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Evolution of Kimberlite Exploration – A New Look at Kimberlite Indicator Morphology from the Southern Slave Craton, NWT

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Introduction

Kimberlite indicator minerals (‘KIM’) have been key to the first discovery of every kimberlite diamond mine in the world. River panners in South Africa were the first to recognize the association of KIM with diamond which, being more abundant than diamond in the rivers, helped them track diamonds upstream and then inland to discover the Dutoitspan kimberlite in 1870 (Wilson, 1982). The quantitative assessment of KIM to track down kimberlite was then developed, focusing on KIM abundance, grain size, and shape as guides to discovery (Draper and Frames, 1898). For the next several decades, scrutiny of KIM morphology (e.g. grain size, shape, color, and surface features) remained the primary tool for kimberlite discovery. Following the advent of the microprobe for mineral chemistry in the late 1960’s, the first kimberlites in Canada to become a mine at Ekati were discovered in 1991 by tracking both the morphology and mineral chemistry of KIM. Subsequent to their discovery, focus on the mineral chemistry of KIM became most relevant to exploration. This study revisits the physical aspects of KIM in diamond exploration, with a focus on KIM from the CL-25 kimberlite in the Southern Slave Craton.

Methods

CL-25 is one of several early Phanerozoic (>500Myr) kimberlites, emplaced when Canada was in the southern hemisphere. KIM within these kimberlites were exposed to millions of years of chemical weathering as North America moved north through tropical latitudes to reach its present position. The KIM developed distinctive surface features of chemical weathering that can be treated as primary surfaces, formed while in the primary environment of the kimberlite (McCandless, 1990, 2005). These primary surfaces are subsequently modified in the secondary environment as they are transported by glacial processes away from their kimberlite source.

A total of 178 pyrope from 19 glacial samples and ten grains from CL-25 were examined by binocular microscope and SEM to document changes in these surface features with transport, a collective distance of 52 kilometers (**Figure 1**). This study focused on the red to orange low-Cr pyrope populations as they are more prone to chemical weathering relative to the high-Cr compositions (Afanasiev et al., 2013).

Results

Ten pyrope from CL-25 all exhibited features of chemical weathering, including weathering of old conchoidal breaks. Chipping of the intersecting edges of the old and fresh breaks that is expected from transport is mostly absent. These results are consistent with a previous study of pyrope surface features for the higher-Cr pyrope compositions from CL-25 (Pokhilenko et al., 2010).

To quantify the physical changes in pyrope glacially-transported away from CL-25, a novel approach was undertaken. For each pyrope grain in a sample, the percentage of primary surfaces ('PS%') and the percentage of surfaces modified by wear from chipping ('WC%') were estimated for each pyrope grain. The resulting percentages are therefore a measure of the total primary and wear surfaces, not of the total pyrope grains.

The percentage of PS initially decrease with distance from CL-25, then increase again at distances of roughly 20 and 40 kilometers from the kimberlite. More importantly, the percentage of WC increase with distance from CL-25, but with decreases at roughly 20 and 40 kilometers from CL-25 (**Figure 2**). This cyclical behavior could reflect unusual glacio-fluvial processes in the dispersion of the pyrope, unusual weathering behavior of the CL-25 kimberlite, or the presence of additional sources of kimberlite within the CL-25 indicator train.

The results confirm that subtle changes in pyrope surfaces do correlate with distance from CL-25, in contrast to a previous study that focused on a broader population of pyrope compositions and were looking for significant changes in shape and size (Pokhilenko et al., 2010). The changes observed here are subtle, but also exhibit a cyclical behavior with distance from CL-25 that most likely coincide with ice advance and retreat episodes, whose boundaries have been documented for other areas of the southern Slave (Knight, 2017). During ice advance, pyrope are transported into glacial material at the leading edge of the ice front and are deposited in tills. During ice retreat, glaciofluvial processes wash in pyrope from the same area but inflict greater wear over a similar distance. As the cycles of ice advance and retreat repeat, the final till deposits will exhibit a mixed morphology due to these competing processes. Despite these complicated processes, the pyrope shed from CL-25 have recorded a surface feature history that leads back to their kimberlite source.

