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Report of activities for predictive surficial geology mapping derived from LANDSAT 7, Wecho River, NTS 85-O, Northwest Territories

GEM2 Mackenzie Project

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Abstract

The Geo-mapping for Energy and Minerals (GEM) program lays the foundation for sustainable economic development in the North, and the Mackenzie Corridor region of interest represents the largest unmapped (bedrock and surficial geology) area of Northwest Territories. The lack of geologic knowledge in this area is a significant detriment to the economic potential of the region. The Wecho River map (NTS 85-O) identifies surficial geology and associated landforms left by the retreat of the last glaciers which covered the area about 9500 years ago. This preliminary map of surficial geology is based on remote predictive mapping, airphoto interpretation and fieldwork. The goal is to develop a timely first-version map, validated in selected areas and reviewed by geological experts, which reasonably depicts the distribution of surficial sediments for northern industry exploration and development purposes.

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Foreword

The Geo-mapping for Energy and Minerals (GEM) program is laying the foundation for sustainable economic development in the North. The Program provides modern public geoscience that will set the stage for long-term decision making related to investment in responsible resource development. Geoscience knowledge produced by GEM supports evidence-based exploration for new energy and mineral resources and enables northern communities to make informed decisions about their land, economy and society. Building upon the success of its first five-years, GEM has been renewed until 2020 to continue producing new, publically available, regional-scale geoscience knowledge in Canada's North.

During the summer 2015, GEM program has successfully carried out 17 research activities that include geological, geochemical and geophysical surveying. These activities have been undertaken in collaboration with provincial and territorial governments, northerners and their institutions, academia and the private sector. GEM will continue to work with these key collaborators as the program advances.

Project Summary

The preliminary Wecho River map (NTS 85-O) identifies surficial geology and associated landforms left by the retreat of the last glaciers which covered the area about 9500 years ago. The surficial geology is based on remote predictive mapping, airphoto interpretation and fieldwork. This work contributes to effective mineral exploration useful in drift prospecting for a variety of commodities including diamonds, precious and base metals, and supports informed decision making for resource development and land use. As part of the Surficial Geology Mapping of the Mackenzie Sedimentary Basin – Bear/Slave Province Boundary activity in the GEM Mackenzie Region Project, this work provides new geological knowledge and improves our understanding of the distribution, nature and glacial history of surficial geology.

Introduction

The Mackenzie Corridor region of interest (Figure 1) represents the largest unmapped (bedrock and surficial) area of Northwest Territories. Nearly one-half of surficial geology of the Northwest Territories remains unmapped, and the bulk of this resides within the Mackenzie Corridor. Given the high mineral potential and realized development within the Bear/Slave Geological Provinces, and the significant energy/mineral potential within the northern Shield to sedimentary basin transect, the lack of geologic knowledge across this boundary is a significant detriment to the economic potential of the region. One of the remaining unmapped areas is Wecho River (NTS 85-O) (Figure 1).

