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# Predictive Surficial Materials and Surficial Geology from LANDSAT-7, Upper Carp Lake, NTS 85-P, Northwest Territories

**I. Olthof, D.E. Kerr, S.A. Wolfe, and S. Eagles**

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## ABSTRACT

Surficial materials and surficial geology maps provide important geoscience information required for geological reconstructions, mineral exploration and development, and land use planning in northern Canada. In this study, remote predictive mapping was used to map surficial materials and derive surficial geology for Upper Carp Lake NTS 85-P, located within the Slave Geological Province. The maps were generated using radiometrically balanced LANDSAT 7 imagery and ancillary data in conjunction with knowledge gained from field observations, airphoto interpretation and legacy datasets. This Open File contains graphical and digital georeferenced versions of the predictive maps. A printable version of the predictive surficial geology map is provided in pdf format (map scale 1:125 000).

# TABLE OF CONTENTS

Page

## LIST OF FIGURES

Page

## LIST OF TABLES

# 1. INTRODUCTION

Despite the detailed knowledge of bedrock geology in the mineral-rich Slave Geological Province, knowledge of surficial materials and surficial geology is lacking. This lack of geoscience information limits the ability to identify terrain risks associated with various surficial materials along proposed and existing infrastructure corridors (e.g. northern roads). Surficial maps also play a vital role in mineral exploration (e.g. drift prospecting and bedrock mapping), and in the identification of granular aggregates.

Natural Resources Canada has begun to use Remote Predictive Mapping (RPM) to map surficial materials (Grunsky et al., 2006; Brown et al., 2007; Harris, 2008; Stevens et al., 2012) and bedrock (Harris et al., 2010) over large areas where existing geological knowledge is insufficient. These RPM map products provide a first order assessment of surficial materials and bedrock, which can guide traditional field mapping and provide regional information for geotechnical investigations and mineral exploration.

A remote predictive surficial materials map has been derived for the Upper Carp Lake map sheet NTS 85-P, as part of research conducted through Great Slave-TRACS (Transportation Risk in the Arctic to Climatic Sensitivity) and GEM (Geo-mapping for Energy and Minerals). In addition, a predictive surficial geology map that interprets the origin of the sediment deposits has been derived from the surficial materials map. This Open File contains graphical and digital georeferenced versions of the predictive maps for Upper Carp Lake NTS 85-P. A printable surficial geology map for NTS 85-P is provided in pdf format at a scale of 1:125 000.

## 1.1. Regional Surficial Geology

The Upper Carp Lake map sheet (NTS 85-P) is located within the south-central part of the Slave Geological Province of the Northwest Territories (Figure 1). The terrain mainly consists of exposed bedrock, open to dense forests of black spruce, jack pine, and paper birch mixed with marshes, fens and peat bogs in low-lying areas. The region is located within the extensive discontinuous permafrost zone and the treeline to tundra transition that occurs within the northwestern portion of the map sheet from southeast to northwest. Fires predominately occur below treeline in the forested region along the southwestern portion of the map sheet as shown in Figure 1 and most pre-date 2000 AD.

The regional geological information indicates the last glacial episode was the Late Wisconsin glaciation, which reached its maximum extent about 18,000 BP. The Yellowknife region was ice covered to about 11,000 BP and became ice-free by about 10,000 BP (Dyke and Prest, 1987). Paleo ice flow was generally to the southwest, as evident by striae and fluted bedrock measurements (Kerr, 1990, 2006) and the orientation of eskers and drumlinoid features. With the retreat of ice in the region, a large glacial lake (Glacial Lake McConnell) occupied the Great Bear and Great Slave basins, up to an elevation of 280 m (Craig, 1965; Smith, 1994) in the western part of the basin, and up to 320-350 m in the easternmost section of the basin (Kerr et al., 2014), resulting in the deposition of fine-grained glaciolacustrine sediments below this elevation. Wave-washed bedrock and reworked glacial and glaciofluvial sediments are also present, predominantly in the southwest portion of the map sheet. Till increases in thickness and distribution in the western and northwestern regions of the map sheet.

