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Advances in soil geochemical exploration methods for areas of glacial cover

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INTRODUCTION

The Attawapiskat cluster of kimberlites in northern Ontario, Canada was chosen as a study site to evaluate geochemical anomalies in surface media associated with kimberlites. Kimberlites contain abundant ultramafic minerals and during weathering should impart electrochemically reducing conditions to surrounding surficial materials, both groundwater and sediments (Hamilton et al., 2004; Sader et al., 2007). The purpose of the study was to evaluate the processes of metal dispersion in wetlands overlying glacial and glaciomarine deposits, thereby assessing the validity of using geochemical techniques to discriminate kimberlites from other geophysical targets in similar terrain. Kimberlites in the Attawapiskat cluster are Jurassic in age (~170 Ma) and were emplaced through Ordovician and Silurian strata (Webb et al., 2004). They are overlain by glacial sediments which are capped by marine clays of the post-glacial Tyrrell Sea (~ 4000 – 12000 years BP). One to four meters of peat overlie kimberlites in this region (Fraser et al., 2005).

METHODOLOGY

Samples collected for this study consist of peat, peat water, shallow groundwater, dissolved gas within groundwater, and spontaneous potential (SP) surveys. Samples were collected at eight kimberlites (and a control site) in the Attawapiskat cluster in 2006 and 2007. Samples were taken at 25-50 m intervals along linear transects. Transects captured background values on either side of the 2D surface expression of the kimberlite delineated from ground magnetic data. Transects were positioned from air photos and high resolution satellite imagery which showed peat-covered areas that were not covered in open water or floating bogs. At each sample site, soil or peat, pH, Oxidation Reduction Potential (ORP), alkalinity and conductivity of water, shallow water and gas were collected. Soil and peat samples where sent to Acme Analytical Laboratories Ltd. for acetate leach analyses, and to Activation Laboratories Ltd. for Soil Gas Hydrocarbon (SGH) analyses. Water samples were analyzed for major cations, anions, dissolved inorganic carbon (DIC), dissolved organic carbon (DOC), and carbon isotope analysis.

RESULTS

Detectable signals related to kimberlite mineralization occur in peat, although some anomalies (e.g., REEs) are weak and diffuse. This is consistent with soil partial leach results that generally show higher relative concentrations over kimberlites at Attawapiskat (Hattori et al., 2007) and at other locations in northeastern Ontario (McClenaghan et al., 2006). Peat samples show precipitation of high REE carbonates and Fe-O-OH, which are mobile above kimberlites due to reduced conditions.

Peat water composition shows prominent anomalies. The rare earth elements (REEs) over both Zulu and Yankee show elevated concentrations compared to concentrations outside of the kimberlites (Fig. 1). REE enrichments at Yankee tend to occur at the margins of the kimberlite, where as concentrations at Zulu are centered over the kimberlite. The pH and ORP anomalies in peat water become more accentuated with greater sample depth (1.1 m compared with 40 or 60 cm) (Sader et al., 2008). Sader et al. (2008) have determined that with increasing depth over the Zulu kimberlite, peat waters are more acidic and oxidized relative to off the kimberlite. Conversely, with depth over the Yankee kimberlite, peat waters become more alkaline and reduced relative to outside the kimberlite.

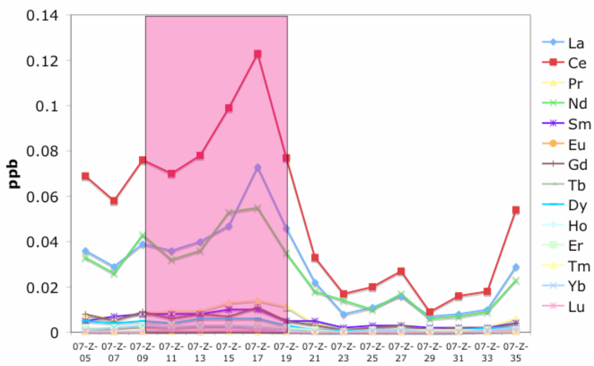

Figure 1: Rare earth element concentrations over Zulu kimberlite from peat water samples. Surface extent of kimberlite from ground magnetic data in pink (from Sader et al., 2008).

Concentration of metals vary at Zulu (Fig. 2) compared with Yankee. Peat waters over Yankee tend to show metal enrichments occurring as single-sample spikes. The low concentration of Fe over Zulu suggests oxidation and precipitation of Fe hydroxides (Sader et al., 2008).