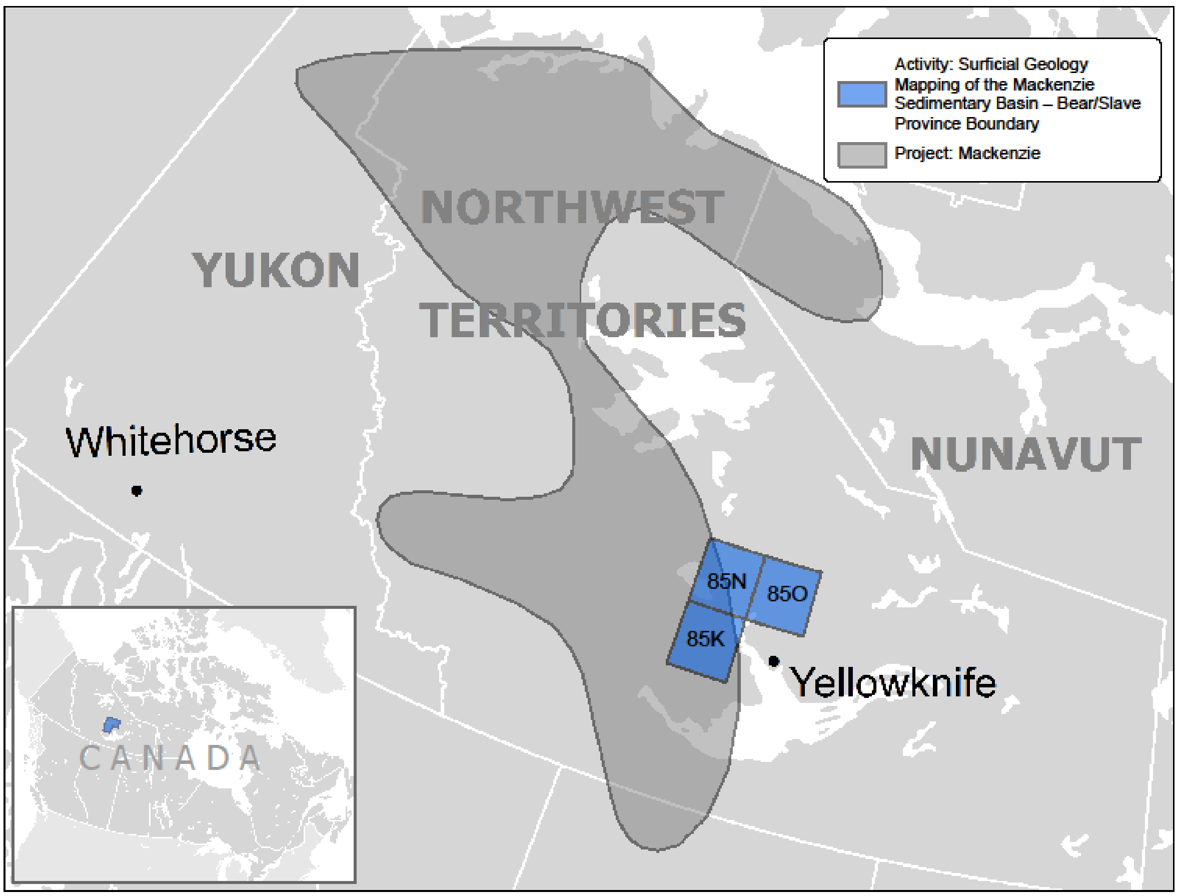

Figure 1. Location of mapping areas: NTS 85-O (ongoing), 85-K (anticipated), 85-N (Ednie et al., 2014).

Goal & objective

This activity aims to provide a better understanding of the nature and distribution of surficial geology and glacial history of the southern Mackenzie Corridor. It fills in a major knowledge gap in the NWT, essential for the implementation of successful mineral and petroleum exploration surveys in this poorly-mapped, drift-covered region. Mapping the extent of glacial lake McConnell sediments in the central and southern regions is of particular aid to resource and infrastructure development potential of this region.

Scientific question addressed

The regional framework scientific question being addressed by this research activity is, how can improved surficial mapping facilitate exploration and support resource discovery in the Mackenzie Corridor region (Figure 1)?

Methodology

The remote predictive mapping (RPM) methodology adopted for mapping NTS 85-O was based on the availability of remote sensing data and the authors' field experience of surficial materials and geology found in the region (Figure 1). Surficial materials were converted to surficial geology using expert knowledge and the Geological Survey of Canada's Surficial Data Model (Cocking et al., 2015). The classification approach involved the use of a decision-tree model calibrated on training classes mapped using air photographs. The resulting model was used to predict surficial geology by applying the training classes to satellite imagery, fire history map and a digital elevation model (DEM) for the 85-O map area. Decision-tree methodology was chosen as the classification algorithm due to its ability to handle large training datasets irrespective of their statistical distributions. Cross validation generates error statistics on a holdout sample from a single trial, and boosting reduces model errors by weighting the incorrectly classified cases more heavily in the subsequent trial runs. This process is repeated for the specified number of trials using a different random holdout sample each time. The final map is generated using the majority prediction from all trials. These techniques build upon experience gained in previous surficial RPM activities in adjoin areas (Olthof et al., 2014, Stevens et al., 2012, 2013, 2015).

Datasets

Mapping was undertaken using multiple LANDSAT 7 imagery taken in 2001 (normalized bands 2,3,4,5, and 7) which was downloaded from Glovis (http://glovis.usgs.gov/). All scenes were pre-screened by Glovis so only minor cloud and cloud shadow were present. Mid-summer acquisition dates were chosen 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. All scenes were projected to the common UTM zone 12 and ellipsoid GRS 1980 to correspond to the mapsheet projection.

Scenes were radiometrically balanced using Thiel-Sen robust regression on each spectral band in adjacent overlap regions between scenes (Olthof et al., 2005). Scenes were mosaiced into the mapsheet extent that included extra data on all four sides. They were first mosaiced east to west and south to north and then again into separate channels in the opposite order to generate two separate mosaics with each one representing one of two overlap regions between scenes. The final mosaic was produced by selecting pixels in overlap regions based on the maximum Normalized Difference Vegetation Index (NDVI = (NIR-Red) / (NIR+Red)) that is used to preferentially select clear-sky pixels over cloud and cloud shadow.