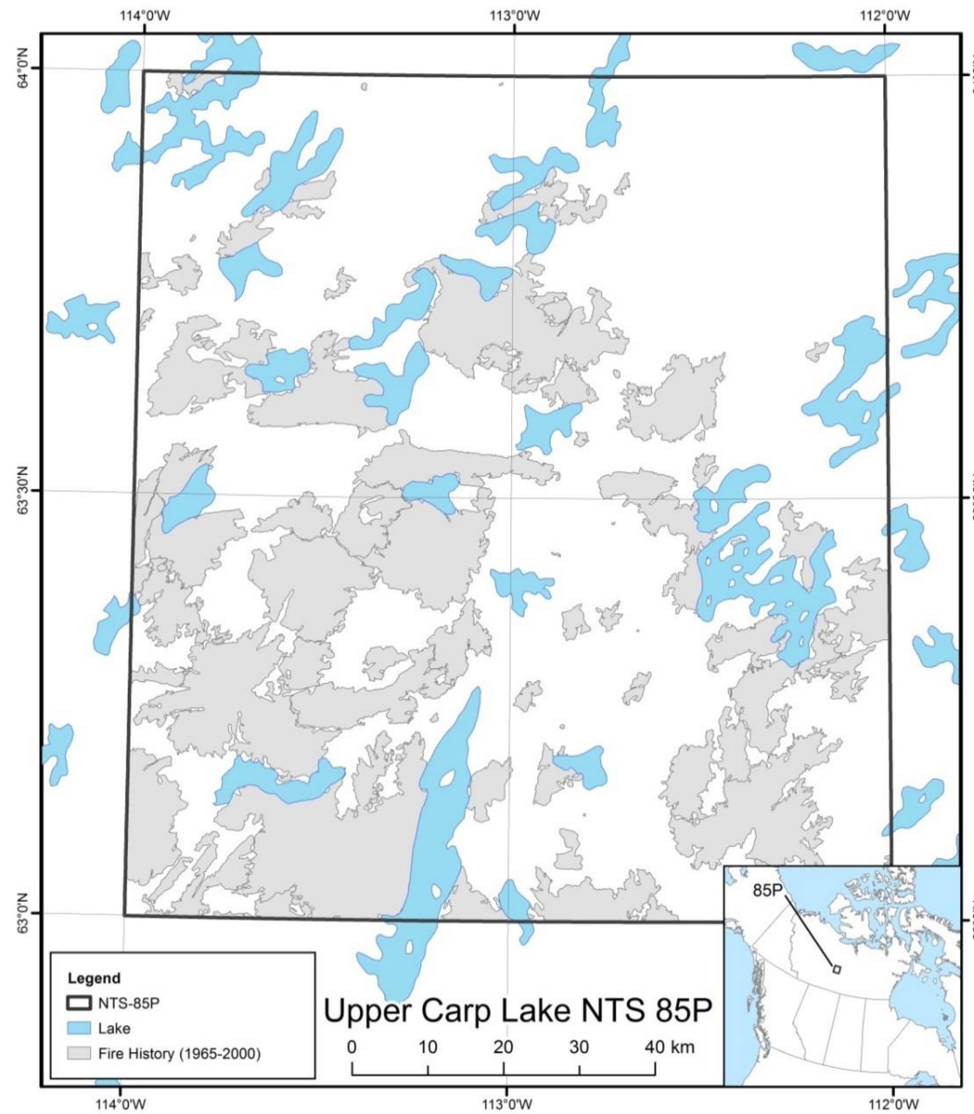


**Figure 1.** Study area map showing the location of Upper Carp Lake NTS 85-P (solid back line) and historical forest fire distribution.

Existing surficial maps for this area include information at a national scale 1:5M (Fulton, 1995) and regional scale at 1:1M (Aylsworth and Shilts, 1989). A reconnaissance map of the Yellowknife River basin at 1:250K has also been produced for the region (Kerr, 1990). However because of their scale, these maps are inadequate for most applications, such as geological reconstructions, mineral exploration, resource development and government land use planning. Remote predictive surficial materials and surficial geology maps have been published recently for Hearne Lake NTS 85-I, located immediately to the south of the present study area (Stevens et al., 2012).

## 1.2. Remote Predictive Mapping (RPM)

RPM integrates multiple remotely sensed datasets to classify surficial material units based on statistically robust models built from user-defined training areas (Figure 2). The integration of multiple types of remotely sensed data attempts to improve map accuracy by increasing the distinction between each training class (surficial material type). From these predictive maps and field data, predictive surficial geology maps can be generated to infer the origins and environments into which the materials were deposited.

A predictive map does not represent geological truth, but rather an estimate of what may be present on the ground, based on the signatures derived from the interpreted data (geophysical, geochemical, remotely sensed). Traditional geological maps derived from airphoto interpretation are normally used in this process to construct the classification models and independently validate the resulting map. It should be recognized that all maps, including those based on airphoto interpretations, inherently contain some form of spatial and/or classification error.

