum or forest peat formed in an ombrotrophic environment caused by the slightly elevated nature of the bog. They tend to be disassociated from nutrient-rich groundwater or surrounding mineral soils. *Source: Canadian System of Soil Classification, 3rd edition.*

borehole: a circular hole made by drilling; esp. a deep hole of small diameter, such as an oil well or a water well. *Source: Glossary of Geology, 4th ed.*

boulder: clast with a grain size of greater than 256 mm. *Source: Wentworth 1922.*

boulder pavement: (a) an accumulation of boulders produced on a terrace by the eroding action of waves or river currents in removing finer material from littoral or fluvial deposits. (b) a slightly

inclined surface composed of randomly spaced, flat-surfaced, usually frost-shattered blocks resulting from solifluction or other mass movement. (c) a desert pavement consisting of boulders. It also means in glacial geology (d) an accumulation of glacial boulders once contained in a moraine and remaining nearly in their original positions when the finer textured material has been removed by waves and currents. (e) a relatively smooth surface strewn with striated and polished boulders, abraded to flatness by the movement of an overriding glacier. *Source: Glossary of Geology, 4th ed.*

cavettos: curvilinear, undercut channels eroded into steep, commonly vertical or near vertical rock faces. The upper lip is usually sharper than the lower one. Centimetres to tens of centimetres in depth, a few metres in width. Up to tens of metres in length. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

channel: (a) the bed where a natural body of surface water flows or may flow; a natural passageway or depression of perceptible extent containing continuously or periodically flowing water, or forming a connecting link between two bodies of water; a watercourse (b) the deepest or central part of the bed or a stream, containing the main current, and occupied more or less continuously by water; the thalweg (c) a term used in quantitative geomorphology for a line or pattern of lines, without regard to width or depth, in the analysis of streams (d) an abandoned or buried water course represented by stream deposits of gravel and sand (e) an artificial waterway, such as an open conduit, an irrigation ditch or canal, or a floodway (f) an obsolete term for a stream or small river. Source: *Glossary of Geology, 4th ed.*

chattermark: one of a series of small, closely spaced, short curved scars or cracks (smaller than a cresentic fracture) made by vibratory chipping of a firm but brittle bedrock surface by rock fragments carried in the base of a glacier. Each mark is roughly transverse to the direction of ice movement (although a succession of such marks is parallel to that direction), and usually convex toward the direction from which the ice moved (its "horns" point in the direction of ice movement). *Source: Glossary of Geology, 4th ed.*

clay: particle with a grain size of less than 0.002 mm. *Source: Soil Survey Staff 1951.*

coarse-textured: a grain size dominated by sand and gravel-sized particles. As an example, coarse-textured lacustrine deposits consist primarily of sand and gravel or sand with various amounts of gravel. *Derived from Bajc 1992b.*

cobble: clast with a grain size of between 64 and 256 mm *Source: Wentworth 1922.*

colluvial: pertaining to any loose, heterogeneous and incoherent mass of soil material and/or rock fragments deposited by rainwash, sheetwash, or slow continuous downslope creep, usually collected at the base of gentle slopes or hillsides. *Source: Glossary of Geology, 4th ed*.

comma forms : similar to sichelwannen but with only one arm well developed. Proximal slope is normally steeper than the distal slope. Centimetres to tens of centimetres in depth, a few metres in width. Up to tens of metres in length. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

contact: a plane or irregular surface between two types or ages of rock; examples are faults, intrusive borders, bedding planes separating distinct strata, and unconformities. *Source: Glossary of Geology, 4th ed*

crag and tail (stoss and lee): a) an elongate hill or ridge resulting from glaciation, having at the stoss end a steep, often precipitous, face or knob of ice-smoothed resistant bedrock (the crag) obstructing the movement of the glacier, and at the lee end a tapering, streamlined, gentle slope (the tail) of intact weaker rock and/or drift protected by the crag. *Source: Glossary of Geology, 4th ed* The tail is often composed of subglacially deposited till. **b)** streamlined ridges consisting of a "crag" of hard rock at the higher upflow end and a "tail" at the lower, elongated, tapered, gentle slope, downflow end of intact softer rock and sediments. Metres to tens of metres in length; metres in width and height. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

