Finding the Geochemical Evidence for Buried Kimberlites in Wetland: Case study in the James Bay Lowlands, Ontario, Canada

uOttawa

NSERC CRSNG

De Beers Canada

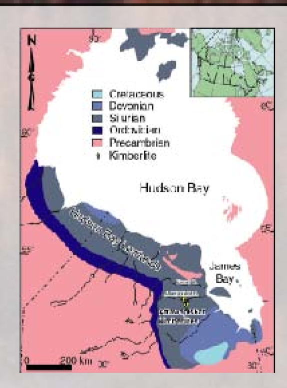
Jamil. A. Sader and Keiko Hattori

University of Ottawa, Earth Sciences Department, Ottawa, Ontario K1N 6N5, Canada (e-mail: jamilsader@yahoo.com)

Summary

- A study was undertaken to evaluate the effectiveness of shallow groundwater geochemistry for exploration of buried kimberlites in wetlands.
- Shallow groundwaters show large variations in pH, Eh, EC, carbonate saturation index, and metal concentrations.
- Deep groundwater is upwelling near kimberlite margins due to fractures along the boundaries between kimberlite pipes and host limestone.
- Shallow groundwaters at these upwelling sites contain high kimberlite pathfinder metals, such as Ni, Cr, REE+Y, Ba and alkalis.
- Low $\mathbf{d}^{13}C_{(DIC)}$ was commonly observed directly over kimberlites suggesting methane is migrating vertically over kimberlites and oxidizing in the peat.
- The results of this study show that shallow groundwater is a good medium in detecting buried kimberlites in wetlands.

Location and Geology

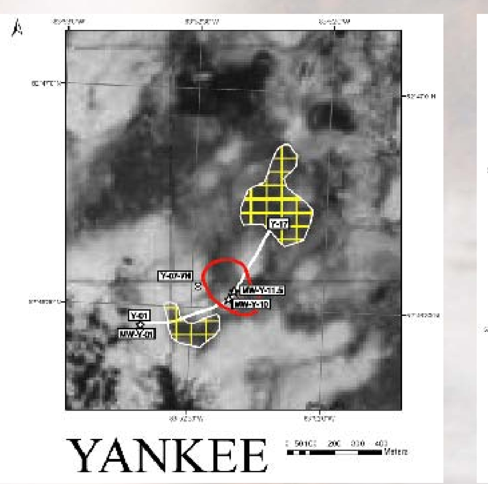


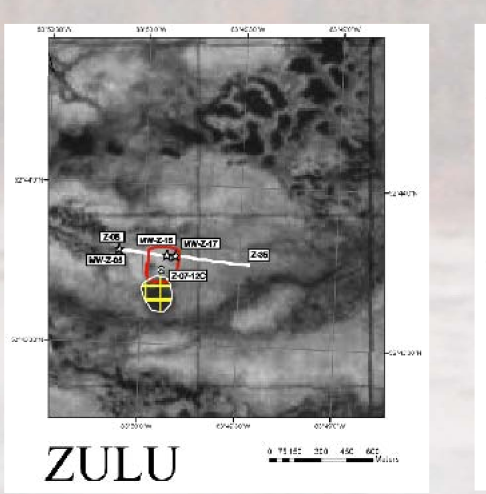
Kimberlite Geology

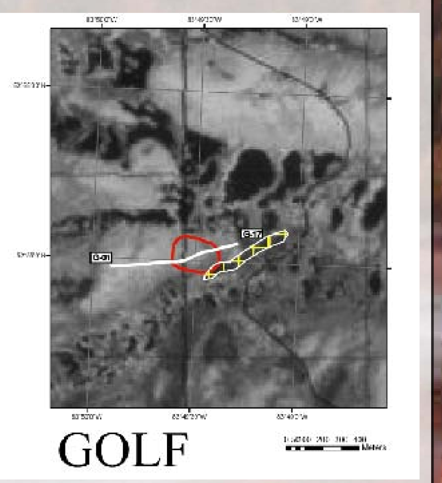
- Jurassic kimberlites are were emplaced into Paleozoic limestone (Webb et al., 2004).
- kimberlites have both volcaniclastic and hypabyssal facies.
- kimberlites consists of olivine, ilmenite, garnet, Cr-diopside, phlogopite, and spinel (Kong et al., 1999).