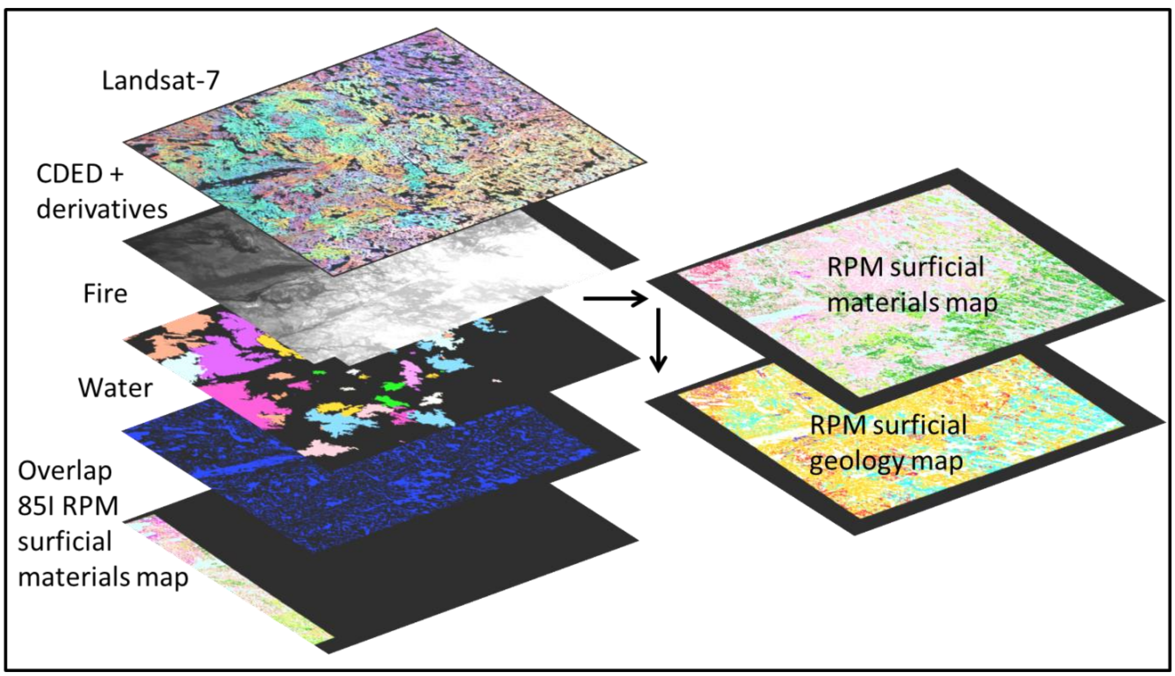


**Figure 2.** Schematic diagram showing the integrations of multiple remotely sensed datasets used to produce surficial materials and derived surficial geology maps. The data layers used in the analysis are based on the availability and usefulness of various sources of data.

## 2. REMOTE PREDICTIVE MAPPING APPROACH (NTS 85-P)

The RPM methodology adopted for mapping NTS 85-P was based on the availability of remote sensing data and the authors' field experience of surficial materials and geology found in the region. Mapping was undertaken using LANDSAT 7 imagery (bands 2,3,4,5 and 7 at 30 m spatial resolution). The LANDSAT 7 imagery was downloaded from Glovis (http://glovis.usgs.gov/) and GeoBase (http://www.geobase.ca/). Each LANDSAT scene was radiometrically balanced using robust regression applied to overlap regions between adjacent scenes.

The overall classification approach involved the use of decision trees trained on overlapping data between the present 85-P area, and the 85-I RPM surficial map located immediately to the south. Decision trees were chosen as the classification algorithm due to their ability to handle large training datasets irrespective of their statistical distributions. Satellite imagery and ancillary data in 85-P were trained to predict surficial classes in the 85-I map based on a large number of overlapping pixels between 85-I and satellite and ancillary data that extended beyond 85-P. The resulting classification model was then used to predict surficial materials by applying it to satellite image and ancillary variables mapped over 85-P.

Decision trees are non-parametric classifiers that have an advantage of being able to use both categorical and continuous independent data for classification unlike, for example, the maximum likelihood classifier. The See5™ decision tree algorithm (Quinlan, 1993) was used with cross validation and boosting. Cross validation generates error statistics on a random holdout sample from a single trial, and boosting weights incorrectly classified cases more heavily in the subsequent trial. This process is repeated for the specified number of trials using a different holdout sample each time. The final boosted map is generated using the majority prediction from all trials.

The RPM surficial materials map for 85-I was produced using the robust classification method (Harris et al., 2012) and validated in Stevens et al. (2012), producing an average class accuracy of 81.7% for six surficial classes. The surficial knowledge that is imbedded in that map was used to train 85-P with the objective of generating one seamless map across both sheets. Independent variables included radiometrically balanced Landsat bands 2-5 and 7, while band 1 was discarded due to atmospheric contamination and thermal band 6 was not used due to its limited use for identifying surficial materials. Additional variables included fire age, treated as a discrete variable, elevation as well as derived variables slope, aspect, and elevation texture (a measure of surface roughness), and a wetness index, all treated as continuous variables. Finally, all classified non-water pixels beneath a water body mask were re-assigned to water.

## 2.1. Satellite and Ancillary Data

The Landsat series of satellites has been acquiring medium resolution remotely sensed imagery since 1972, providing the longest satellite data record at this scale. Landsat 7 experienced failure of its scan line corrector in 2003. Prior to that date, it provided full 30 m resolution images every 16 days in six reflectance bands, five of which were used to map surficial materials in map sheet 85-P (Table 1).

**Table 1.** Description of LANDSAT-7 bands used to map surficial materials

| Band | Spectrum | Spectral range ($\lambda$; μm) |
|---|---|---|
| Band 2 | reflected green energy | 0.52-0.60 |
| Band 3 | reflected red energy | 0.63-0.69 |
| Band 4 | reflected near infrared energy | 0.76-0.90 |
| Band 5 | short wave infrared energy | 1.55-1.75 |
| Band 7 | short wave infrared energy | 2.08-2.35 |

Landsat 7 data were acquired from the United States Geological Service (USGS) Glovis and Natural Resources Canada Geobase (Table 2). Four scenes from WRS paths 45 - 46 and WRS rows 15 - 16 were necessary to cover the entire map sheet 85-P. Cloud-free data and an acquisition anniversary date near mid-summer were criteria used to select scenes while year of acquisition was less important due to the temporal stability of surficial materials. All scenes were pre-screened by Glovis and Geogratis for cloud cover, containing only minor cloud and cloud shadow. Acquisition dates were chosen to be as close to mid-summer as possible when vegetation is at peak greenness to facilitate normalizing radiometry among scenes and to ensure stable radiometric signatures representing each surficial class. Native projection was Universal Transverse Mercator (UTM) zone 12 with Datum WGS 84 for Glovis and NAD 83 for Geobase. All scenes were projected to the common UTM zone 12 and ellipsoid GRS 1980 to correspond to the map sheet projection.