crescentic fractures/scars: a) a crescentic mark in the form of a hyperbolic crack, of larger size (up to 10-12 cm long) than a chattermark; it is convex towards the direction from which the ice moved (its horns point in the direction of ice movement) and consist of a single fracture without removal of any rock. *Source: Glossary of Geology, 4th ed*. **b)** are generally more openly spaced than chattermarks, similarly aligned and open-ended downflow; common on flat surfaces, a few to several centimetres wide to a metre or more in length. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

crest: the highest point or line of a landform, from which the surface slopes downward in opposite directions; esp. the highest point of a mountain or hill, or the highest line or culminating ridge of a range of mountains or hills. *Source: Glossary of Geology, 4th ed.*

crevasse filling: a short, straight ridge of stratified sand and gravel believed to have been deposited in a crevasse of a wasting glacier and left standing after the ice melted; a variety of kame. May also occur as long, sinuous ridges and linear complexes of till or drift. *Source: Glossary of Geology, 4th ed.*

deformation – (a) a general term for the process of folding, faulting, shearing, compression, or extension of the rocks as a result of various earth forces. (b) strain (c) the change in the geometry of a body of rock that occurs as a consequence of stress, e.g. translation, ridge body rotation about an axis, and strain or distortion. Source*: Glossary of Geology, 4th ed.*

deformation structure: a feature that has been folded, faulted, sheared, compressed or extended as a result of forces imparted by actively moving glacial ice. *Derived from Glossary of Geology, 4th ed.*

DeGeer moraine: a) a series of small, parallel or subparallel, closely spaced ridges, oriented transverse to ice movement. They are typically composed of till and intimately associated with subaqueously deposited sediments (i.e. they form in a standing body of water). Each ridge marks the former margin of an intermittently retreating glacier. *Derived from: Glossary of Geology, 4th ed, BC Ministry of Environment, Lands and Parks and Benn and Evans (1998)* **b)** narrow, straight to undulating ridge of unconsolidated sediments, transverse to flow; formed in a subaqueous environment. Generally occur in groups, commonly with a uniform spacing. Metres in height, metres to tens of metres in width, tens to hundreds of metres, rarely kilometres, in length. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

delta: mass of sediment built out into standing water (freshwater or marine) by subaerial streams, by a combination of fluvial processes above the water line and some combination of gravitational mass movement and suspension settling below water level. *Source: Benn and Evans 1998.*

diamicton: a comprehensive, nongenetic term for a nonsorted or poorly sorted, nonlithified sediment that contains a wide range of particle sizes. *Glossary of Geology, 4th ed.*

drumlin: A low, smooth, elongated oval hill, mound, or ridge of compact till that has a core of bedrock or drift. It usually has a blunt nose facing the direction from which the ice approached and a gentler slope tapering in the other direction. The longest axis is parallel to the general direction of glacier flow. Drumlins are produced in subglacial environment through a combination of erosion and deposition*. Modified from National Soil Survey*.

drumlinoid ridge: an elongated ridge similar to drumlins but which exhibits a less well defined asymmetrical profile which does not indicate a flow direction. Generally occur in groups. Hundreds of metres to kilometres in length; tens of metres in height and width. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database.*

dune: a low mound, ridge, bank or hill of loose, wind-blown granular material (generally sand) either bare or covered with vegetation and capable of movement from place to place. *Modified from Glossary of Geology, 4th ed.*

eolian: pertaining to the wind, especially said of such deposits as loess and dune sand, of sedimentary structures such as wind-formed ripple marks, or erosion and deposition accomplished by the wind. *Source: Glossary of Geology, 4th ed*

episode: A diachronic stratigraphic unit and the proposed late Quaternary sequence stratigraphy consists in a descending order of Hudson, Wisconsin, Sangamon and Illinois in the Great Lakes area in late Quaternary. *Adopted from North American Stratigraphic Code 1983; Johnson et al. 1997.*

escarpment: (a) a long, more or less continuous cliff or relatively steep slope facing in one general direction, breaking the continuity of the land by separating two level or gently sloping surfaces, and produced by erosion or by faulting. The term is often used synonymously with scarp, although escarpment is more often applied to a cliff formed by differential erosion. (b) a steep, abrupt face of rock, often presented by the highest strata in a line of cliffs, and generally marking the outcrop of a resistant layer occurring in a series of gently dipping softer strata; specifically the steep face of a cuesta. *Source: Glossary of Geology, 4th ed*