Quaternary Geology

- sphagnum peat (2.5-4 m) and fine-grained marine Tyrell Sea sediment (2-22 m; ~ 4000 - 12000 years BP) overlie a thin layer of till and kimberlite/limestone.
- Bioherms (coral and other marine organisms) outcrop occasionally above the peat surface.

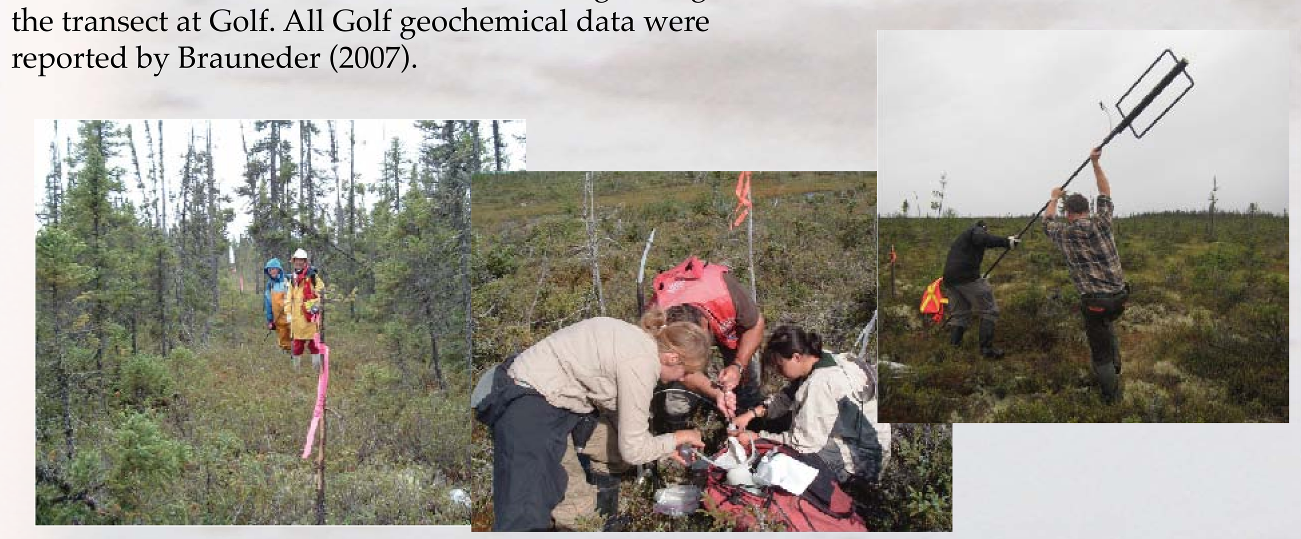






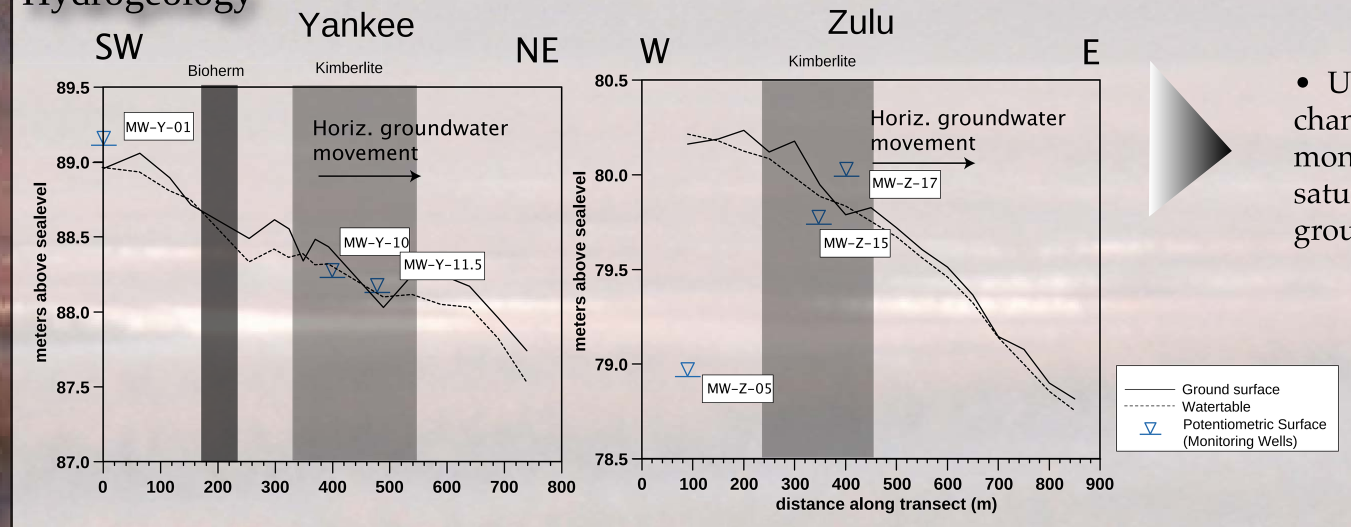
Groundwater Sampling

