

Peat groundwater as a medium for surficial geochemical exploration

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ABSTRACT: Kimberlite-specific chemical responses are visible in shallow peat groundwater over kimberlites from the Attawapiskat region in the James Bay Lowlands, Canada. These chemical responses are visible due to the physical movement of deeper groundwater that has interacted with kimberlite and migrated through the Tyrell Sea sediment into shallow peat groundwater. The presence of elevated values of electrical conductivity, CaCO₃ saturation index, Ca, and alkalinity indicate groundwater upwelling. Upwelling groundwaters that have high concentrations of Ni, Cr, Fe, Mg, and REEs are likely due to water-kimberlite rock interactions rather than interactions with limestone, or Tyrell Sea sediment. Some of these elements may behave more conservatively in peat groundwaters and are sometimes observed down the horizontal hydraulic gradient. This study has also determined that it is preferable to collect peat groundwater samples deeper into the saturated zone where waters are more reducing and are likely to have higher concentrations of elements. Increased depth into the saturated zone provides better groundwater geochemical resolution between locations of high element contents and lower contents along transects. More oxidized groundwaters near the surface tend to produce oxyhydroxides that can adsorb to peat and lower element concentrations in peat groundwater.

KEYWORDS: *kimberlite, exploration, geochemistry, groundwater, peat*

INTRODUCTION

In regions where bedrock is hidden by sequences of sediment, surficial geochemical exploration has been used with a great deal of success. A variety of models and methods have been developed to explain the migration of elements through these sequences to the surface from hidden kimberlites and other ore deposits (i.e. Hamilton et al., 2004a; Hamilton et al., 2004b; Hattori & Hamilton, 2008; Mann et al., 2005; McClenaghan et al., 2006). These models have focused on identification of geochemical responses in soil.

In many northern regions, peat bogs are common occurrences. We present results that suggest that peat groundwater geochemistry can have geochemical responses consistent with groundwaters that have interacted with kimberlite rock (Sader et al., 2007). Exploration in peat bog terrains requires specific sampling methods, and there are specific

geochemical responses that are not shared with soil geochemical exploration.

GEOLOGICAL SETTING

The kimberlites in this study are located in the James Bay Lowlands and are in close proximity to the DeBeers Victor Mine. The kimberlites are mid Jurassic (~170 Ma) in age and have been emplaced into Paleozoic limestone (Webb et al., 2004). These kimberlites all have similar groundmass mineralogies consisting mainly of carbonate, spinel, and serpentine with lesser monticellite, mica, apatite, and perovskite (Kong et al., 1999) and they are all of volcanoclastic facies near ground surface. Varying thicknesses of clay and fine marine sediment of the Tyrell Sea (~ 4000 – 12000 years BP) and 1 to 4 m of peat overlie kimberlites (Fraser et al., 2005). Bioherms composed of coral and skeletal remains of other marine organisms sometimes outcrop.

METHODOLOGY

Fieldwork was conducted at Attawapiskat kimberlites (Yankee, Zulu, Alpha-1, Bravo-1, and X-ray), and at the Control location August 14-23, 2007 and October 14-18, 2007. Shallow piezometers were used in this study for peat groundwater sampling. At the Yankee and Zulu kimberlites piezometers were installed along transects between 25 to 50 m apart. Between 3 and 5 piezometers were installed at Alpha-1, Bravo-1, and X-ray. Piezometers were typically pushed into the peat 1.2 m with a loosely fitting plastic champagne cork at the end to prevent peat entering the pipe while it was being pushed down. The pH, oxidation-reduction potential (ORP), electrical conductivity (EC), dissolved oxygen content (DO), temperature, and CaCO_3 alkalinity were measured on-site at the time of sampling for all piezometer, monitoring well, and borehole water samples.

Waters collected from piezometers and monitoring wells were analyzed for metals using an inductively-coupled plasma emission spectrometer and inductively-coupled plasma mass spectrometer at the Ontario Geological Survey. Anion contents were also determined at the Ontario Geological Survey using an ion chromatograph.

RESULTS AND DISCUSSION

Our results indicate that peat groundwater can be an effective medium for surficial geochemical exploration. The dilute, acidic peat groundwaters contrast well with groundwaters that have interacted with kimberlite.

Elevated Ca, CaCO_3 -SI, alkalinity, and EC in peat groundwaters are good indicators of groundwater discharge from deeper locations to surface. These elevated parameters correlate with locations of measured groundwater upwelling and indicate that groundwater movement is the dominant method for ion transport to near-surface groundwaters. They are especially good indicators in peatlands because there is high contrast

between groundwaters that have interacted with host or kimberlite rock, compared to the dilute peat groundwaters.

In order to differentiate waters that have discharged to the surface from the host limestone from groundwaters that have interacted with kimberlite, we have identified elevated elemental responses that are likely related only to water-kimberlite interactions. Elevated concentrations of elements such as Mg, Ni, Cr, and REEs can assist in discriminating host rock groundwaters from kimberlite waters. For example, elevated Mg is found only where waters are discharging over the Yankee kimberlite even though Ca is elevated over the kimberlite plus where groundwater is discharging from the bioherm (Fig. 1). Select elements appear to be more chemically conservative in acidic peat groundwater and can sometimes be found down gradient of the kimberlite margin.

