KIMBERLITE INDICATOR MINERALS IN TILL, CENTRAL SLAVE PROVINCE, N.W.T., CANADA

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INTRODUCTION

As part of the Geological Survey of Canada's National Mapping Programme (NATMAP), the Terrain Sciences Division has mapped the surficial geology of the central Slave Province, currently the centre of extensive diamond exploration and the location of what will be Canada's first diamond mine. Numerous diamondiferous kimberlites have been reported in the area. Surficial geology mapping, till sampling, and ice flow studies were carried out in 1993 and 1994 over areas covered by 5 ½ 1:250 000 map sheets including Winter Lake, Point Lake, Napaktulik Lake, Aylmer Lake, Lac de Gras, and Contwoyto Lake, south ½. One objective of this activity was to determine the regional distribution and background concentrations of kimberlite indicator minerals in the area, and relate this distribution to regional ice flow patterns. Kelyphite reaction rims on pyrope grains were also examined in order to assess the effects of glacial abrasion and transport on soft kimberlitic material. It is hoped that results presented here can be used as a guide in other areas of kimberlite exploration in glaciated terrains, by way of providing potential background and anomalous concentrations of various kimberlite indicator minerals.

METHODS

A total of 300 10-kg bulk till samples were collected from shallow hand dug pits, with a sampling density of one sample per 180 km^2. Samples were processed at Overburden Drilling Management, Nepean, Ontario. Processing included disaggregation, sieving, tabling and separation in heavy liquid. Non-ferromagnetic heavy mineral fractions, obtained from ferromagnetic separation, were sieved to 0.25–0.5 and 0.5–1.0 mm to recover kimberlite indicator minerals. For all samples, the 0.25–0.5 mm fraction was sent to I. & M. Morrison Geological Services, Delta B.C., to pick out potential kimberlite indicator minerals including pyrope garnet, eclogitic garnet, Cr-diopside, Mg-ilmenite and chromite. Pyrope grains that showed surface features such as kelyphite rims, resorption surfaces and orange peel textures, indicative of derivation from kimberlites, were noted. The 0.5–1.0 mm fraction was picked for potential indicator minerals only for samples that contained five or more suspected pyropes in the 0.25–0.5 mm fraction, because of the rarity of indicator minerals in the 0.5–1.0 mm fraction in certain map areas compared to the 0.25–0.5 mm fraction. Potential indicator mineral grains were mounted in 25 mm epoxy mounts and analyzed using the electron microprobe facilities at the Geological Survey of Canada. Additional information on the mineral grains (color, specific gravity, magnetic susceptibility) were used to improve or confirm identification based on mineral chemistry.

Kimberlite indicator minerals identified in till samples were primarily pyrope, Cr-diopside, chromite, and Mg-ilmenite. Kimberlites contain diopsides with a wide range of Cr_2O_3 values which overlap at the lower end of the Cr_2O_3 spectrum with diopside compositions in other ultrabasic rocks, making discrimination between kimberlitic and other diopsides on the basis of chrome content difficult. Diopsides were classified into three groups according to Cr_2O_3 content:

1. diopside < 1 wt.% Cr_2O_3,
2. Cr-diopside < 1.4 wt.%, and
3. high Cr-diopside > 1.4 wt.%.

Diopside with < 1 wt-% Cr_2O_3 was not considered as a kimberlite indicator in this study. The cut-off value of 1% for Cr-diopsides is conservative (relatively high) and likely excludes some diopsides that come from kimberlites; however, below this value the diopsides could also originate from non-kimberlitic sources. Ilmenite containing > 6 wt.% MgO was classified as Mg-ilmenite. Chromite with < 61 wt.% Cr_2O_3 and > 11 wt.% MgO is considered to be diamond-inclusion chromite.

RESULTS

The concentrations of indicator minerals ranged from 0 to 676 grains per 10-kg till sample. The majority of the indicator minerals were found in the 0.25–0.5 mm fraction (Dredge *et al.*, 1997). In this fraction, 91 of the 300 samples contained confirmed indicator minerals, with the majority of these samples containing <5 indicator minerals. Of the samples examined for indicators in the 0.5–1.0 mm fraction, only 20 samples

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contained indicator minerals. These data indicate that for smaller samples (~10 kg), the finer grain size must be picked, or more subtle anomalies might be missed. The relative proportion of indicator minerals in the 0.25–0.5 mm size fraction is ~75% pyropes, ~22% chrome diopsides, ~2% Mg-ilmenites, ~1% chromites and <<1% eclogitic garnets. Almost every sample with > 5 pyropes contains "G10" or sub-calcic garnets. These indicators suggest that most of the kimberlites in the area have sampled potentially diamondiferous hartzburgitic mantle. The lack of eclogitic garnets precludes a significant source of diamond from eclogite. In order to understand the direction and distance of dispersal of kimberlite indicator minerals, knowledge of ice flow history and till types is essential. One single till sheet was sampled and ice flow directions were determined from striation sequencing. Ice flowed initially southwestward across the entire study area, then westward in the southern and central regions, followed by northwestward in the southern and northern regions with a shift to west northwestward and westward in the central and western regions, and finally northwestward to north northwestward in the central and northern regions at the end of glaciation. A young, very localized, southwestward flow was also recorded in a few isolated localities in the central study area. However, the dominant ice flow most responsible for transport of kimberlitic debris was the northwestward and westward flows, as evidenced by striae, as well as large scale ice flow landforms, and local kimberlite dispersal trains.