- Shallow groundwaters were collected using PVC piezometers at 1.1 meters below ground surface at the Yankee and Zulu kimberlites and at 0.4 mbgs along the transect at Golf. All Golf geochemical data were reported by Brauneder (2007).
- Monitoring wells were installed 70 cm below the peat into Tyrell Sea sediments to collect deeper groundwater.



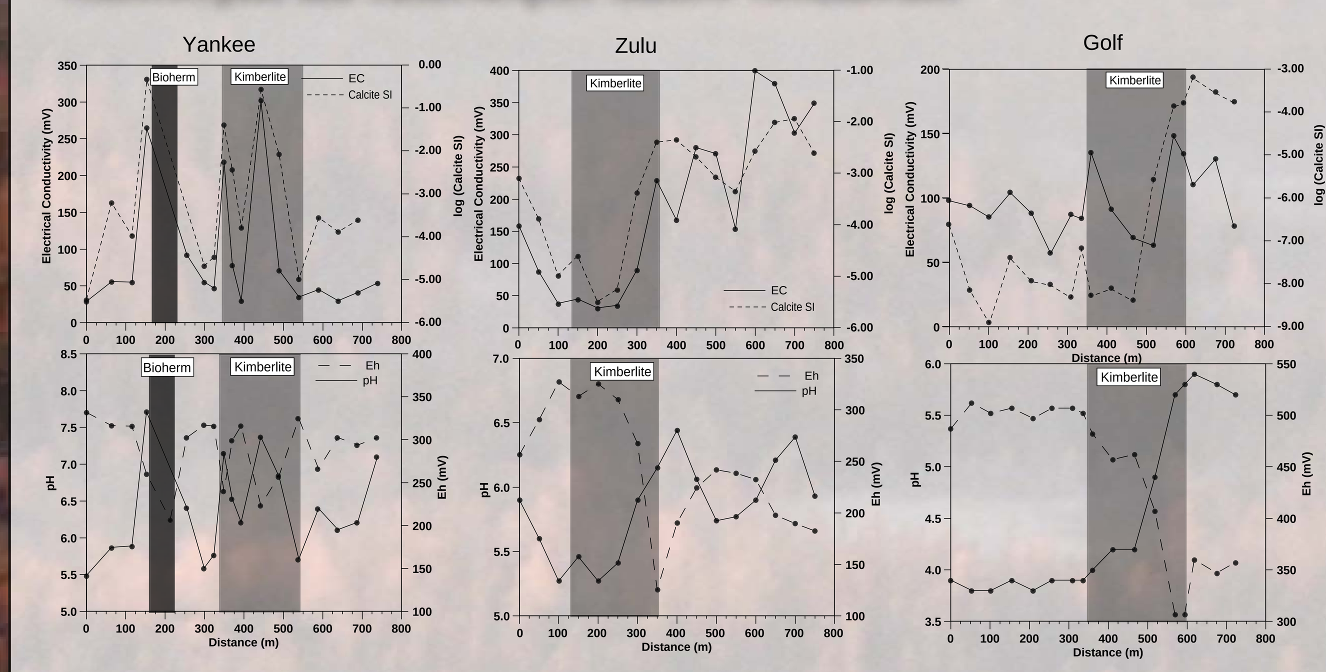
Indicators of Upweling Deep Groundwaters