**Table 2.** Landsat scenes used as input to map 85-P surficial materials.

| WRS Path | WRS Row | Scene | Acquisition date | Source | Projection |
|---|---|---|---|---|---|
| 45 | 15 | L1045015_01520010703 | July 3 2001 | USGS Glovis | UTM 12, WGS 84 |
| 45 | 16 | 045016_0100_000630_L7 | June 30 2000 | Geobase | UTM 12, NAD 83 |
| 46 | 15 | L71046015_01520010811 | August 11 2001 | USGS Glovis | UTM 12, WGS 84 |
| 46 | 16 | 046016_0100_010811_L7 | August 11 2001 | Geobase | UTM 12, NAD 83 |

Scenes were radiometrically balanced using Thiel-Sen robust regression on each spectral band in adjacent overlap regions between scenes following Olthof et al., 2005. Scenes were mosaiced into the map sheet extent that included extra data on all four sides. The maximum Normalized Difference Vegetation Index (NDVI = (NIR-Red) / (NIR+Red)) was used to preferentially select clear-sky pixels over cloud and cloud shadow in overlap regions covered by more than one scene. These steps were taken to ensure the most seamless and clear image data possible over the whole map sheet.

Ancillary data included water bodies obtained from CanVec, fire history obtained from the Northwest Territories Centre for Geomatics, and Canadian Digital Elevation Data (CDED) from Geobase (Table 3). Polygons representing fires that preceded Landsat acquisition dates were gridded at 30 m resolution into the map sheet extent. Fire dates ranged from 1970 to 2000. CDED was downloaded as 1:50k NTS grids in lat/long projection with a resolution between 0.75 and 3 arc seconds, which was set at 30 m when reprojected to the map sheet projection.

**Table 3.** Ancillary data layers

| Data | Source | URL | Scale | Derived Layers | Native Projection |
|---|---|---|---|---|---|
| Water Bodies | CanVec | http://ftp2.cits.rncan.gc.ca/pub/canvec/ | 1:50k gridded to 30m | Hydrography | Lat/Long |
| Fire History | NWT Centre for Geomatics | http://www.geomatics.gov.nt.ca/nwtdp.aspx | | Fire age | Lambert Conformal Conic |
| CDED | Geobase | www.geobase.ca/geobase/en/data/cded/ | 1:50k gridded to 30m | Elevation and slope, aspect, surface roughness and moisture index | Lat/Long |

Derived variables from CDED included slope, aspect, and surface roughness that was calculated by applying a 3 x 3 window co-occurrence texture measure to the elevation data. The moisture index was computed from the elevation data based on local slope gradient and upslope contributing area (Beven and Kirkby, 1979).

## 2.2. Training Data

Training data included more than 1.16 million pixels in the overlap region between surficial map 85-I and the mosaic that included 85-P with overlap on all sides (Table 4).

**Table 4.** Surficial materials classes used as training data for classification. The GeoCode corresponds to the digital numbers embedded within the digital surficial materials data product accompanying this Open File (RPM_NTS map sheet 85P.tif).

| GeoCode | Surficial material classes | Number of pixels |
|---|---|---|
| 1 | Sand and gravel | 24952 |
| 2, 8 | Silt and clay (lacustrine and glaciolacustrine) | 93549 |
| 3 | Till veneer | 147385 |
| 4 | Till blanket | 94079 |
| 5 | Bedrock | 517785 |
| 6 | Organic | 3240 |
| 7 | Water | 286966 |
| | Total | 1167956 |

## 2.3. Classification and Post Processing

The predictive surficial materials map produced in this report was based on a boosted See5™ decision tree with 25% holdout and 10 trials applied to the normalized LANDSAT bands (2-5+7), fire history, elevation and derived variables. Because decision trees can handle both categorical and continuous variables, there was no need to generate separate models for different fire ages, unlike the robust classification method used to map 85-I.

The number of misclassified cases and error rates for the ten trials are shown in Table 5 along with error statistics for the final, boosted classifier obtained through a majority prediction of the ten classifications. Error rates vary between 12.6 and 18.3% for the ten trials, which was reduced to 7.8% for the boosted classification assessed against all training data from the overlap region with 85-I.

**Table 5.** See5™ Decision Tree trials, number of incorrectly classified cases and percent error rates.

| Trial | Error | |
|---|---|---|
| | Pixels | Percent |
| 0 | 147256 | 12.6% |
| 1 | 203591 | 17.4% |
| 2 | 203902 | 17.5% |
| 3 | 206899 | 17.7% |
| 4 | 213894 | 18.3% |
| 5 | 212104 | 18.2% |
| 6 | 205554 | 17.6% |
| 7 | 193890 | 16.6% |
| 8 | 179048 | 15.3% |
| 9 | 166953 | 14.3% |
| boost | 90945 | 7.8% |

The classified surficial material classes were then converted into predictive surficial geology units based on knowledge gained from airphoto interpretations, field observations and legacy information (Table 6). Class 2 (Silt and clay) included both lacustrine and glaciolacustrine sediments, which were separated based on an elevation threshold of 300 m below which all of class 2 was considered glaciolacustrine while above was mapped as lacustrine. This rule was included based on the knowledge of the approximate extent of Glacial Lake McConnell during the last glacial ice retreat. The predictive surficial materials map was generalized in order to conform to cartographic standards for a 1:250 000 map sheet. The generalization process included 3 iterations of a 3x3 pixel majority filter, conversion of the data from raster to vector format and removal of polygons less than 15,300 $m^2$ (17 pixels). Polygons below this minimum size threshold were replaced with the neighbouring classes using the expand tool in ArcGIS. The surficial material classes were expanded by 2 pixels where the minimum size threshold was met.