esker: a long, narrow, sinuous, steep-sided ridge composed of irregularly stratified sand and gravel that was deposited by a subglacial or englacial stream flowing between ice walls or in an ice tunnel of a stagnant or retreating glacier, and was left behind when the ice melted. It may be branching and is often discontinuous, and its course is usually at a high angle to the edge of the glacier. Eskers range in length from less than 100 m to more than 500 km (if gaps are included), and in height from 3 to more than 200 m. *Source: Glossary of Geology, 4th ed.*

fan: a gently sloping, fan-shaped mass of detritus forming a section of a very low cone commonly at a place where there is a notable decrease in gradient. *Source: Glossary of Geology, 4th ed*

fill: man-made deposits of natural earth materials and waste materials. *Source: Glossary of Geology, 4th ed*

fen: deposits consisting of sedge peat derived primarily from sedges with inclusions of partially decayed stems of shrubs formed in a eutrophic environment due to the close association of the material with mineral-rich waters. *Source: Canadian System of Soil Classification, 3rd edition.*

fine-textured: a grain size dominated by silt and clay-sized particles. As an example, *fine-textured* lacustrine deposits consist primarily of silt and clay*. Derived from Bajc 1992b.*

flute or fluting: an elongate, streamlined ridge of sediment aligned parallel to former glacier flow in subglacial environment. They are generally a few tens of centimetres to a few metres high and wide, and occur in groups of subparallel ridges on many modern glacier forelands and some older glacier landscapes. Flutings commonly begin downglacier from lodged boulders or clast clusters. They tend to consist of subglacial till, although cores of deformed pre-existing sediments have been reported. *Source: Benn and Evans 1998.*

fluvial: of or pertaining to a river or rivers; produced by the action of a stream or river. *Source: Glossary of Geology, 4th ed*

foreshore/basinal: the zone of deposition generally not affected by nearshore processes such as wave action, longshore drift and tidal currents.

formation: the fundamental unit in lithostratigraphic classification. A formation is a body of rock identified by lithic characteristics and stratigraphic position; it is prevailingly but not necessarily tabular and is mappable at the Earth's surface or traceable in the subsurface *Source: North American Stratigraphic Code 1983*. Many till formations have been defined such as Catfish Creek, Tavistock, Port Stanley, Elma, Rannoch, Newmarket, St Joseph and Halton tills in the Great Lakes area and their summary can be found in *Barnett 1992*.

fossil: any remains, trace, or imprint of a plant or animal that has been preserved in the Earth's crust since some past geologic or prehistoric time. *Source: Glossary of Geology, 4th ed.*

furrows: linear troughs. Much longer than wide carrying a variety of secondary forms and remnant ridges on their beds and walls. Rims are straight when viewed over the full length of furrows but are usually sinuous in detail. Centimetres to tens of centimetres in depth, a few metres in width. Up to tens of metres in length. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

gas seepage feature: circular features visible on aerial photographs as light coloured, donut-shaped rings with no topographic expression, generally less than 20 m in diameter and believed to be

associated with the vertical migration of hydrocarbons from the bedrock surface, up through Quaternary cover to the surface. These features have also been observed on quarry floors as dark-coloured rings. *Source: Morris (1994).*

glacial: (a) pertaining to processes such as transportion and deposition by or from glacier ice with little or no subsequent sorting by water. *Source: Dreimanis (1982)*. (b) refering to cold conditions related to glaciers. Source:

glaciofluvial: pertaining to the meltwater streams flowing from wasting glacier ice and especially said of the deposits and landforms produced by such streams, as kame terraces and outwash plains; relating to the combined action of glaciers and streams. *Glossary of Geology, 4th ed*.