Hydrogeology



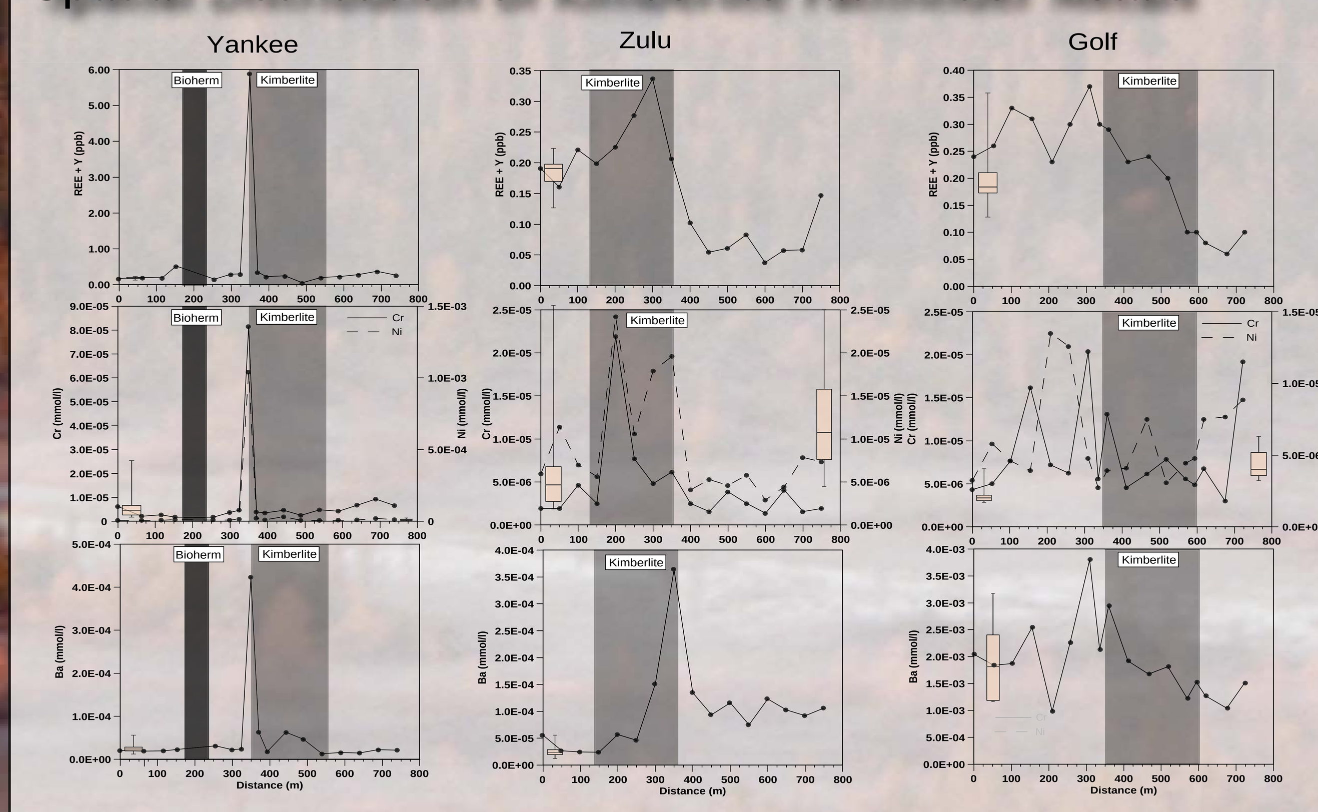
- Upwelling is suggested by the changes in the pressure head of monitoring wells and where the saturated zone is close to, or above the ground surface.