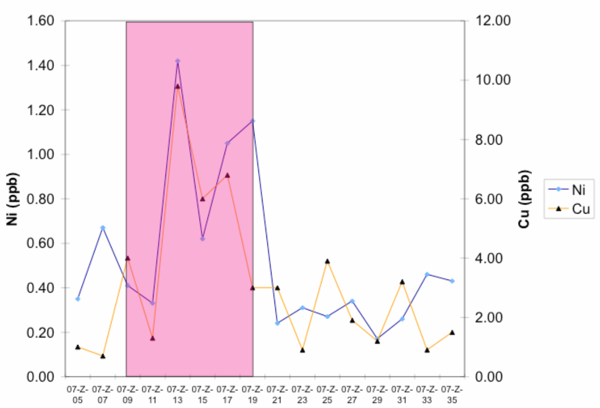

Figure 2: Nickel and copper concentrations over Zulu kimberlite from peat water samples. Surface extent of kimberlite from ground magnetic data in pink (from Sader et al., 2008).

Anaerobic and aerobic microbial counts are higher in samples taken over kimberlites suggesting that the kimberlite is enhancing the biosphere (Fig. 3). Where pH and ORP anomalies in peat water are shifted with respect to the observed surface magnetic expression of the kimberlite, the enhanced microbial population exhibits the same shift.

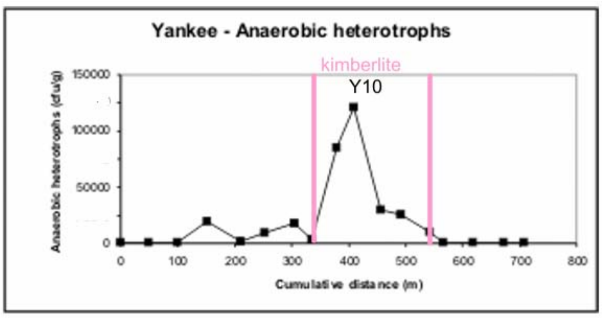

Figure 3: Anaerobic heterotroph population over Yankee kimberlite. Surface extent of kimberlite from ground magnetic data bounded by pink bars.

TRANSPORT PROCESSES

Results suggest that there are two different vertical transport mechanisms bringing ions from the Zulu and Yankee kimberlites to surface. At Zulu, higher ORP and lower pH relative to outside of the kimberlite suggest the oxidation of reduced species originating from the kimberlite are producing an acidic cap over a reduced chimney (Sader et al., 2008). These results are consistent with electrochemical or diffusion vertical transport of ions (Hamilton et al., 2004). Upwelling is suggested at Yankee by Sader et al., (2008) due to differences in hydraulic gradient observed across the Yankee kimberlite. These differences correlate well with spikes in high relative metal content, alkaline pH and low ORP observed at Yankee (Sader et al., 2008). A bioherm is exposed at surface west of the Yankee kimberlite. This bioherm effectively punctures the Tyrrell Sea marine clay seal which isolates surface waters from underlying groundwater. This puncture enables groundwater connectivity and transport at Yankee.

It appears that both electrochemical processes and physical groundwater advection play key roles in the vertical transport of ions to surface (Sader et al., 2008). Understanding which process is active is significant for exploration. A possible critical variable on the effectiveness of both mechanisms is temperature. The Attawapiskat kimberlite cluster is located in an area of discontinuous permafrost (Fig. 4). If physical groundwater advection is the primary transport mechanism, the system will effectively shut down if water is sequestered in discontinuous permafrost. Permafrost may also effect the formation of a reduced chimney over kimberlites as cold temperatures will slow any reactions responsible for starting the electrochemical process. If this hypothesis is correct then there will be a northern limit to effectiveness of selective leach and SGH techniques for both discontinuous and continous permafrost zones in areas with significant cover (Hamilton, 2007a).

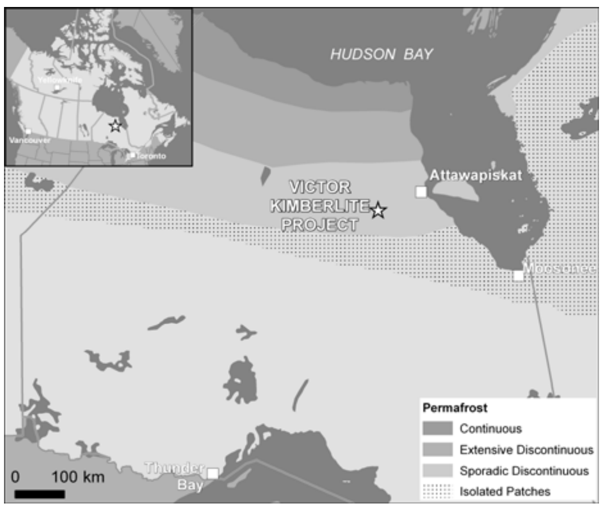

Figure 4: Sporadic discontinuous permafrost in the region of the Attawapiskat cluster which includes the Victor kimberlite mine.