glaciolacustrine: pertaining to, derived from, or deposited in glacial lakes; especially said of the deposits and landforms composed of suspended material brought by meltwater streams flowing into lakes bordering the glacier. *Source: Glossary of Geology, 4th ed*

glaciomarine: pertaining to, derived from, or deposited in glacial marine settings; especially said of the deposits and landforms composed of suspended material brought by meltwater streams flowing into marine settings bordering the glacier. *Source: after Glossary of Geology, 4th ed.*

granule: clast with a grain size ranging between 2 and 4 mm. *Source: Wentworth 1922.*

gravel: particles ranging in size from pebbles (2 mm) to boulders (> 256 mm). *Source: Canadian System of Soil Classification, 3rd edition.*

grooves: linear depressions in rock with parallel edges, generally straight, oriented parallel to flow. Grooves range in size from a few centimetres deep and wide and a few metres long, to depths and widths in excess of one meter and several tens of metres long. *Modified from Benn and Evans 1998.*

hummock: any one of rounded or conical knolls, mounds or hillocks formed in a variety of geomorphic processes although some geomorphologists often use this term to indicate those formed in permafrost environment. *Syn*. Hammock. *Derived from Glossary of Geology, 4th ed* and *Benn and Evans 1998.*

hillock: a small, low hill, generally between 3 to 30 m in height and slopes between 5 and 50% (e.g., bigger than a mound but smaller than a hill). *Modified from Glossary of Geology, 4th ed and National Soil Survey*.

hummocky: abounding in hummocks, or uneven; said of topographic landforms, as a hummocky dune, and of hummocked ice. *Source: Glossary of Geology, 4th ed*

hummocky topography: a term used to describe an irregular landscape consisting of hillocks and hollows. Amplitude of irregularity is generally greater than 5 m and, in some cases, greater than 20 m. *Modified from Glossary of Geology, 4th ed* and *Canadian System of Soil Classification, 3rd ed.*

iceberg keel mark: features such as grooves and troughs left by a partially grounded mass of drifting glacier ice or iceberg calved from a glacier margin in a lake or marine basin. See *Iceberg scour*. *Derived from Benn and Evans 1998.*

iceberg scour: groove or trough cut by a partially grounded mass of drifting glacier ice or iceberg calved from a glacier margin in a lake or marine basin. Iceberg scours are generally observed on aerial photographs and can attain lengths up to several kilometres. *Derived from Benn and Evans 1998.*

ice-contact: of or pertaining to a deposit deposited by glacial meltwater, adjacent or in direct contact with glacier ice. *Source: Barnett 1992.*

ice-contact delta: a delta built out directly from a glacier margin. *Source: Benn and Evans 1998.*

ice-contact slope: the steep slope of sediment that was deposited against a wall of glacier ice, marking the former position of an ice margin; an irregular scarp against which ice once rested. *Source: Glossary of Geology, 4th ed*

ice-contact stratified deposits: stratified deposits of sand and gravel deposited in contact with melting glacier ice, such as an esker, a kame, a kame terrace or a feature marked by numerous kettles. *Source: Glossary of Geology, 4th ed.*

ice-wedge cast: wedge-shaped feature produced by the infilling of thermal contraction cracks with water and snow producing vertically foliated ice. Sediments on either side of the ice body may become deformed and bent upwards. When the ground thaws and the ice melts, the wedge is infilled with material which slumps in from the sides and from the surface. Ice wedge casts are indicative of permafrost conditions. *Source: French (1976).*

interlobate moraine: ridge of unconsolidated sediment that defines ice marginal positions between lobes of ice. Generally metres or tens of metres in height and hundreds metres to several kilometres in length, exceptionally hundreds of kilometres. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

kame: a low mound, knob, or short irregular ridge, composed of stratified sand and gravel deposited by a subglacial stream as a fan or delta at the margin of a melting glacier; by a supraglacial stream in a low place or hole or crevasse on the surface of the glacier; or as a ponded deposit on the surface or at the margin of stagnant ice. *Source: Glossary of Geology, 4th ed*

karst (solution weathering feature): a type of topography that is formed on limestone, gypsum, and other rocks by dissolution, and that is characterized by sinkholes, caves, and underground drainage. *Source: Glossary of Geology, 4th ed*

karst (clint and gryke topography): observed on limestone plains where slabs of limestone that are separated from adjacent slabs by solution fissures developed along joints. *Source: Glossary of Geology, 4th ed*

kettle: a steep-sided, bowl-shaped depression commonly without surface drainage (closed depression) in drift deposits, often containing a lake or swamp, and formed by the melting of a large, detached block of stagnant ice that had been wholly or partly buried in the drift. Kettles range in depth from 1 to tens of metres, and with diametres up to 13 km. *Source: Glossary of Geology, 4th ed*

