Revitalising exploration in a key diamond district: A case study in the Northwest Territories, Canada

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Introduction

In 2014 and 2015 the Northwest Territories Geological Survey (NTGS) carried out the Slave Province Surficial Materials and Permafrost Study (SPSMPS), a two-year collaborative government–industry–academic research program in the Lac de Gras region, Northwest Territories, Canada. The overall goals of the project were to advance our understanding of glacial history, develop innovative exploration techniques for glaciated terrain and update surficial maps in targeted areas. The project was funded through the Strategic Investments in Northern Economic Development program of the Canadian Northern Economic Development Agency.

Our industry partners included Dominion Diamond Ekati Corp, Diavik Diamonds Mines Inc., North Arrow Minerals Inc., Peregrine Exploration Ltd., Artic Star Exploration Corp., New Nadina Explorations Limited, and TNT Mineral Science. Our research partners included the Canadian Mining Institute Research Organization, Palmer Environmental Consulting Group Inc., GGL Resources Corporation, DCGeo Applied Sedimentary Geology Consulting, the University of Waterloo, Simon Fraser University, Carleton University and the University of British Columbia. Much of this work was carried out by or with assistance from Aurora Geosciences Ltd.

Highlights include a new database of indicator mineral counts, indicator mineral chemistry and till geochemistry, new three dimensional (3D) models of kimberlite indicator mineral (KIM) trains, a study on the application of surficial geochemistry to the detection of kimberlites, a study on esker transport distance, updated surficial mapping products and a case study in the application of ground penetrating radar (GPR) and Ohm Mapper, a Capacitively Coupled Resistivity (CCR) system, to determine depth to bedrock in permafrost rich environments. To accomplish these objectives, 1131 sediment samples (primarily till) were collected from 235 boreholes. Over 1500 square kilometres of field mapping and approximately 150 line-kilometres of ground geophysics complement the drill data. Logistical support, large proprietary indicator mineral, remote sensing, and mapping datasets were generously provided by our industry partners.

New 3D Indicator mineral datasets

A 3D database of surface and subsurface indicator mineral counts, indicator mineral chemistry and till geochemistry from 174 boreholes has been published by the NTGS (Elliott and Normandeau, 2017, Elliott and Normandeau, 2016, Normandeau, et al. 2016). These reports document several instances of anomalous concentrations of indicator minerals at depth that are not reflected in surficial samples. A more in-depth assessment of this data is currently underway, but this data clearly implies that traditional

indicator mineral sampling may not be sufficient to assess the mineral potential of areas with complex or poorly understood surficial geology.

New 3D Indicator Mineral Entrainment Models

Based on the concepts of glacial dynamics, glacial sediment production, transport and deposition, drift prospecting has been used to trace indicator mineral grains back to a buried bedrock source. Here, 94 reverse circulation (RC) boreholes were drilled, to collect 254 till samples and generate a subsurface model of the dispersal train from the DO-27 / DO-18 kimberlite pipes. The effect of changing ice flow on the composition of till has been well-studied in both map-view, as well as longitudinally in cross section (i.e., dispersal curves). Through a combination of borehole data, field work, and modelling, we are able to compare three-dimensional dispersal patterns in the subsurface with local ice flow records, measured from erosional ice flow indicators in the field.

This dataset allows us to evaluate the role that changing ice flow, as well as local bedrock surface topography, play in controlling dispersal and deposition of clastic sediment by past ice sheets. Our modelling documents buried palimpsest terrains along older ice flow trajectories, demonstrating lateral and vertical variability within a single, relatively thin and discontinuous till sheet. Furthermore, we observe relationships between local indicator mineral concentrations and bedrock topography, with indicator mineral dispersal concentrated along a bedrock-controlled topographic low. This work demonstrates the benefit of more complete mapping and visualisation of a dispersal plume, even in areas of relatively thin and discontinuous till cover, highlighting the role basal topography and shifting ice flow play in shaping the surface expression of a dispersal train.