**Table 6.** Surficial Materials and equivalend surficial geology units used for map sheet NTS 85-P.

| Surficial Material GeoCode | Surficial Geology Unit | Description of Surficial Geology Unit |
|---|---|---|
| 6 | O | Organic deposits: undifferentiated fen, bog and floating aquatic vegetation |
| 2 reclassified GL above 300m | L | Lacustrine sediments: undifferentiated, exposed sediment surrounding modern lakes, variable thickness |
| 8 | GL | Glaciolacustrine sediments: undifferentiated silt and clay, may include small outcrops of till veneer, variable thickness |
| 1 | GF | Glaciofluvial sediments: undifferentiated sand and gravel to cobbles, forming esker ridges, terraces, outwash plains, may be reworked by wave action forming raised beaches, variable thickness |
| 3 | Tv | Till veneer: poorly sorted silt to gravel diamicton, may be modified by glaciolacustrine and meltwater processes, may contain small bedrock outcrops and glaciolacustrine veneer, variable thickness but generally <2 m |
| 4 | Tb | Till blanket: poorly sorted silt to gravel diamicton, variable thickness but generally >2 m |
| 5 | R | Bedrock: undifferentiated, may be overlain by discontinuous cover of till veneer, glaciolacustrine veneer and isolated glaciofluvial patches |

## 4. REMOTE PREDICTIVE MAP

The predictive surficial materials map derived from LANDSAT 7 imagery is shown in Figure 3. An error matrix relating classified pixels to reference data from all training pixels is shown in Table 7. Water is included in the matrix whereas lacustrine is absent due to their respective presence / absence in the overlap with 85-I that served as both training and validation data. Confusion exists primarily between all classes and bedrock for two reasons. First, bedrock has a spectral signature that is similar to recent fires, which often contain a significant amount of bedrock outcrop due to the removal of vegetation. Thus a significant percentage of the large area occupied by recent burns in Figure 1 is classified as bedrock. Second, fire has a homogenizing effect through the removal of vegetation and replacement by a singular spectral class consisting of a mixture of bedrock, charred trees and understory. Therefore, all types of surficial materials beneath recent fires may be predicted to be bedrock. For example, Table 7 shows 3.4% of the area classified as bedrock is actually till veneer according to reference data from map sheet 85-I. In addition, further confusion may arise as numerous bedrock outcrops smaller than a 30 m Landsat pixel may also exist within the till veneer class, leading to spectrally mixed pixels that may be assigned to either class depending on the spectral dominance of one over the other.

The overall accuracy of 92.2% due to an error rate of 7.8% reported in Table 5 does not represent true accuracy relative to ground truth, but instead represents an agreement with predicted surficial materials in map sheet 85-I. Assuming the accuracy in the overlap region used to train and evaluate the classification is representative of the 81.7% accuracy reported for map sheet 85-I, the true accuracy becomes the product of the accuracy of 85-I and agreement between 85-I and 85-P. Thus, one could expect the overall accuracy of 85-P to be in the range of 75%. However, it should be noted that 85-I was trained using polygons derived from airphoto interpretation, which itself is a prediction of ground truth. An improved measure of the accuracy of both map sheets should be conducted using ground truth collected in the field. However, several helicopter flights were made over both map sheets and geo-located, low-level oblique photos were taken en route, and verification of the map sheets using these airphotos, as well as surficial knowledge of the region, suggests a suitable map quality s for the intended purpose.

Table 8 presents the percent coverage of each surficial material within map sheet NTS 85-P. Surficial materials with the largest coverage include; bedrock (R) (69.40%), till blanket (Tb) (20.28%) and till veneer (Tv) (8.30%).

The derived predictive surficial geology map for Upper Carp Lake NTS 85-P is presented in Appendix A. Bedrock (R) outcrops are widespread throughout the map sheet, whereas glaciolacustrine silt clay (GL) predominately occurs in the lowlands in the southwestern portion. Glaciolacustrine silt and clay are interpreted to be deposited by Glacial Lake McConnell and former higher water levels of Great Slave Lake. Glaciolacustrine sediments also extend across the adjoining map sheet NTS 85-I, located to the south (Stevens et al., 2012). The northeast region of the map sheet consists mainly of till blanket (Tb) and bedrock. Till blanket (Tb) is mainly restricted to topographically low depressions between bedrock highs. Glaciofluvial (GF) sand and gravels forming eskers and outwash deposits are typically reworked by glaciolacustrine and meltwater processes. Till veneer (Tv) occurs thought the map sheet whereas organic deposits (O) representing fen, bog and floating aquatic vegetation are nearly non-existent.