lacustrine: pertaining to sediments deposited on a lake bed; or beach and other nearshore sediments transported and deposited by wave action. Examples: lake sediments and beaches. *Source: Canadian System of Soil Classification, 3rd edition.*

landfill: a land site where municipal solid waste is buried in a manner engineered to minimize environmental degradation. Commonly the waste is compacted and periodically covered with soil or other earth material. *Source: Glossary of Geology, 4th ed*

landslide: a general term covering a wide variety of mass-movement landforms and processes involving the downslope transport, under gravitational influence, of soil and rock material en masse. Usually the displaced material moves over a relatively confined zone or surface of shear. *Source: Glossary of Geology, 4th ed.*

landslide scar: a bare or relatively bare surface or niche on the side of a mountain or other steep slope, left by the removal of earth material from the place where a landslide started. *Source: Glossary of Geology, 4th ed.*

lateral moraine: ridge like feature formed near or at the side margin of a mountain glacier. Metres to tens of metres in height and width. Hundreds of metres to kilometres in length. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database.*

lateral meltwater channel (or side hill channel): channel interpreted to have formed in an ice marginal position; one side of the channel was generally ice supported. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

littoral/foreshore: referring to the deposits laid down in the nearshore environment, includes shoreface, beach ridges, bars, etc

longshore bar: a low, elongate sand ridge, built chiefly by wave action, occurring at some distance from, and extending generally parallel with, the shoreline, being submerged at least by high tides, and typically separated from the beach by an intervening trough. Syn: ball; offshore bar; submarine bar; barrier bar. *Source: Glossary of Geology, 4th ed*

moraine: (a) [material] A mound, ridge, or other topographically distinct accumulation of unsorted, unstratified glacial drift, predominantly till, deposited primarily by the direct action of glacier ice, in a variety of landforms. (b) [landform] A general term for a landform composed mainly of till that has been deposited by a glacier; a kame moraine is a type of moraine similar in exterior form to other types of moraines but composed mainly of stratified outwash materials. Types of moraine include: end, ground, kame, lateral, recessional, and terminal moraines. *Source: National Soil Survey.*

marl: a soft, greyish to white, earthy or powdery, usually impure calcium carbonate precipitated on the bottom of present-day freshwater lakes and ponds largely through the chemical action of aquatic plants, or forming deposits that underlie marshes, swamps and bogs that occupy the sites of former lakes. The calcium carbonate can range from 90% to less than 30%. *Source: Glossary of Geology, 4th ed*

megaripple: a large sand wave or ripple-like feature having a wavelength greater than 1 m or a ripple height greater than 10 cm composed of sand, and formed in a subaqueous environment. *Source: Glossary of Geology, 4th ed*

meltwater: water derived from the melting of snow or ice, especially the stream flowing in, under, or from melting glacier ice. *Source: Glossary of Geology, 4th ed*

meltwater channel: a natural passageway or depression of perceptible extent within which water derived from the melting of glacier ice travels. *Modified from: Glossary of Geology, 4th ed*

modern floodplain: a surface or strip of relatively smooth land adjacent to a river channel, covered with water when the river overflows its banks. It is built of alluvium carried by the river during floods and deposited in the sluggish water beyond the influence of the swiftest current. *Source: Glossary of Geology, 4th ed.*

moraine: a) a wide variety of depositional features collectively defining a linear landform produced by the complex interactions of numerous glaciogenic and paraglacial processes at the present and former margins of glaciers and ice sheets. The outermost moraine formed at the limit of a glacier advance is known as a *terminal moraine*. Younger moraines nested within a terminal moraine are termed *recessional moraines*. *Modified from: Benn and Evans (1998)* **b)** ridge of unconsolidated sediment, transverse to flow, which defines an ice front position. Generally metres or tens of metres in height and hundreds of metres to several kilometres in length, occasionally hundreds of kilometres. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

muschelbruche: mussel-shell-shaped, shallow depressions with sharp convex upflow rims and indistinct downflow margins merging imperceptibly with adjacent rock surface. Proximal slope is normally steeper than the distal slope. There are generally no other distinguishing, internal form elements. Centimetres to tens of centimetres in depth, a few metres in width. Up to tens of metres in length. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

