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*

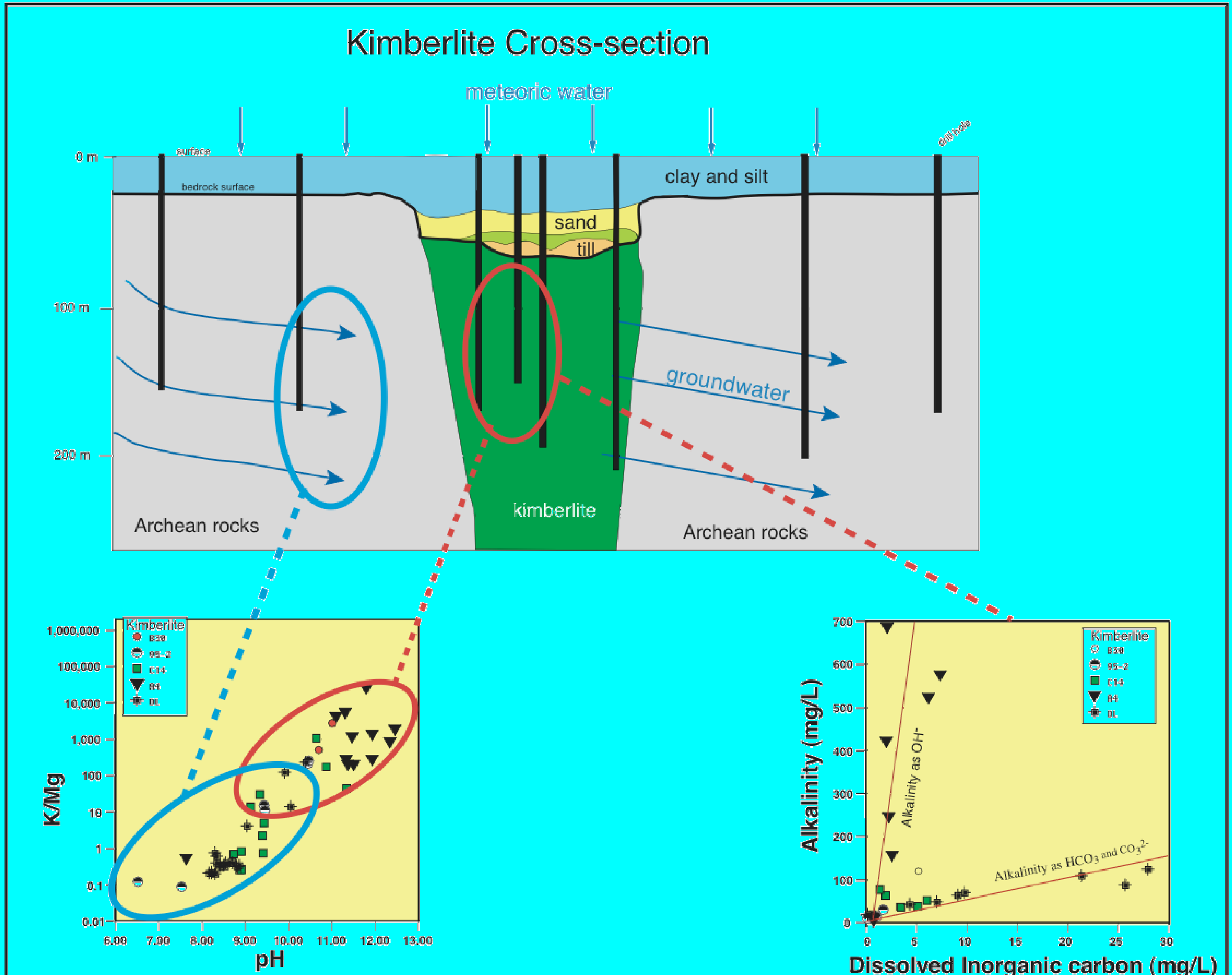
Beth M. McClenaghan

•*Geological Survey of Canada*

Stewart M. Hamilton

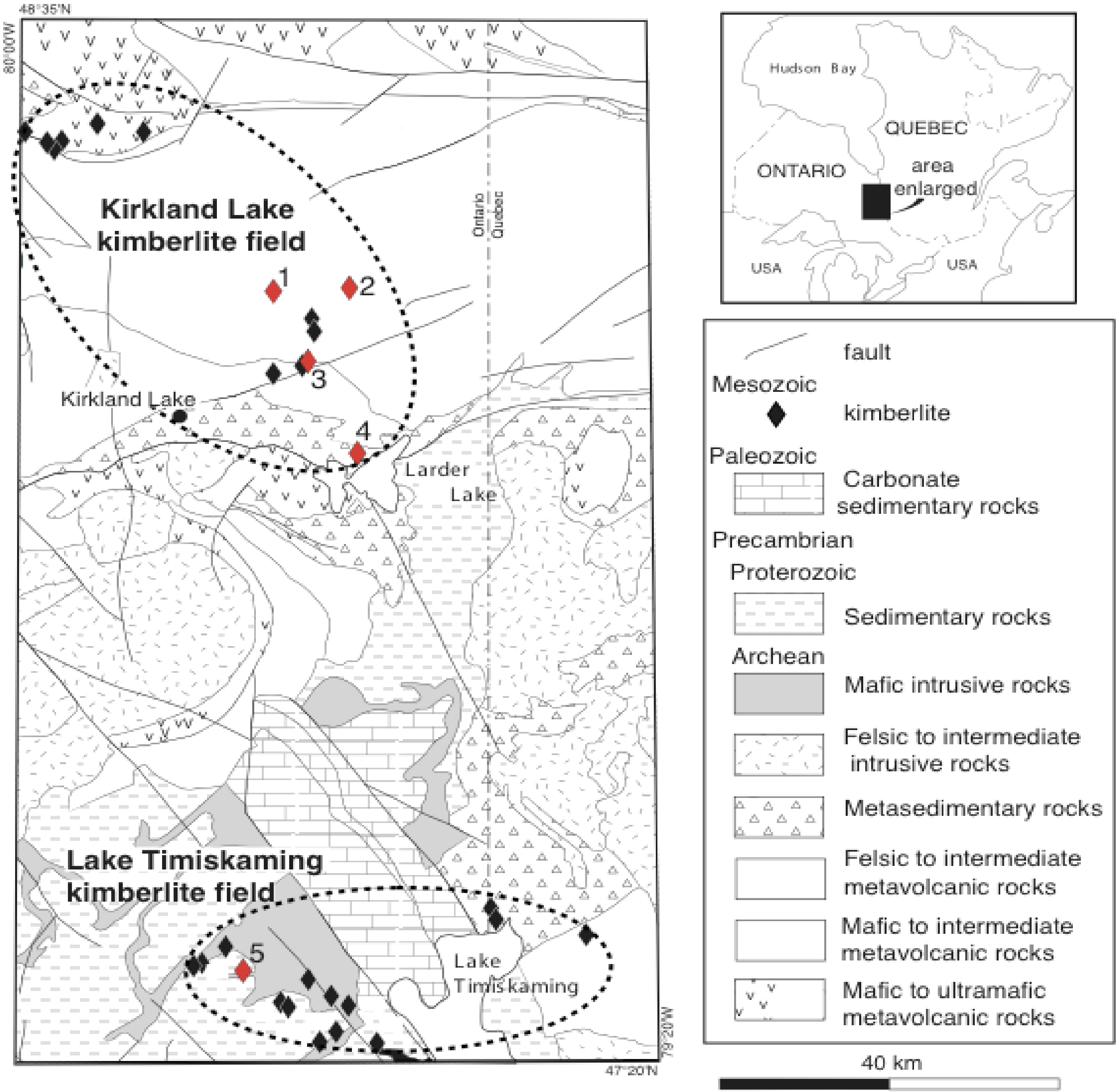
•*Ontario Geological Survey*