Water bodies were masked from the LANDSAT imagery using the near infrared channel (band 4) and with thresholding applied to DN (digital numbers) <40. The derived mask may also include cloud shadows and some wetlands with water at the surface. The selected mask was then merged to water polygons from the NTDB (Geogratis (http://www.geogratis.gc.ca)) to complete the water mask layer.

Elevation data in the form of a digital elevation model (DEM) was downloaded from Geogratis (http://www.geogratis.gc.ca) as 1:50k NTS grids in lat/long projection with a resolution between 0.75 and 3 arc seconds that was set at 30 m when projected to UTM. Entropy of the elevation data was calculated using a 7x7 pixel moving window in order to provide local texture of the elevation values. The use of entropy data (surface roughness) has been shown to increase the transformed divergence values between surficial materials (Stevens et al. 2012; Ednie et al. 2014).

Fire history was obtained from the Northwest Territories Centre for Geomatics (http://www.geomatics.gov.nt.ca). Polygons representing forest fires burn areas that preceeded the Landsat acquisition dates were gridded at 30 m resolution. Fires dates ranged from 1965 to 2000. A total of 8 bands of data were used to produce the surficial geology map, including normalized bands 2-5+7, a 30 m digital elevation model, digital elevation entropy, and fire history.

Training classes of surficial materials were established by performing traditional air photography interpretation. The final training classes were based on the outcome of air photograph interpretation, legacy data, and expert knowledge based on field experience in the region. Field surveys of surficial geology were also conducted from helicopter in 2013 and 2014. Information gained from this field work was used in the development of the training areas.

Results

The preliminary predictive surficial geology map produced for this report (Figure 2) was based on the Boost mode of the decision-tree methods in See5^{TM}. The boost trial incorporates information from the previous 10 trial runs in order to minimize classification errors. All of the trial runs were applied to normalized bands 2-5+7, a 30 m digital elevation model, digital elevation entropy, and fire history data. Each repetition was run with a random sample of 75% of the training data for model input while withholding 25% for validation. Nearly 12000 cases (pixels) were used to calibrate the training classes in the decision-tree model (Table 1). Overall model error is shown in Table 2. The overall error of the surficial geology map using the Boost mode in the decision-tree model is 0.1% when compared to the training data. The boosted accuracy for the surficial geology map is 99.9%. Results from the model runs are presented in Table 3. Results from 100 cross-validations using 75% randomly sampled data for training and the remaining 25% for validation indicate and average overall accuracy of the training areas of over 97%.

Though recognized in adjacent map sheets, undifferentiated till sediments were not included as a surficial unit in the decision-tree model because of under representation in the training classes identified from aerial photography. Further, based upon comparison of mapping results with extensive field survey data, several glaciofluvial deposits were confused with bedrock. Recognizing these deficiencies, a subsequent iteration of the NTS 85-O surficial geology map will include more extensive training classes and an improved predictive map.