OPTIMIZED SAMPLING PROTOCOL

A 3-component soil geochemical methodology is recommended that includes analysis by (1) a selective leach method; (2) a soil hydrocarbon technique; and (3) pH and ORP. Using all three methods at once will improve the likelihood of success as they each detect a different aspect of the large-scale geochemical process (Hamilton, 2007b). Selective leaches target the primary (i.e., originating from ore) and secondary (i.e., resulting from pH/Eh changes) elemental responses. Soil hydrocarbon techniques target the reduced chimney indirectly by measuring the products of autotrophic organisms that thrive at soil redox boundaries. Soil slurry pH and ORP targets the acidic cap but may also detect a 'basic chimney' below the water table or alkaline groundwaters from kimberlites or ultramafics that may have reached the soil zone. Interpretation must always consider the possibility of 'false anomalies', which occur commonly due to changes in surficial conditions. Variable moisture content is a major source of false anomalies in mineral soils, whereas variable clastic input is the dominant source of false anomalies in peatlands.

To optimize the effectiveness of geochemistry in discriminating buried targets, it is recommended that all three techniques be used simultaneously on single sampling lines crossing the targets. Maximizing the consistency of both the medium and the sample depth will decrease the geochemical ‘noise’ and improve the chances of success. This 3-component technique is considered ideal for target discrimination and prioritization but not for target generation. Proper field sampling protocols are critical and data interpretation must be carried out by personnel with a basic understanding of surficial geochemical processes.

CONCLUSIONS

Deep penetrating geochemical techniques yield anomalies over kimberlites in the Attawapiskat area. Elemental and microbial anomalies are created in peat overlying glacial and glaciomarine sediments over kimberlites. Anomalies may be diffuse and displaced due to physical transport from horizontal water flow and/or due to the low oxidation and acidic conditions in the peat being unfavourable for fixing metals. Peat water shows an enhanced response compared with peat and the response in peat water is accentuated with increased sample depth. It appears that both electrochemical processes and physical groundwater advection play key roles in the vertical transport of ions to surface. Permafrost may effect both the physical movement of water and slow any reactions associated with the formation of a reduced chimney over kimberlites. It is recommended that pH/ORP, selective leach and SGH be used simultaneously for discrimination and prioritization of targets.

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REFERENCES

Fraser, C., Hill, P. R., Allard, M., 2005. Morphology and facies architecture of a falling sea level strandplain, Umiujaq, Hudson Bay, Canada. Sedimentology 52, 141-160.

Hamilton, S.M., 2007a. Major advances in soil geochemical exploration methods for areas of thick glacial drift cover. Exploration 07, the Fifth Decennial International Conference on Mineral Exploration, Toronto, Ontario, Sept 9-12, 2007.

Hamilton, S.M., 2007b. A prospector’s guide to the use of selective leach and other deep penetrating geochemical techniques in mineral exploration. Ontario Geological Survey Open File Report 6209, 39 p.

Hamilton, S.M., Cameron, E.M., McClenaghan, M.B., Hall, G.E.M., 2004. Redox, pH, and SP variation over mineralization in thick glacial overburden. Part II: field investigation at Cross lake VMS property. Geochemistry: Exploration, Environment, Analysis 4, 45-58.

Hattori, K. H., Hamilton, S. M., Januszczak, N., 2007, Geochemical characteristics of soil and peat overlying concealed kimberlites in the Attawapiskat area, northern Ontario. Ontario Forum and Ontario Prospectors Symposium in Sudbury, Ontario, Dec. 10-12, 2007.

McClenaghan, M. B., Hamilton, S. M., Hall, G. E. M., Burt, A. K., Kjarsgaard, B. A., 2006, Selective Leach Geochemistry of Soils Overlying the 95-2, B30, and A4 Kimberlites, Northeastern Ontario. Geological Survey of Canada, Open File 5069, 28 p.

Sader, J.A., Hattori, K.H., Hamilton, S.M., Brauneder, K., 2008. Development of surficial geochemical exploration methods for diamond deposits in the Attawapiskat region, James Bay Lowlands, Ontario. Northeastern Ontario Mines and Minerals Symposium (NEOMMS) in Thunder Bay, Ontario, April 7-9, 2008.

Sader, J.A., Leybourne, M.I., McClenaghan, M.B., Hamilton, S.M., 2007. Low-temperature serpentinization processes and kimberlite ground water signatures in the Kirkland Lake and Lake Timiskiming kimberlite fields, Ontario, Canada; implications for diamond exploration. Geochemistry – Exploration, Environment, Analysis 7, 3-21.

Webb, K. J., Scott Smith, B. H., Paul, J. L., Hetman, C. M., 2004. Geology of the Victor Kimberlite, Attawapiskat, northern Ontario, Canada: cross-cutting and nested craters. Lithos 76, 29-50.