Studies of pebble lithology and sand mineralogy of the till samples indicate that pebble-sized clasts have been glacially transported in till for distances up to 40 km, and sand grains for up to 75–100 km from rock sources. Samples with the highest concentration of indicator minerals were found adjacent to and down-ice from the Lac de Gras kimberlite cluster in the northern half of the Lac de Gras map area, where more than 50 kimberlite pipes have been reported. Samples containing >15 indicator minerals in number are common for this area. This zone is informally termed the Lac de Gras dispersal plume and likely represents the combined signature of the kimberlite field just north of Lac de Gras. Several samples with low concentrations of indicator grains (up to 7) occur in the westward/northwestward down-ice direction in the Winter Lake and to a lesser degree in the Point Lake map areas. This distribution forms the distal part of the dispersal plume. There are also a number of sites with low concentrations of grains west-southwest of the Lac de Gras kimberlite cluster. The combination of earlier phases of southwestward and westward flow and the subsequent dominant northwestward flow over the principal zone of kimberlites in the Lac de Gras area and dominant westward flow in the Winter Lake area, could account for the presence of indicator minerals at some of the sites. However, because of high quantities of indicators at some sites and a lack of indicators directly southwest of the Lac de Gras pipes, it is also probable that there are additional unmapped kimberlite sources in the Winter Lake area. Very few kimberlite indicator minerals occur up-ice of the Lac de Gras kimberlite cluster, in the Aylmer Lake area, where the presence of one indicator mineral would be considered anomalous. There is also a paucity of indicator minerals in the southern Contwoyto Lake map area, north of the Lac de Gras kimberlite field. Isolated samples with variable concentrations of indicator minerals in the Napaktulik Lake map area may be related to a few known kimberlite pipes in the Contwoyto Lake area, as they occur down-ice of these potential source areas. Similarly, a small number of sites with low concentrations of indicator minerals do not relate to any known source pipes, and are not part of the Lac de Gras dispersal train. Localities with one or more indicator grains warrant further investigation.

Individual types of indicator minerals also show strong regional differences. The distribution of pyropes strongly reflects the Lac de Gras dispersal plume, with the highest concentrations over the kimberlite field, decreasing in concentration down-ice westward into the Winter Lake map area and southern Point Lake area. Chrome-diopsides and high Cr-diopsides have similar geographic distributions. Chromites and Mg-ilmenites are generally associated with the main plume in the northern Lac de Gras map area. Low Cr-diopsides are relatively abundant throughout the southern and central study area. The southeastern Napaktulik Lake map area and the northeastern Point Lake map area have three to four samples with relatively high concentrations of Cr-diopside, Mg-ilmenite, low Cr-diopside and rare pyrope and chromite. Kimberlites in the southeastern Lac de Gras map area and eastern Aylmer Lake map area were not detected in the samples collected in this study. There are several possible explanations for this. Because of the low sampling density and small number of known pipes, the individual dispersal plumes for these pipes may not have been identified. More likely, these kimberlites have different heavy mineral suite signatures from those in other areas. The high concentrations of low Cr-diopsides, small abundances of diopsides and high chrome diopsides, and lack of pyropes in the Aylmer Lake map area suggest that there are regional differences in kimberlite heavy mineral suites. Alternatively, the low Cr-diopsides in the Aylmer Lake map area may be derived from ultrabasic rocks in the region. Relatively high Mg-ilmenite grain counts relative to pyrope at a site east of Winter Lake suggests that any pipes in that area also have a different indicator assemblage than the kimberlites of the Lac de Gras cluster.

Kelyphite studies

Reaction surfaces (kelyphite) typically develop around individual pyrope garnet grains as a result of reactions in the source regions of the xenoliths from the mantle and interaction of the garnets with kimberlite magma. Particular attention is focussed on kelyphite because its presence has been used previously to suggest the proximity of kimberlite pipes. Pyrope grains from four till samples were examined on the scanning electron microscope for thickness, texture, surface coverage, and composition. Transport distances for samples varied from <1 km to > 30 km from source kimberlite pipes. All grains that have undergone glacial transport remain angular and retain their conchoidal fracture habit. Grains that were transported 20 to 30 km, however, have more conchoidal fracture faces, than those much closer to source pipes. Although kelyphite is soft and its surfaces are rounded even near pipes, it was still present on far travelled grains, although the surface area and thickness of the kelyphite layer decreases as distance of transport increases. For indicators in till, the presence of kelyphite does not necessarily imply proximity to a kimberlite pipe.

CONCLUSIONS

Important implications with respect to mineral exploration methodology result from this regional study. Despite the fact that many kimberlite pipes are recessive and occur under lakes, till sampling is an effective drift prospecting technique. The regional distribution of indicator minerals displays wide variability which can be explained by the ice flow history and the location of the principal zone of known kimberlites for the area. The area with the highest concentration of indicator minerals occurs in the northern half of the Lac de Gras map area, either adjacent to or down-ice from most of the known kimberlites. The areas with the lowest concentrations of indicator minerals are the Aylmer Lake area, which is up-ice from most of the known kimberlites, and areas in the Napaktulik Lake and Point Lake regions which are not directly down-ice of known kimberlites. Regional till sampling led to the identification of the Lac de Gras dispersal plume which reflects the combined signature of all the pipes in the area. Its elongate nature to the northwest corresponds to the dominant direction of glacial transport. However, sampling density was too low to resolve dispersal trains from individual pipes. Preliminary data on kelyphite preservation on pyrope grains reported here are among the first from glacially transported material. Not all kelyphite is removed during glacial transport. The abundance of conchoidal fracture faces on pyrope grains appears to increase with increased distance from source pipes and this may be a useful indication of transport distance.

REFERENCES

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