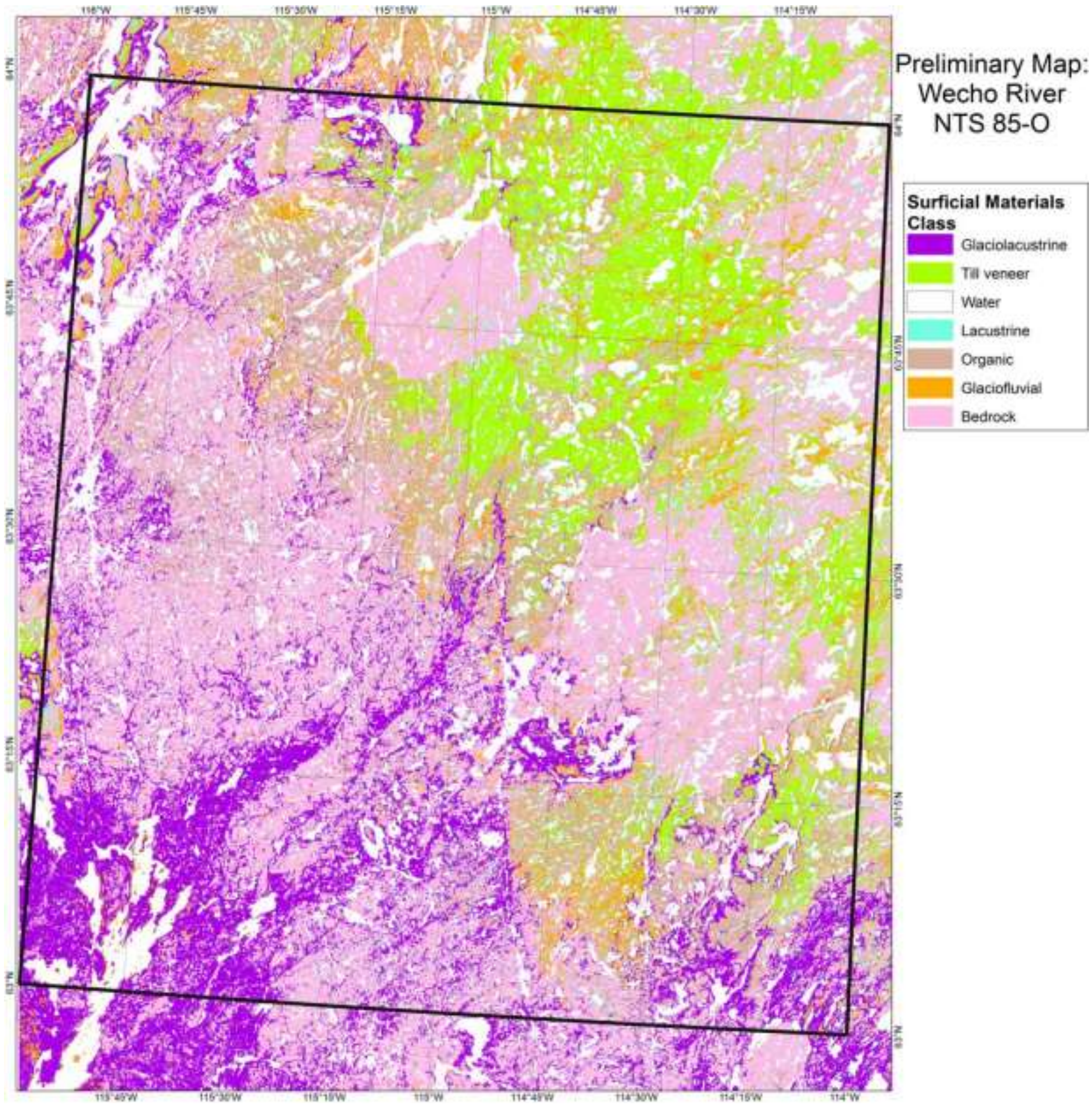

Figure 2. Preliminary results for the remote predictive surficial geology map for Wecho River NTS 85-O based on LANDSAT, elevation, and fire history data.

Table 1. Surficial geology units used for mapsheet NTS 85-O.

Geocode	Surficial Materials Class	Description of Surficial Geology Unit	Training Pixels (n)
1	GL	Glaciolacustrine sediments: undifferentiated silt and clay, may include small areas of till veneer, variable thickness	2056
2	GF	Glaciofluvial sediments: undifferentiated sands and gravels, may contain small bedrock outcrops	2497
3	O	Organic deposits: undifferentiated fen, bog and floating aquatic vegetation	779
4	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	1940
5	R	Bedrock: undifferentiated, may be overlain by discontinuous cover of till veneer, glaciolacustrine veneer and isolated glaciofluvial patches	3596
6	L	Lacustrine sediments: undifferentiated, exposed sediment surrounding modern lakes, variable thickness	868

Table 2. List of all trial runs for the decision-tree model along with errors in cell counts and percentage.

Trial #	# Errors	% Error
0	178	1.5
1	1045	8.9
2	599	5.1
3	693	5.9
4	653	5.6
5	569	4.8
6	654	5.6
7	662	5.6
8	680	5.8
9	911	7.8
Boost	7	0.1

Table 3. Confusion matrix of accuracy for predictive surficial geology classes (predicted class) compared against training classes (actual class).

	Actual Class Pixels						
Predicted Class Pixels	Material class	Glaciolacustrine	Glaciofluvial	Organic	Till veneer	Rock	Lacustrine
	Glaciolacustrine	2056					
	Glaciofluvial		2497				
	Organic	2		777			
	Till veneer				1939		1
	Rock				2	3594	
	Lacustrine					2	866

Conclusions

Experience has shown that remote predictive mapping can be used for rapid production of preliminary surficial materials and surficial geology maps in the north. For relatively uncomplicated areas, surficial maps can be derived and published using training areas, expert knowledge and the robust classification method. The goal is to develop timely first-version maps, validated in selected areas and reviewed by geological experts, which reasonably depict the distribution of surficial sediments for northern industry exploration and development purposes.

Future work 2015-2016

Production of predictive surficial geology maps at 1:250,000 scale for NTS 85-O and NTS 85-K in the Canadian Geoscience Map (CGM) format.

Future work 2016-2018

Production of predictive surficial geology maps at 1:250,000 scale for NTS 85-L and NTS 85-M in the Canadian Geoscience Map (CGM) format.

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