Flow model - Exploration



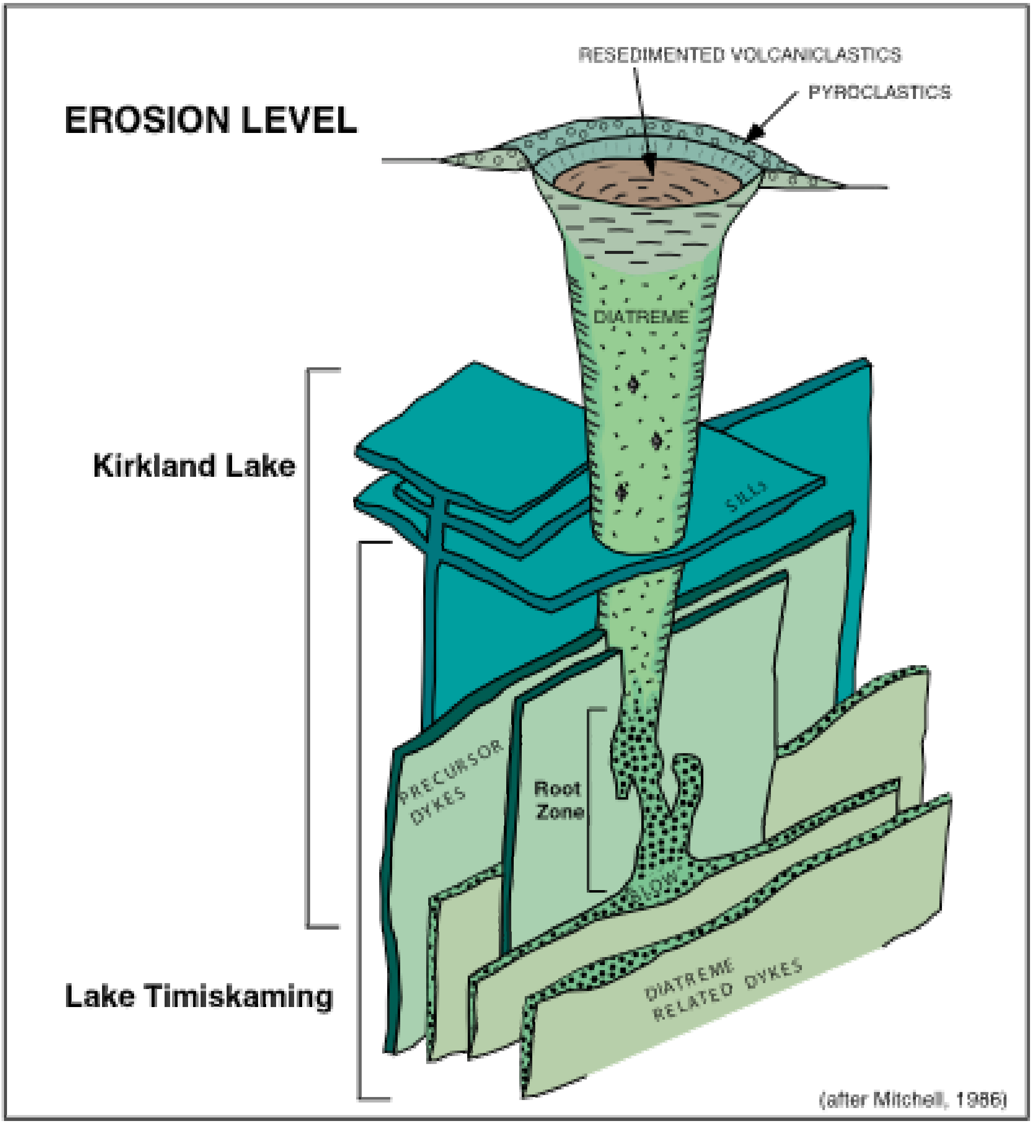
elevated pH and K in kimberlite

High alkalinity in kimberlite



. Bedrock geology from Ontario Geological Survey (1991).

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

- Indicator mineral methods
- 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.

- Geophysical methods
- Involves the use of airborne magnetic succeptability in order the locate possible kimberlite targets.