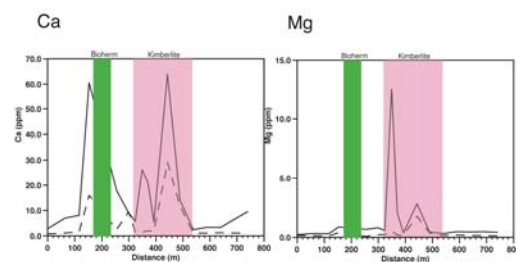


Fig. 1. Calcium exhibits a strong response over the kimberlite, also elevated due to water interaction with the bioherm. Magnesium, generally abundant in kimberlite rock, only shows responses over the kimberlite.

A “reduced chimney” is visible in the peat groundwater over both the Yankee and Zulu kimberlites, where elevated ORP responses correspond with low to non-detectable DO (Fig. 2). The “reduced chimney” model was first described by (HAMILTON et al., 2004a; HAMILTON et al., 2004b). Elevated ORP is a result of increased reduced ions that have migrated to more oxygen-rich peat groundwaters, consumed oxygen, and oxidized. But because these ions have

consumed oxygen, there is also a depletion of DO.

The depth that peat groundwater samples are collected is important. Deeper sample collection consistently results in increased elemental

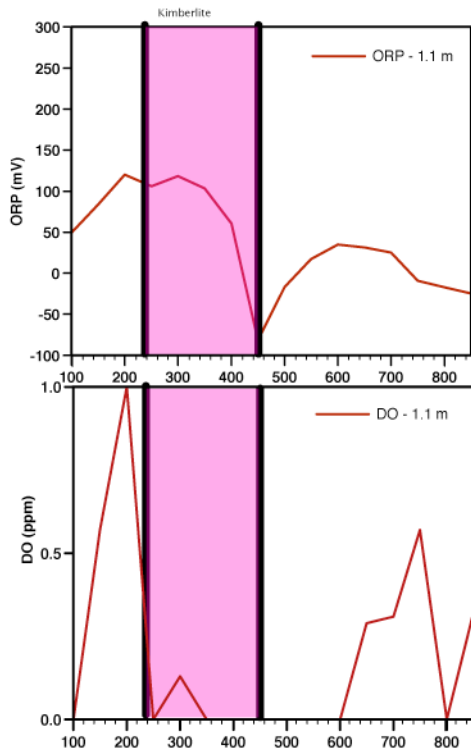


Fig. 2. The high ORP values and the corresponding low DO concentration in peat groundwaters along a transect at Zulu is an indication of reduced ions moving to the surface and oxidizing.

concentrations. Our results also indicate that absolute depth below ground surface is not the only important factor to consider when collecting peat groundwater samples. Samples that are collected deeper below the vadose/saturated boundary tend to be more reducing and have the potential to contain higher elemental concentrations (Fig. 3). Although piezometers were installed at a uniform depth into peat in this study, the water sampled from the piezometer was not necessarily from the same depth into the saturated zone. These variations can

lead to imprecise results and interpretations. A sample that is collected deep into the saturated zone will likely contain higher element concentrations relative to other samples along a transect where groundwaters are not collected as deep. This can erroneously indicate the presence of a buried kimberlite when none really exist.

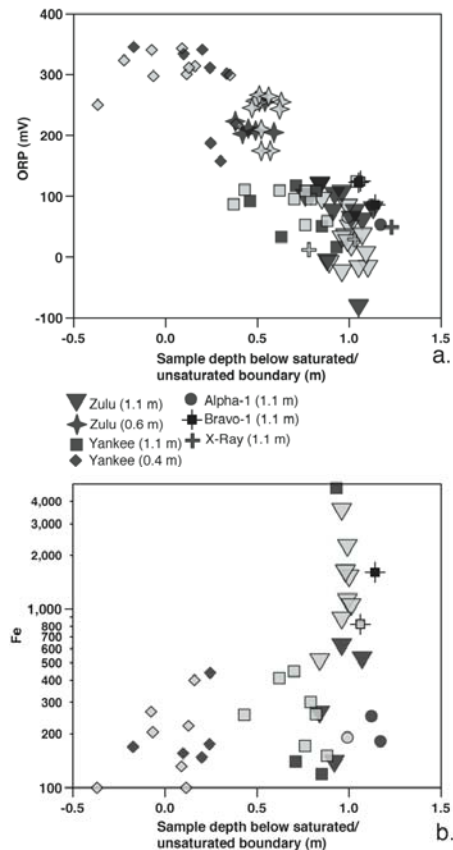


Fig. 3. Sample collection deeper into the saturated zone results in more reducing conditions (a) and increase in redox sensitive elements such as Fe (b).

CONCLUSIONS

This contribution can be summarized in the following points:

- (1) Kimberlites can be detected in shallow peat groundwater, organic rich environments using surficial geochemistry.

(2) Elements that are common to kimberlite rock are elevated in peat groundwater over buried kimberlite.

(3) The elevated concentrations of reduced ions that are migrating from a kimberlite produce a "reduced chimney" over the kimberlite, where ORP highs are found where DO lows are found.

(4) Unlike the protocol associated with the sampling of the upper B horizon, where the tell-tail reddish-brownish oxidized soil sits just below the more leached grayish soil, there are few visual signs in peat to indicate that sample collection is at the appropriate depth. Therefore we are reliant on geochemical and hydrogeological parameters in the field to guide us where best to collect a peat groundwater sample.

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