Ombrotrophic and Minerotrophic Shallow Groundwater



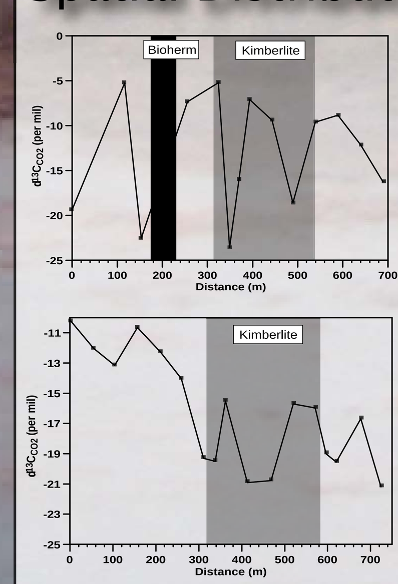
- Higher values of pH, and low Eh are associated with higher EC and calcite saturation indices, common features of minerotrophic waters (sites of upwelling deeper groundwaters.
- Waters upwelling from limestone have high EC, $CaCO_3$-SI, pH, and low Eh, but metal contents are low.

Spatial Distribution of Kimberlite Pathfinder Metals

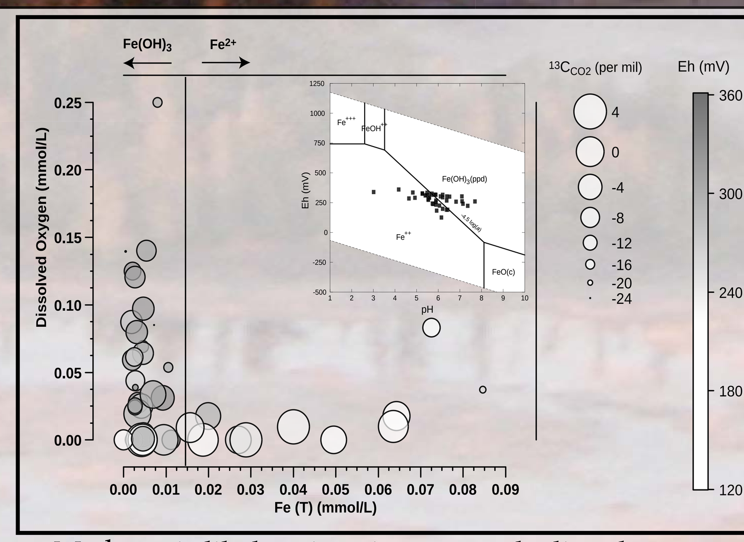


- Waters originated from kimberlites have high concentrations of Ni, Cr, REE, Y, and Ba.

Spatial Distribution of Carbon Isotopes



- Highly depleted $\mathbf{d}^{13}C_{(CH4)}$ (as low as -83‰) will preferentially be used by methanotrophs and easily decreases the $\mathbf{d}^{13}C_{(CO2)}$ over kimberlites.
- Outside the kimberlite high $\mathbf{d}^{13}C_{(CO2)}$ values suggest CO_2 reduction, as methanogens prefer to utilize lighter ^{12}C, resulting in $\mathbf{d}^{13}C_{(CO2)}$