Determination of Depth to Bedrock in Permafrost Rich Overburden

To develop a method of rapidly determining the depth to bedrock in areas covered with permafrost-rich overburden, GPR and CCR geophysical surveys were carried out in the vicinity of the DO-27 / DO-18 kimberlites and their associated indicator-mineral trains. This work used the high-density drilling from the 3D indicator mineral entrainment study to provide control for the geophysical data. The most reliable depths to the bedrock were obtained by interpreting the CCR and GPR data together. Based on the results of both geophysical surveys, the top of the bedrock can be reliably interpreted from surface to >20 metres in the surveyed area.

Applying Surface Geochemistry Models for the Detection of Kimberlites

One hundred and fifty soil samples were taken from the oxidised upper B-horizon in a 50 x 60 metre grid crossing the DO-18 kimberlite to assess the potential of various geochemical techniques, to detect the presence of a kimberlite concealed by 5-20 metres of till. In conjunction with surface materials mapping and landscape evolution models, four-acid and aqua regia digestions successfully detect the kimberlite, displaying a dispersal of Cr, Mg, Nb and Ni, from directly above the kimberlite in the northern region, to the edge of the sampling grid, in the down-ice direction. Fundamental Parameters X-ray fluorescence analysis repeat the pattern in all elements except Mg, where the concentrations are too low for reliable detection, though a low-level Zn anomaly was detected. A similar pattern was also observed in the Soil Gas Hydrocarbon data, particularly in the light benzenes. Sequential leach on selected samples was undertaken to identify which phases within the soil are host to the aforementioned anomalous elements. Surficial mapping included soil type, topographic variation, landforms, environment and vegetation, giving insight to the surface controls on the geochemistry.

The observed soil geochemical anomaly is hypothesised to have been generated by clastic dispersion of these elements in the direction of glacial movement with geomorphological processes exhibiting a strong influence on surface geochemistry. Part of the study area is interpreted to have been inundated with water, generating lower topography and subduing the soil geochemical responses.

Esker Transport Distance

Eskers are commonly sampled for KIMs during the early stages of diamond exploration, with the understanding that they likely function as "regional dipsticks", much like large streams do in non-glacial settings. Esker sampling was integral to the discovery of the Lac de Gras kimberlite field. During the SPSMPS, a large integrated dataset consisting of Light Detection and Ranging (LiDAR) data, GPR data, , grain-size samples, and surficial mapping observations was collected from the Exeter Lake esker, Canada's longest esker. The results suggest that the esker was deposited in short segments, each several kilometres in length, as the ice front retreated, and not as a single, long segment beneath the ice as has commonly been assumed. Segmental Deposition may explain why previously reported esker dispersal trains tend not to considerably overshoot underlying till trains from which they were sourced. If the results of this study are proven representative, eskers may commonly provide similar information as the nearby till, and the "regional dipstick" model of esker-exploration may require reinterpretation.

Updated Surficial Maps

Approximately 60,000 square kilometres of 1:50,000 scale surficial mapping products in the southern Slave Craton have been graciously provided by GGL Resources Corporation. The maps emphasised the role of melt water and enabled the first publicly available comprehensive geographic reconstruction of the paleo-lakes present over the Slave Craton. These lakes reconstructions help explain the presence of distinct surficial materials and landforms across geomorphologic elevation zones, such as washed bedrock field hosting vestiges of esker complexes, disrupted esker complexes hosted by moderately reworked till, and esker complexes with well-defined esker corridors hosted by till.

The nature of these esker corridors and the sediments they contain is the subject of a related study drawing on LiDAR, 3D surficial sediment mapping, sediment composition and granulometry analysis, and geomorphic analysis. This study highlighted the presence of melt water erosive corridors not containing eskers, as well as the ubiquitous presence of sediment mounds in all melt water corridors. The mound composition differs from that of the regional till, and are now interpreted to result from episodic drainage events during late deglaciation. Recognising these features may modify the design and the interpretation of drift prospecting sampling campaign.

References

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