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Evolution of Kimberlite Exploration - Advances in Drift Prospecting in Canada's North (Part 1): Fundamentals and Foundations

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The combination of drift prospecting and geophysics have been the principal methods for diamond exploration in Canada's Slave Geological Province (SGP) for over 30 years (*e.g.,* Fipke *et al.,* 1995). These methods were responsible for the first diamond-bearing kimberlite discovery in the Slave Geological Province in Northwest Territories in 1991. The discovery was initiated by sampling glacial sediments (drift) to find kimberlite indicator minerals (KIMs) and using geomorphological and sedimentological principles to trace them back to their source (Fipke *et al.,* 1995). Since then, numerous kimberlite occurrences (and other mineral deposits) have been found with the aid of drift prospecting, and several case studies have been published to document KIM and surficial geochemical dispersal patterns in glacial sediments (*e.g.,* McClenaghan *et al.,* 2002). In addition, the Geological Survey of Canada published guidelines for the use of KIMs and surficial geochemistry for the exploration of kimberlite in glaciated terrain (McClenaghan and Kjarsgaard, 2007). Till, a glaciogenic sediment that is a first derivative of bedrock, is widely considered the ideal sample medium because it contains a predictable dispersal pattern related to the flow direction of glaciers (Shilts, 1996). Kimberlites are most easily discovered through drift prospecting when associated with a linear glacial dispersion of KIMs pointing back to their source (*e.g.,* McClenaghan *et al.,* 2002).

For many years, drift prospecting was used to delineate target areas, over which geophysical surveys were completed to identify anomalies for drill testing. Eventually, the standard approaches became less successful. The kimberlites with associated linear glacial dispersals and geophysical signatures were more easily identified but explorers struggled to find success in areas with more complex surficial geology. This was partially due to post-depositional modification of till by deglacial processes that altered or erased the primary glacial dispersal of KIMs. In addition, datasets included numerous surveys that used different sampling and analytical protocols, resulting in variable KIM recovery rates that did not consistently represent concentrations in the surficial environment. These mixed results further obscured the recognition of primary glacial dispersions. Investors responded to this dwindling success by preferentially focusing on projects around known occurrences, and, as a result, expansive areas of prospective ground remain under-explored. While a common belief is that there are few remaining undiscovered kimberlites in the SGP, we believe there are still vast opportunities for discovery using a refined and systematic approach.

The tools used for kimberlite exploration have evolved over the years, allowing for a more strategic approach to exploration. Advancements in the geophysics 'toolbox' are discussed in Epp *et al.* (2024) and Lyon *et al.* (2024). In drift prospecting, the availability of centimetre-resolution elevation models and imagery provide the means to improve our understanding of, and map, the surficial geology and geomorphological processes that influence the dispersion of KIMs (*e.g.,* Sacco *et al*., 2022) This detailed surficial framework informs the evaluation and collection of data, ultimately allowing for improved success when exploring in complex environments where primary dispersal patterns are difficult to recognize. Of particular importance is identifying where deglacial processes have remobilized and reworked till, altering its geochemical and mineralogical composition, and masking the primary dispersion from a kimberlite.

Successful drift prospecting requires contrast in the dataset, specifically a contrast resulting from geology (*e.g.*, mineralized versus background values). Internal variability caused by genetic differences in sample medium, sampling methods, or analytical protocols, must be reduced to ensure contrasts resulting from those factors are not masking the signal of mineralization (Sacco *et al.*, 2018). Glacial meltwater is the primary source of post-depositional modification in till in the SGP. KIMs may have concentrated in higher energy environments, such as within meltwater corridors (*e.g.*, DesRosiers, 2021), or along modern or paleo shorelines (*e.g.*, Eccles, 2008). Conversely, KIM concentrations can be diluted where barren glaciolacustrine sediment has been incorporated into the till through cryoturbation (Figure 1). Knowledge of where meltwater has affected till, or simply the distribution of till in reference to other materials, allows for a more detailed interpretation of existing data, and the planning of tailored surveys that ensure only material that will provide reliable results will be collected. Detailed surficial geology mapping provides the framework necessary to mitigate the genetic variability in surficial exploration datasets.