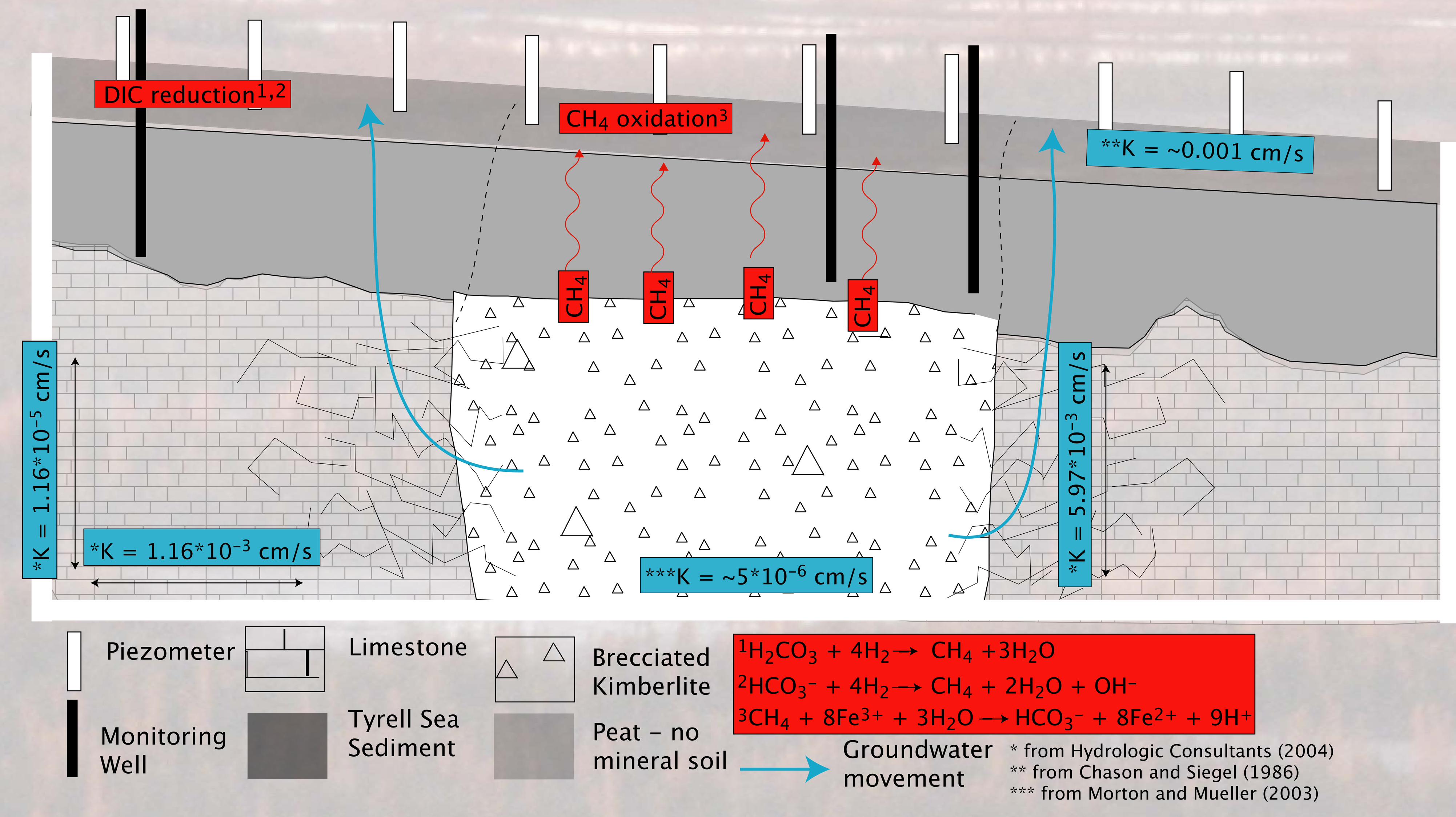


- Methane is likely migrating upwards directly over kimberlites and oxidizing anaerobically due to the reduction of ferric Fe via bacterial pathways.