nail-head striation: a short, blunt striation broad and deep at one end and tapering and shallow at the other, flow is usually from the tapered end toward the blunt end. A few millimetres in width and depth, centimetres in length. Sometimes, it is called wedge striation. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

nearshore: extending seaward or lakeward an indefinite but generally short distance from the shoreline; specifically said of the indefinite zone extending from the low-water shoreline well beyond the

breaker zone, defining the area of nearshore currents, and including the inshore zone and part of the offshore zone. Nearshore is sometimes defined as extending across the area of longshore bars. Depths are generally less than 5 fathoms (10m). *Source: Glossary of Geology, 4th ed*

nearshore bar: a low, elongate sand and/or gravel ridge, built primarily by wave action, occurring at some distance from, and generally parallel to the shoreline, being submerged at least by high tides, and typically separated from the shoreline by an intervening trough. *Modified from: Glossary of Geology, 4th ed*

organic deposits: deposits arising from biological activity (peat, muck, marl, etc). *Source: Cooper 1974.*

outcrop: that part of a geologic formation or structure that appears at the surface of the earth. Bedrock that occurs at the ground surface with little or no unconsolidated sediment cover. *Source: Glossary of Geology, 4th ed.*

Paleozoic bedrock: bedrock above Precambrian but below Mesozoic bedrocks, ranging between 570 and 240 million years old. *Glossary of Geology, 4th ed.*

patterned ground: a group term for certain well-defined, more or less symmetrical forms, such as circles, polygons, nets, steps and stripes that are characteristic of, but not necessarily confined to, surficial material subject to intense frost action. It is classified according to the type of pattern and the presence or absence of sorting *Source: Glossary of Geology, 4th ed.*

peat: an unconsolidated deposit of semi-carbonized plant remains in a water-saturated environment such as a bog or fen, and of persistently high moisture content (at least 75%). When dried, peat burns freely. *Source: Glossary of Geology, 4th ed.*

pebble: clast with a grain size between 4 and 64 mm. *Source: Wentworth 1922*.

Phase: A diachronic stratigraphic unit in a lower order than Subepisode, and the proposed sequence-stratigraphic classification, e.g. , Erie, , Port Huron, Mackinaw, , Port Bruce andNissouri , in the eastern and northern Great Lakes area. *Derived from North American Stratigraphic Code 1983; Karrow et al. 2000.*

pit: open workings, usually for the extraction of sand and gravel. *Source: adapted from Glossary of Geology, 4th ed*

pop-up: See *bedrock pressure release ridge*.

postglacial: pertaining to the time interval since the total disappearance of continental glaciers in middle latitudes or esp. from a particular area. Source: *Glossary of Geology, 4th ed*

Precambrian bedrock: below Paleozoic bedrock, generally greater than 570 million years old. *Glossary of Geology, 4th ed.*

proglacial channel (or direct overflow channel): channel interpreted to have formed beyond the front of a glacier. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

proglacial outwash: stratified detritus removed or washed from a glacier by meltwater streams and deposited in front of or beyond the end moraine or the margin of an active glacier. The coarser material is deposited nearer to the ice. *Source: Glossary of Geology, 4th ed*

quarry: open workings, usually for the extraction of stone. *Glossary of Geology, 4th ed*

rainout: process of deposition whereby sediment frozen either within and/or on the outer edges of floating ice (ice shelf or icebergs) fall through a column of standing water by gravitational processes resulting in a massive to well laminated deposit. *Derived from Benn and Evans 1998.*

reservoir: an artificial or natural storage place for water, such as a lake or pond, from which the water may be withdrawn, as for irrigation, municipal water supply, or flood control. *Source: Glossary of Geology, 4th ed.*

reverse crescentic fractures/scars: are of similar appearance to crescentic fractures but are of reverse configuration (open-ended upflow), scattered, and tend to occur on the stoss sides of outcrops. A few centimetres in width and length, millimetres in depth. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

ribbed moraine: crescentic ridge of unconsolidated sediment, transverse to flow, whose arcuate forms are aligned with their outer limbs bent down-glacier; occur as fields of coalescing crescentic ridges up to 30 m high and 100 m wide lying transverse to former ice flow. It is believed that they are formed during subglacial deformation processes. Individual ridges have asymmetric profiles with shallow up-ice and steep down-ice flanks giving the impression of a fish-scale texture in aerial photographs. *Syn*. Rogen moraine. *Derived from Benn and Evans (1998).*