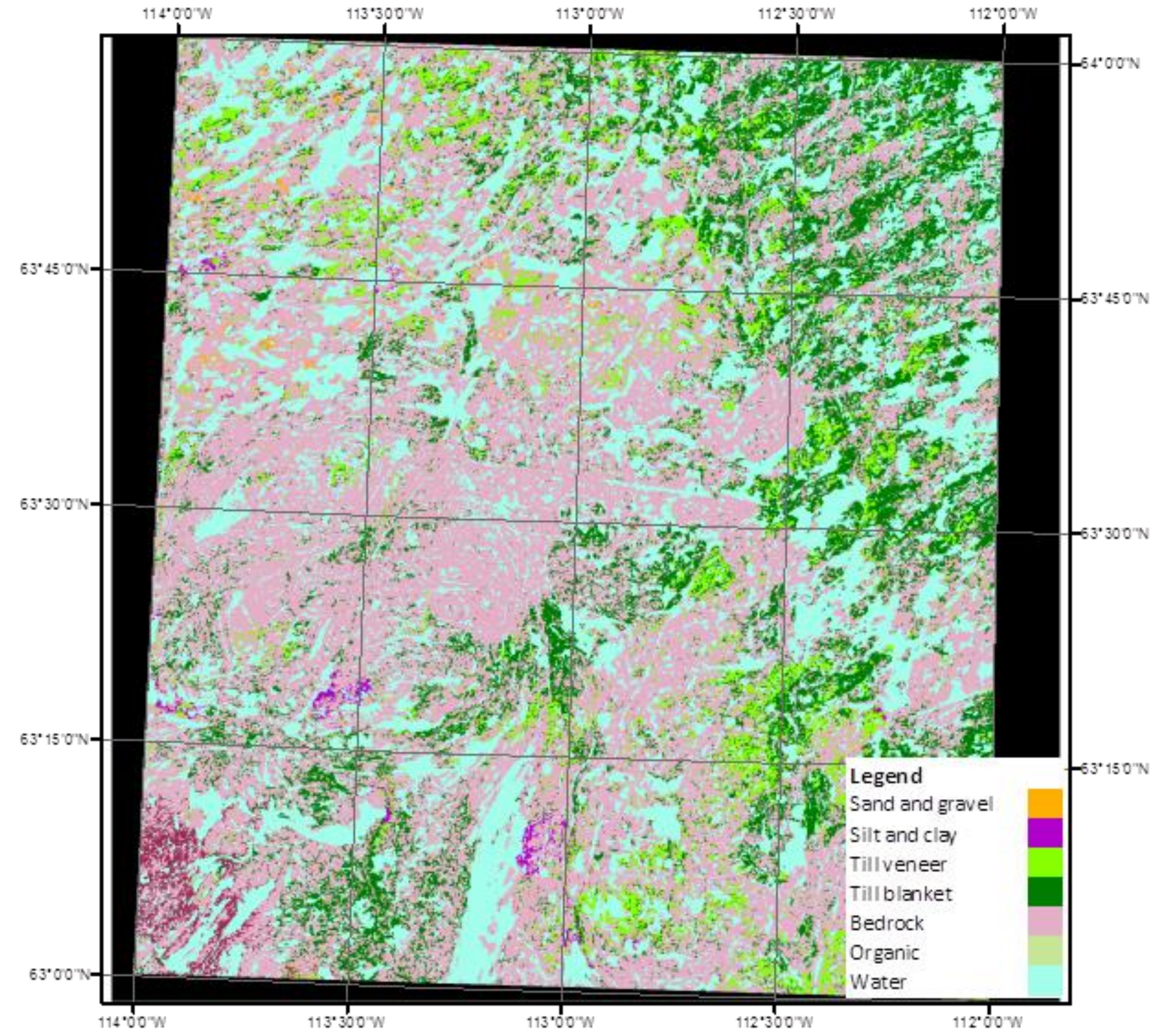


**Figure 3.** Remote predictive surficial materials map for Upper Carp Lake NTS 85-P based on LANDSAT data. Numbers shown on the map correspond to the location of field photographs presented in Appendix A. Map scale at 1:125 000.

**Table 7.** Error matrix for the region where mapped classes in NTS 85-P overlap the reference map NTS 85-I, showing the correlation of each mapped class with each reference class as a percentage, the overall accuracy of within this region, and the estimated overall accuracy of NTS 85-P.

| Reference class | Mapped class | | | | | | |
|---|---|---|---|---|---|---|---|
| | Glaciofluvial | Glaciolacustrine | Till veneer | Till blanket | Bedrock | Organic | Water |
| Glaciofluvial | **92.7%** | 0.3% | 0.2% | 1.8% | 2.0% | 0.9% | 0.0% |
| Glaciolacustrine | 0.4% | **87.3%** | 2.7% | 0.7% | 0.9% | 1.1% | 0.0% |
| Till veneer | 0.4% | 6.3% | **87.0%** | 4.9% | 3.4% | 0.3% | 0.0% |
| Till blanket | 0.4% | 1.8% | 3.0% | **87.4%** | 2.4% | 0.1% | 0.0% |
| Bedrock | 5.7% | 3.8% | 7.0% | 5.0% | **91.1%** | 2.0% | 0.0% |
| Organic | 0.2% | 0.1% | 0.0% | 0.0% | 0.1% | **95.4%** | 0.0% |
| Water | 0.2% | 0.3% | 0.1% | 0.2% | 0.1% | 0.2% | **100.0%** |
| | | | | Overall agreement with 85I in the overlap region: | | | 92.2% |
| | | | | Overall accuracy of NTS 85P: | | | ~75% (see text) |