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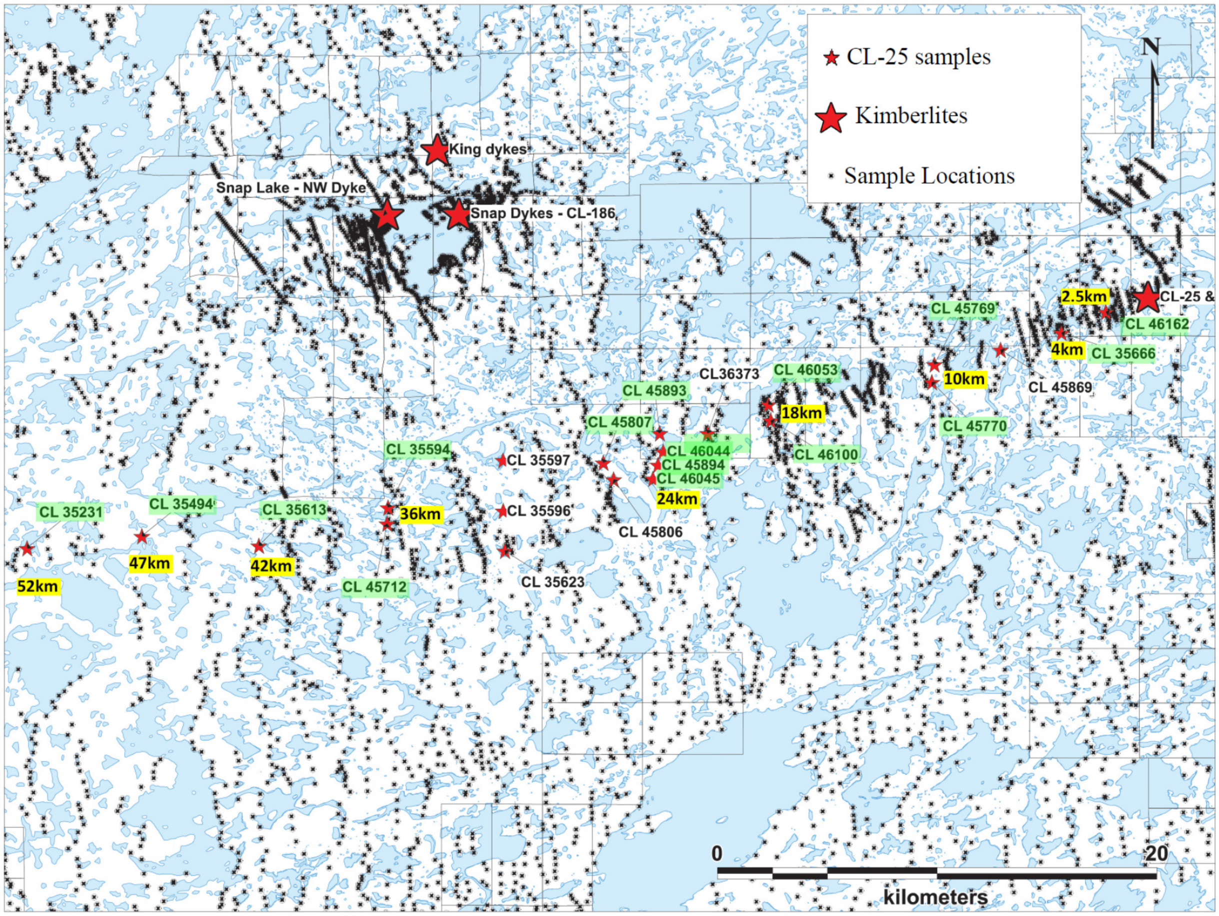

Figure 1. Location map for samples examined in this study. Selected samples are highlighted in green, approximate distances from the CL-25 kimberlite are highlighted in yellow.

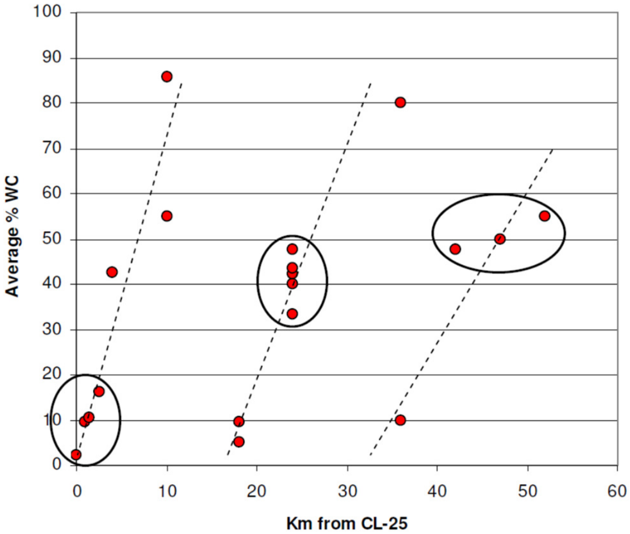

Figure 2. Distance from CL-25 plotted against the average percentage of wear by chipping on pyrope (%WC). For the samples enclosed by the ovals, wear increases with distance from the kimberlite. Samples outside of the ovals may be from other sources, or from glaciofluvial introduction of pyrope from CL-25 during ice retreat episodes.