roche moutonée: a) a small elongate protruding knob or hillock of bedrock, so sculpted by a large glacier as to have its long axis oriented in the direction of ice movement, an upstream (stoss or scour) side that is gently inclined, smoothly rounded and striated and a downstream (lee or pluck) side that is steep, rough and hackly. It is usually a few metres in height, length and breadth. *Source: Glossary of Geology, 4th ed.* **b)** elongated bedrock outcrop generally striated and polished on the stoss (upflow) side and fractured, quarried, or plucked on the lee (downflow) side. Metres to tens of metres in length; metres in width and height. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

Rogen moraine: See *ribbed moraine*.

Sangamonian Stage: last interglacial.

sand: particle with a grain size ranging between 0.063 and 2 mm. *Source: Wentworth 1922*.

scabland: landscape formed by the fluvial incision of bedrock. Consists of a flat bedrock plain deeply incised by *Source: Benn and Evans 1998.*

scarp: (a) a line of cliffs produced by faulting or by erosion. The term is an abbreviated form of *escarpment*, and the two terms commonly have the same meaning, although "scarp" is more often applied to cliffs formed by faulting (b) a relatively straight, clifflike face or slope of considerable linear extent, breaking the general continuity of the land by separating surfaces lying at different levels, as along the margin of a plateau or mesa. A scarp may be of any height. The term should not be used for a slope of highly irregular outline. *Source: Glossary of Geology, 4th ed.*

sewage lagoon: a land site where liquid human wastes are contained in a manner engineered to minimize environmental degradation. *Source: adapted from Glossary of Geology, 4th ed.*

shore cliff: a cliff at the edge of a body of water or extending along the shore. See *shore bluff.*
Source: *Glossary of Geology, 4th ed.*

Shore bluff or scarp: a cliff that occurs at the edge of a body of water or pre-existing body of water and forms by wave erosional processes. *Modified from: Glossary of Geology, 4th ed.*

sichelwannen: sickle-shaped marks with sharp rims convex upflow and a crescentic main depression extending downflow and wrapping around a median ridge. Lateral depressions may flank the main depression. Proximal slope is normally steeper than the distal slope. Central median ridge. Centimetres to tens of centimetres in depth, a few metres in width. Up to tens of metres in length. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

silt: particle with a grain size ranging between 0.002 and 0.063 mm. *Source: Wentworth 1922.*

solution - the process whereby solid matter dissolves in a liquid; commonly used to refer to the dissolving of limestone (calcium carbonate) in rain and ground water. *Source: BC Ministry of Environment, Lands and Parks*

spindle flutes: Narrow, shallow, spindle-shaped marks longer than they are wide with sharp rims bounding the upflow side. They are pointed in the upflow direction and broaden downflow. Whereas open spindle flutes merge indistinctly downflow with the adjacent surface, closed spindles have sharp rims closing at the upflow and downflow ends. Proximal slope is normally steeper than the distal slope. One rim may be more curved than the other. Centimetres to tens of centimetres in depth, a few metres in width. Up to tens of metres in length. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

stoss and lee: An arrangement of small hills or prominent rocks, in a strongly glaciated area, having gentle slopes on the stoss ("up-ice") side and somewhat steeper, plucked slopes on the lee ("down-ice") side. This arrangement is the opposite of crag and tail. Compare – crag and tail, drumlin, drumlinoid ridge, flute. *Source: National Soil Survey.*

stoss moraine: ramp of sediment, usually compact, fissile, till showing foliation structures, slickensides and joints, inclined toward the up-flow end from steeply inclined bedrock obstacles (crags), may be streamlined parallel to flow; vary in size from roche moutonnée scale to whole rock valley walls tens to hundreds of meter high and kilometer long. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

striation (*plural*: striae): one of multiple scratches or minute lines, generally parallel, inscribed on a rock surface by rock particles frozen into the base of a sliding glacier. An individual striation can be several metres long but generally less than a few millimetres wide. *Derived from: Benn and Evens (1998) and Glossary of Geology, 4th ed.*

subaquatic fan: a subaquatic fan is a fan-shaped body composed of stratified sand and gravel whose apex occurs at the point where glaciofluvial deposits carried within a tunnel at or near the base of a glacier enter a standing body of water. The fan typically contains a core of coarse, open-work gravel that quickly gives way to chaotically bedded to massive "quick" sands containing dispersed floating clasts and abundant dewatering structures reflecting high discharge flows entering the lake. Mid-fan sediments display steep-walled channels containing massive flow deposits, ball and pillow structures, dune and ripple cross bedding and flame structures. Distal fan deposits contain climbing ripple sequences and drape lamination which eventually become indistinguishable from lake basin deposits. *Source: adapted from G.M. Ashley, GSA Short Course 1988.*