Schematics

Metals:
- upward migration of deep groundwaters along kimberlite-limestone boundaries is likely due to high hydraulic conductivity in the fractured rocks in that zone. Host rock commonly fractures during explosive emplacement of kimberlite.
- There is little lateral movement of metals in peat once metals have migrated from deeper groundwaters. Peat groundwater at 1.1 mbgs will only migrate at ~50 cm per year (or less if frozen during winter).

Methane:
- Upwelling groundwater does not correlate with evidence of methane oxidation (low $\mathbf{d}^{13}C_{(CO2)}$ over kimberlites).
- Methane formed in kimberlites and/or the overlying Tyrell Sea sediment is likely diffusing vertically in to peat over the kimberlite.



Peat Groundwaters and Diamond Exploration

Application

1) Shallow groundwater is an excellent medium for surficial geochemical surveys.
2) The metals REE, Y, Ni, Cr and Ba are high in kimberlites and are generally low in most sedimentary and igneous rocks in this region.
3) Geochemical reactions such as low-t serpentinization within buried kimberlite likely facilitates the formation of methane and contributes to low $\mathbf{d}^{13}C_{(CO2)}$ in peat groundwater directly over kimberlite.
4) Shallow groundwater geochemistry is most useful as a secondary exploration tool in conjunction with first order methods such as geophysics.
5) Water geochemistry has the potential to be utilized as an exploration tool at other locations where more traditional exploration methods such as soil geochemistry or indicator minerals in till are more challenging, if not impossible to implement.

Geochemical Survey Design

1) Should be combined with a hydraulic survey of the area.
2) Sampling of water samples should be carried out along a transect parallel to the groundwater flow.
3) Samples should be collected at least 200 m beyond the suspected kimberlite margins because of possible displacement of pathfinder metals in shallow groundwater.

Acknowledgements

We thank DeBeers Canada for providing financial and logistic support for the project. Julie Kong, Ed Francisco, and Brad Wood were particularly helpful. The financial support was also provided by a NSERC Collaborative Research grant to Keiko Hattori. Fieldwork was assisted by Kersten Brauneder (University of Ottawa) and Katherine Mellor. All laboratory geochemical analyses were conducted at the Ontario Geological Survey Geoscience Laboratory; Dr. Marcus Burnham is thanked for his help. Stewart Hamilton (OGS) also provided much of the field equipment and helpful guidance. Jamil Sader acknowledges an Ontario Graduate Scholarship and a student research grant from the Society of Economic Geologists.

References

1) Brauneder, K., 2007. Characterization of peatland waters overlying concealed kimberlites in the Attawapiskat region, northern Ontario. B.Sc. Hon. Thesis, University of Ottawa, Ottawa, 76 pp.
2) Chason, D.B. and Siegel, D.I., 1986. Hydraulic conductivity and related physical properties of peat, Lost River peatland, northern Minnesota. Soil Science, 142(2): 91-99.
3) Hydrologic Consultants, I.o.C., 2004. Dewatering of Victor diamond project: Predicted engineering, cost, and environmental factors.
4) Kong, J.M., Boucher, D.R. and Scott Smith, B.H., 1999. Exploration and geology of the Attawapiskat Kimberlites, James Bay Lowland, northern Ontario, Canada. In: J.J. Gurney, J.L. Gurney, M.D. Pascoe and S.H. Richardson (Editors), Proceedings of the International Kimberlite Conference, pp. 452-467.
5) Morton, K.L. and Mueller, S., 2003. Hydrogeology of the Venetia diamond mine, South Africa. South African Journal of Geology, 106(2-3): 193-204.
6) Webb, K.J., Scott Smith, B.H., Paul, J.L. and Hetman, C.M., 2004. Geology of the Victor Kimberlite, Attawapiskat, northern Ontario, Canada; cross-cutting and nested craters. In: R.H. Mitchell, H.S. Gruetter, L.M. Heaman, B.H. Scott Smith and T. Stachel (Editors), Lithos, pp. 29-50.