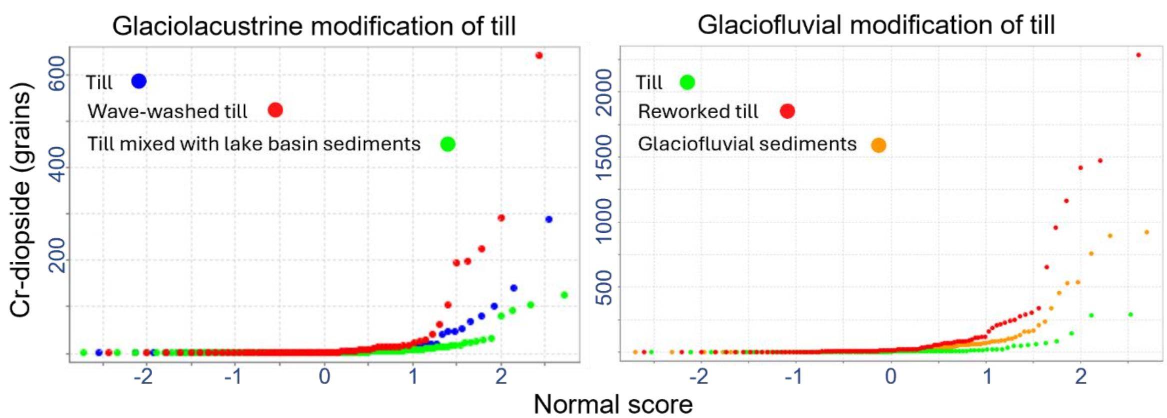

Figure 1. Probability plots demonstrating the difference in KIM concentrations amongst samples collected from different surficial environments (Data source: NTGS (2018)).

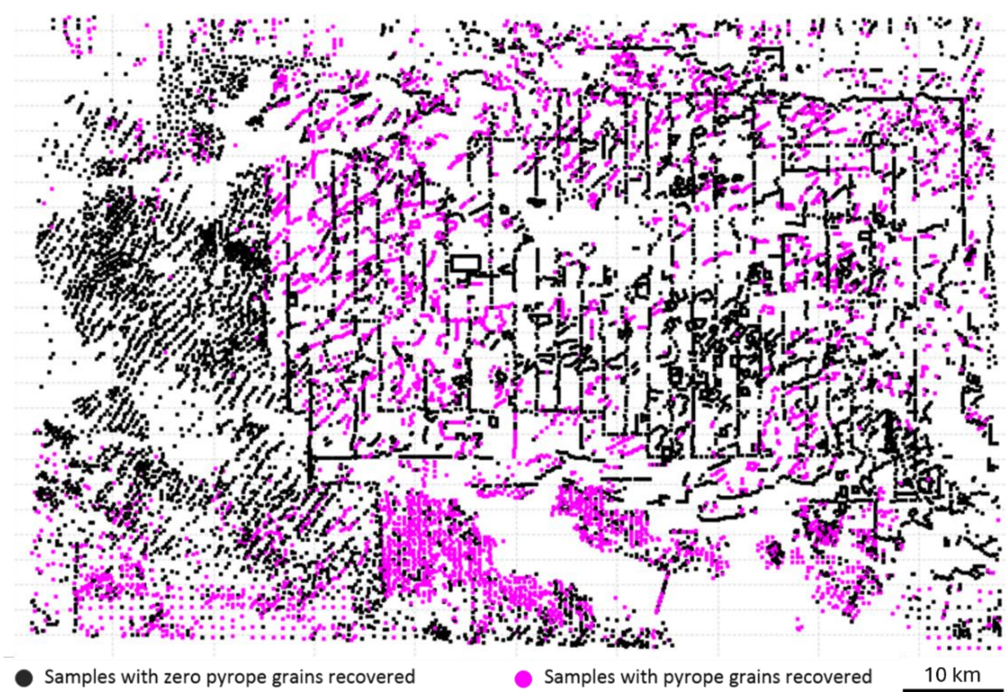

Figure 2. Locations of samples from which pyrope grains were, and were not, recovered (Data source: NTGS (2018)). The apparent grid pattern and extensive regions of null results suggest the low recovery rates may be related to sampling or analytical protocols. The removal of these false negatives reveals opportunities for new discoveries.

Dataset variability associated with sampling or analytical differences can be resolved through a forensic evaluation. For example, differences in sample sizes, concentration methods, grain size-fraction from which KIMs were picked, or what types of KIMs were picked can all influence the comparability of data (Figure 2). Analytical results from samples collected or analyzed using different protocols must be separated into subpopulations and evaluated as separate datasets (*e.g.,* Sacco *et al.*, 2018). In some cases, the data may be misleading and must be removed from the evaluation entirely (Figure 2). There is likely useful information in the historical data, but it can only be revealed if evaluated within the correct context.

The advancements in our understanding of KIM dispersion in the surficial environment and analytical methods provide us with new tools to explore in areas with complex surficial geology. Paired with advancements in the processing and analysis of sediment geochemical and mineralogical characteristics (McCandless *et al.,* 2024), explorers now have the means to recognize and unravel the source of complicated dispersal patterns. High-resolution surficial geology mapping can be used to understand the genetic variability in historical data, and with consideration for sampling and analytical differences, targets and data gaps can be revealed. The surficial geology mapping can be used to target ideal sampling locations to fill data gaps and refine target areas. A systematic approach using advanced drift prospecting strategies, in combination with the geophysical 'toolbox', and a new model of kimberlite architecture (*e.g.*, Epp *et al.*, 2024) will help reinvigorate diamond exploration in the under-explored parts of the Northwest Territories.

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