**Table 8.** Coverage of surficial materials expressed as the number of pixels and the percent area of land for NTS 85-P. Water representing 28.67% of the map sheet was excluded from the analysis.

| Surficial geology unit | Number of pixels | Percent area |
|---|---:|---:|
| GF | 29164 | 0.33% |
| L | 52199 | 0.59% |
| Tv | 729959 | 8.30% |
| Tb | 1783697 | 20.28% |
| R | 6102296 | 69.40% |
| O | 18 | 0.00% |
| GL | 95943 | 1.09% |

## 5. CONCLUSIONS

This report presents a predictive surficial materials map and derived surficial geology map for the Upper Carp Lake map sheet NTS 85-P. These datasets have been generated using a RPM approach in order to provide a first order assessment of surficial materials. This preliminary information is required to assess terrain risks to northern infrastructure and to guide mineral exploration and future mapping within the Slave Geological Province.

## 6. DIGITAL DATA

Digital vector data accompanying this Open File has been compiled into a geodatabase (OF7601.gbd). The georeferenced files include the predictive surficial materials and geology, striation measurements compiled from Kerr (1990, 2006) and data modified from unpublished Geological Survey of Canada manuscript maps. The geocode used in *NTS_85P_Predictive_Surficial_Material.tif* to define each surficial material is summarized in Table 4. Predictive surficial geology units and associated descriptions are summarized in Table 6. The predictive surficial geology map presented in Appendix A is also provided digitally as a printable pdf (map scale 1: 125 000).

## 7. ACKNOWLEDGEMENTS

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## 9. APPENDIX A

Predictive surficial geology map for Upper Carp Lake, NTS 85-P. A printable version of this surficial geology map is also provided in this Open File as a digital pdf (map scale 1:125 000).

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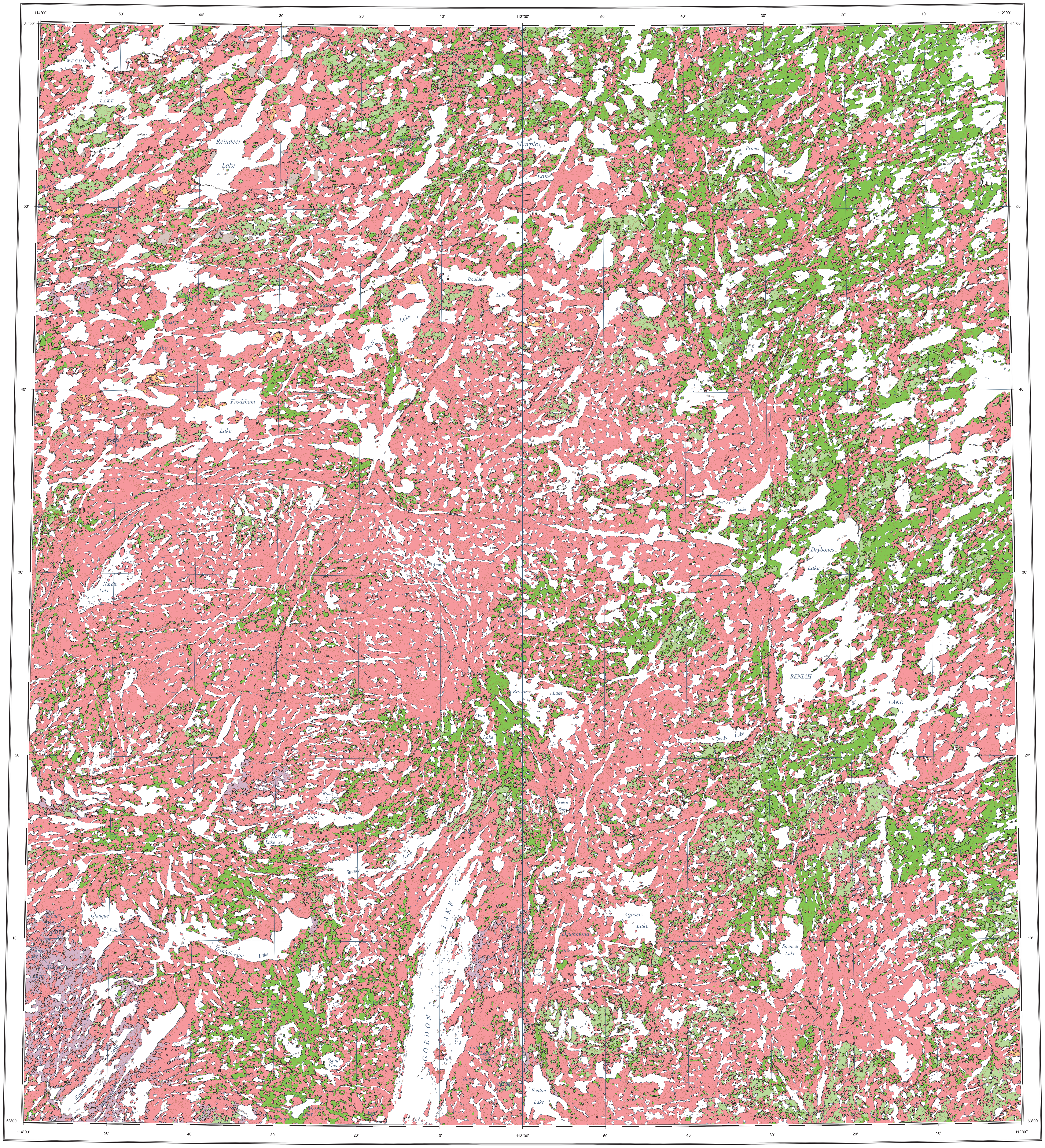
GEOLOGICAL SURVEY OF CANADA — COMMISSION GÉOLOGIQUE DU CANADA




