Geochemical and isotopic characterization of kimberlitic waters

a proposal of a new diamond exploration technique

Jamil A. Sader, Matthew I. Leybourne
• University of Texas at Dallas
Beth M. McClenaghan
• Geological Survey of Canada
Stewart M. Hamilton
• Ontario Geological Survey
Flow model - Exploration

Kimberlite Cross-section

- Elevated pH and K in kimberlite
- High alkalinity in kimberlite

Graphs showing
- Dissolved inorganic carbon (mg/L)
- Alkalinity (mg/L)
Characteristics of a Kimberlite

- Kimberlites are ultramafic bodies.
- Kimberlite groundmass is consists mainly of alteration minerals.
- The host rock of kimberlites in northeastern Ontario are Archean metasedimentary, and felsic volcanics.
Currently Used Methods of Kimberlite Exploration

<table>
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<th>Indicator mineral methods</th>
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<tbody>
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<td>Involves tracing the path of past glaciers and their processes using minerals such as Cr-pyrope, Cr-diopside and Cr-ilmenite to determine kimberlite location.</td>
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<th>Geophysical methods</th>
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<td>Involves the use of airborne magnetic susceptibility in order to locate possible kimberlite targets.</td>
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Sampling
Why use aqueous geochemistry to locate undiscovered kimberlites?
1) Isotopic Characteristics of a Kimberlitic Water

- Deviations from the Local Meteoric Water Line of high pH waters ($\delta^2$H and $\delta^{18}$O ratios)
- Variations in $\delta^{13}$C
- Waters demonstrate low $^{87}$Sr/$^{86}$Sr ratios
H and O isotopes
Rayleigh Distillation of δ²H

Modern Recharge Waters

Low-T Serpentinitization

Serpentine Brucite Magnesite

Gases H₂ and CH₄

²H
$\delta^{13}C$ Variations in waters

- $\delta^{13}C$ isotopes in waters demonstrate mixing of C from various sources.

- Paleozoic limestone, mantle carbon and alteration of ratios due to biogenic processes are the main sources.
• Kimberlitic waters contain low $^{87}\text{Sr}/^{86}\text{Sr}$ ratios for most samples (average of 0.7065).

• Both graphs indicate that kimberlitic waters are mixing with waters from the Archean host rocks.
The major components of a granitic rock and the growth of $^{87}\text{Sr}/^{86}\text{Sr}$ over time.

Modified from McNutt et al., 1989.

Components affecting the Sr ratio in groundwaters in kimberlites.
2) Geochemical Characteristics of a Kimberlitic Water

- Strongly reducing waters.
- High alkalinity.
- The relationship that K and the pH have to Mg, Ca and Rb.
High pH and low Eh in kimberlitic waters contribute to unusual geochemical characteristics in this area of the Superior province.
Alkalinity and pH
Low temperature serpentinization is responsible for the unusual elemental concentrations in the waters.

- Olivine + $\text{H}_2\text{O} + \text{C}$ (or $\text{CO}_2$) = magnesite + serpentine + $\text{CH}_4$ + brucite + $\text{H}_2$
  (Sherwood Lollar et al., 1993)

- $5\text{Mg}_2\text{SiO}_4 + \text{Fe}_2\text{SiO}_4 + 9\text{H}_2\text{O} = 3\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$
  (olivine) + $\text{Mg}(\text{OH})_2 + 2\text{Fe}(\text{OH})_2$
  (brucite) (ferrous hydroxide)
The ratio of K to Mg

- The ratio of K to Mg increases with pH.
- Mg is becoming increasingly buffered out of the waters when pH becomes high.
The ratio of K to Ca

- The Ca is also buffered out of the water with increasing pH when the K remains in the waters.
The ratio of K to Rb

- The Rb is buffered out of the waters compared to K with increasing pH.
- There is question as to why Rb is buffered but not K (ionic radius of the two are almost exact).
Comparisons with Archean host-rock waters
Flow model - Exploration

Kimberlite Cross-section

- Elevated pH and K in Kimberlite
- High alkalinity in Kimberlite
Future Work

• Complete interpretation of trace element and radiogenic isotope data (can we refine the model to target kimberlites specifically)
• To obtain an accurate mass-balance calculation of the fractionation of $\delta^2$H - gas samples collected this summer will be analyzed.
• Whole rock and mineral separate geochemical analysis of kimberlite drill core.
• Possible extension of this project to other kimberlite fields (NWT, Arkansas?)
Acknowledgements

- TGI program of the Geological Survey of Canada
- Ontario Geological Survey
- Various mining companies for access to properties and samples of kimberlite