Subepisode: A diachronic stratigraphic unit in a lower order than Episode and the proposed sequence-stratigraphic classification, consists in a descending order of Elgin, Michigan and Ontario in the eastern and northern Great Lakes area in the Wisconsin Episode. *Source: Johnson et al. 1997 and Karrow et al. 2000*.

tailings: those portions of washed or milled ore that are regarded as too poor to be treated further, as distinguished from the concentrates or material of value. *Source: Glossary of Geology, 4th ed.*

talus: rock fragments of any size or shape (usually coarse and angular) derived from and lying at the base of a cliff or very steep rock slope. The accumulated mass of such loose broken rock formed chiefly by falling, rolling, or sliding. *Source: Glossary of Geology, 4th ed.*

terrace: any long, narrow, relatively level or gently inclined surface, generally less broad than a plain, bounded along one edge by a steeper descending slope and along the other by a steeper ascending slope; a large bench or step-like ledge breaking the continuity of a slope. The term is usually applied to both the lower or front slope (the riser) and the flattish surface (the tread), and it commonly denotes a valley-contained, aggradational form composed of unconsolidated material as contrasted with a bench eroded in solid rock. A terrace commonly occurs along the margin and above the level of a body of water, marking a former water level e.g. a stream terrace *Source: Glossary of Geology, 4th ed*

thermokarst: karstlike topographic features produced in a permafrost region by the local melting of ground ice and the subsequent settling of the ground. *Glossary of Geology, 4th ed*

thermokarst topography: an irregular land surface containing cave-in lakes, bogs, caverns, pits and other small depressions formed in a permafrost region by the melting of ground ice. *Source: Glossary of Geology, 4th ed.*

till: a sediment that has been transported and deposited by or from glacier ice with little or no sorting by water. *Source: Dreimanis 1982.* Till is often poorly sorted, commonly containing clasts of many sizes in a variable finer-grained matrix. Till is composed of a mixture of minerals and rock types, some of which may be far-travelled. *Source: Barnett 1992.*

transverse trough: relatively straight troughs arranged perpendicular to flow, lengths are much greater than width. Steep relatively planar upflow slope or lee face below a relatively straight rim. Downflow slope is gentler and normally eroded by shallow stoss-side furrows; generally less than ten metres in length and width. A few centimetres deep. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*

tunnel valley/channel: a) large, over-deepened channel cut into bedrock or sediment, which can attain lengths of greater than 100 km and widths in excess of 4 km. They can occur in isolation or as parts of dendritic or anastamosing patterns extending over very large areas. They share many characteristics with Nye channels, including undulatory bed-long profiles, overdeepened basins along their floors and hanging tributary valleys. Individual tunnel valleys usually have wide, relatively flat bottoms and steep sides, and the numerous troughs that occur along their lengths may be occupied by lakes. They are excavated by subglacial meltwater flowing under hydrostatic pressure. They also tend to terminate at major moraines where they may grade into large subaerial ice-contact fans. *Source: Benn and Evans (1998)* b) channel interpreted to have formed underneath a glacier; commonly with an undulating thalweg. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database* .

variable: mixed depositional environments.

wedge striation: See *nail-head striation*.

washboard moraine: See *DeGeer moraine*.

wetland: a general term for a group of wet habitats, in common use by specialists in wildlife management. It includes areas that are permenently wet and/or intermittently water-covered. *Source: Glossary of Geology, 4th ed*

whaleback (or rock drumlin): elongated bedrock outcrop that resembles the back of a whale. It is similar to a roche moutonnée, but lacks the fractured or quarried side. Metres to tens of metres in length; metres in width and height. *Source: GSC Working Group on the Canadian Glacial Landforms and Flow Indicators Database*