## LEGEND

**QUATERNARY**
**HOLOCENE**

**NONGLACIAL ENVIRONMENT**

***ORGANIC DEPOSITS, UNDIFFERENTIATED:*** *fen, bog and floating aquatic vegetation variable thickness*

**PROGLACIAL AND GLACIAL ENVIRONMENT**

***GLACIOLACUSTRINE SEDIMENTS, UNDIFFERENTIATED:*** *silt and clay, variable thickness, may include small outcrops and patches of till veneer, deposited in glacial Lake McConnell and capped by sediments related to ancestral Great Slave Lake*

***GLACIOFLUVIAL SEDIMENTS, UNDIFFERENTIATED:*** *sand and gravel to cobbles, variable thickness, forming esker ridges, terraces, outwash plains; may be reworked by wave action forming raised beaches*

***TILL VENEER:*** *silt to gravel diamicton, poorly sorted, less than 2 m thick; bedrock structure is generally visible; unit may include patches of bedrock, glaciolacustrine sediments and till blanket, may be modified by glaciolacustrine and meltwater processes*

***TILL BLANKET:*** *silt to gravel diamicton, variable thickness but generally > 2 m; occurs as till plains mimicking bedrock topography or as drumlinoids; unit may include patches of till veneer*

***UNDIFFERENTIATED DEPOSITS:*** *Areas of high moisture content or non-classified units based on the near infrared band, includes regions from the hydrological base*

**PRE-QUATERNARY**

***BEDROCK:*** *various bedrock types of the Slave Craton, may be overlain by discontinuous cover of till veneer, glaciolacustrine veneer and isolated glaciofluvial sediment patches*

*Geological contact, defined*
*Esker ridge, sense known*
*Minor moraine ridges*
*Drumlinoid*
*Crag-and-tail*
*Small outcrop*
*Fluted bedrock, direction known*
*Striation, direction known (1 = oldest, 2 = youngest)*
*Striation, direction unknown*

## DESCRIPTIVE NOTES

This predictive surficial geology map is derived from integrating digital datasets of satellite imagery and ancilliary information with knowledge imbedded in adjacent overlapping surficial geology map sheets. The limit of the overlap region defines training areas where surficial geology map units and landforms have been mapped, and used in the generation of the predictive map. Some of the additional geological features in these areas include small outcrops, drumlinoids and eskers.
These features may also exist beyond the boundaries of training areas. Striations have been compiled from fieldwork in Kerr (1990, 2006). Lakes may also include hydrographic layers.

**References and additional paleoflow data modified from:**


Aylsworth, J.M. and Shilts, W.W., 1989. Glacial features around around the Keewatin Ice Divide: Districts of Mackenzie and Keewatin. Geological Survey of Canada, Paper 88-24, 21 p.

Kerr, D.E., 1990. Surficial geology of the Yellowknife River basin, parts of NTS 85 I, J, O, P and 86A. EGS 1990-03, NWT Geology Division, Indian and Northern Affairs Canada.

Kerr, D.E., 2006. Chapter 20, Quaternary Geology and Exploration Geochemistry, In: GAC Special Publication No.3, Gold in the Yellowknife Greenstone Belt, Northwest Territories: Results of the EXTECH III Multidisciplinary Research Project; C.D. Anglin, H,. Falk, D.F. Wright and E.J. Ambrose (Eds), p. 301-324.


Any revisions or additional geological information known to the user would be welcomed by the Geological Survey of Canada

Digital base from Geomatics Canada, modified by the Geological Survey of Canada

APPENDIX A, TO ACCOMPANY OPEN FILE 7601

PREDICTIVE SURFICIAL GEOLOGY

# UPPER CARP LAKE

NORTHWEST TERRITORIES

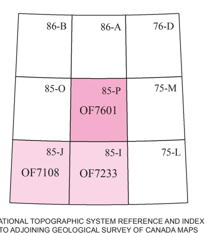
Scale 1:125 000/Échelle 1/125 000

kilometres 2.5 0 2.5 5 7.5 10 kilomètres

Universal Transverse Mercator Projection
North American Datum 1983


Projection transverse universelle de Mercator
Système de référence géodésique nord-américain, 1983


Mean magnetic declination 2014, 16°53'E decreasing 28' annually.
Reading vary from 17°27'E in the SW corner
to 16°13'E in the NE corner of the map




NATIONAL TOPOGRAPHIC SYSTEM REFERENCE AND INDEX TO ADJOINING GEOLOGICAL SURVEY OF CANADA MAPS


**Recommended citation**
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