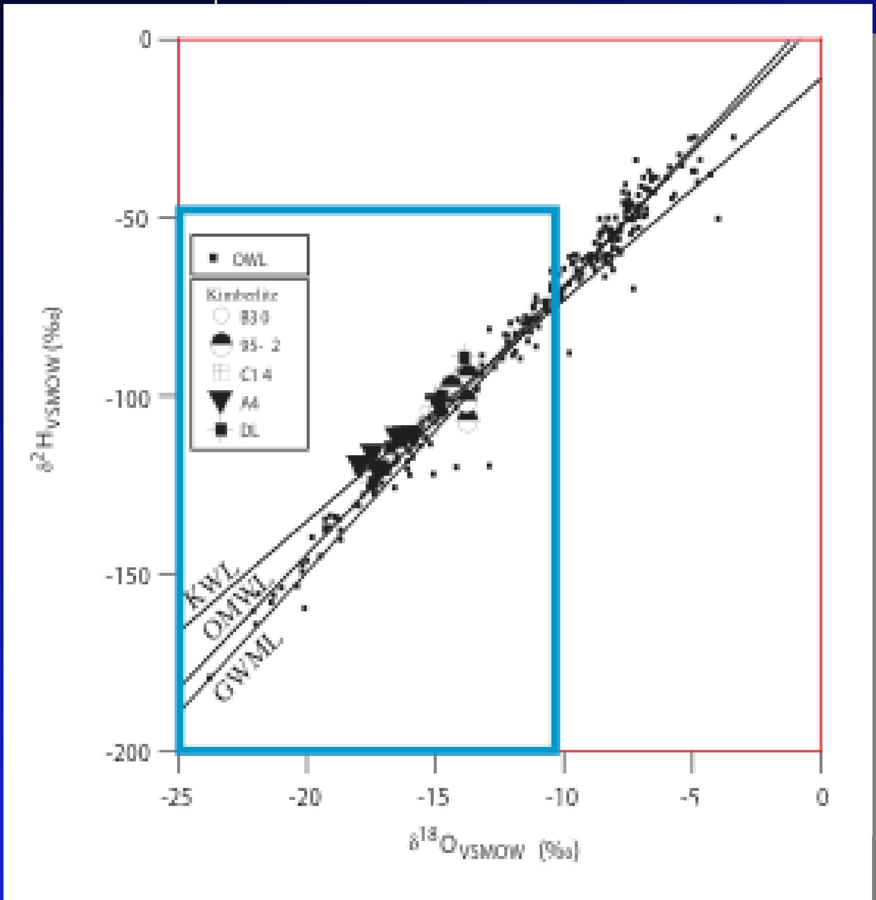
Sampling

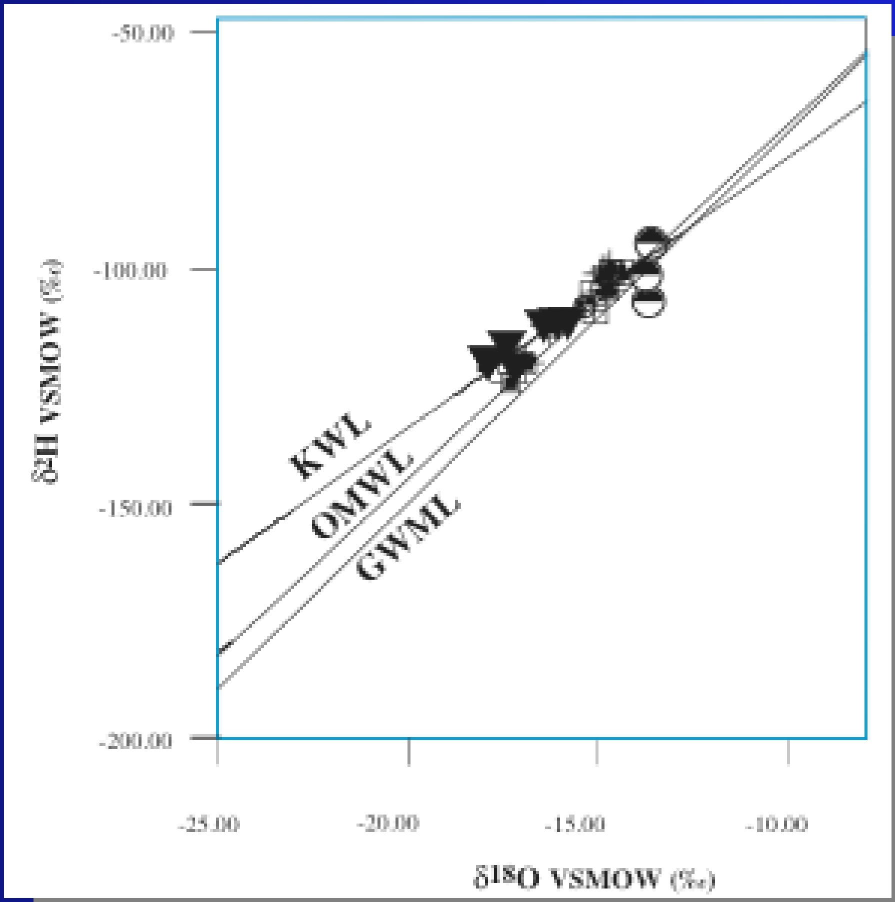
Why use aqeous geochemistry to locate undiscovered kimberlites?

1) Isotopic Characteristics of a Kimberlitic Water

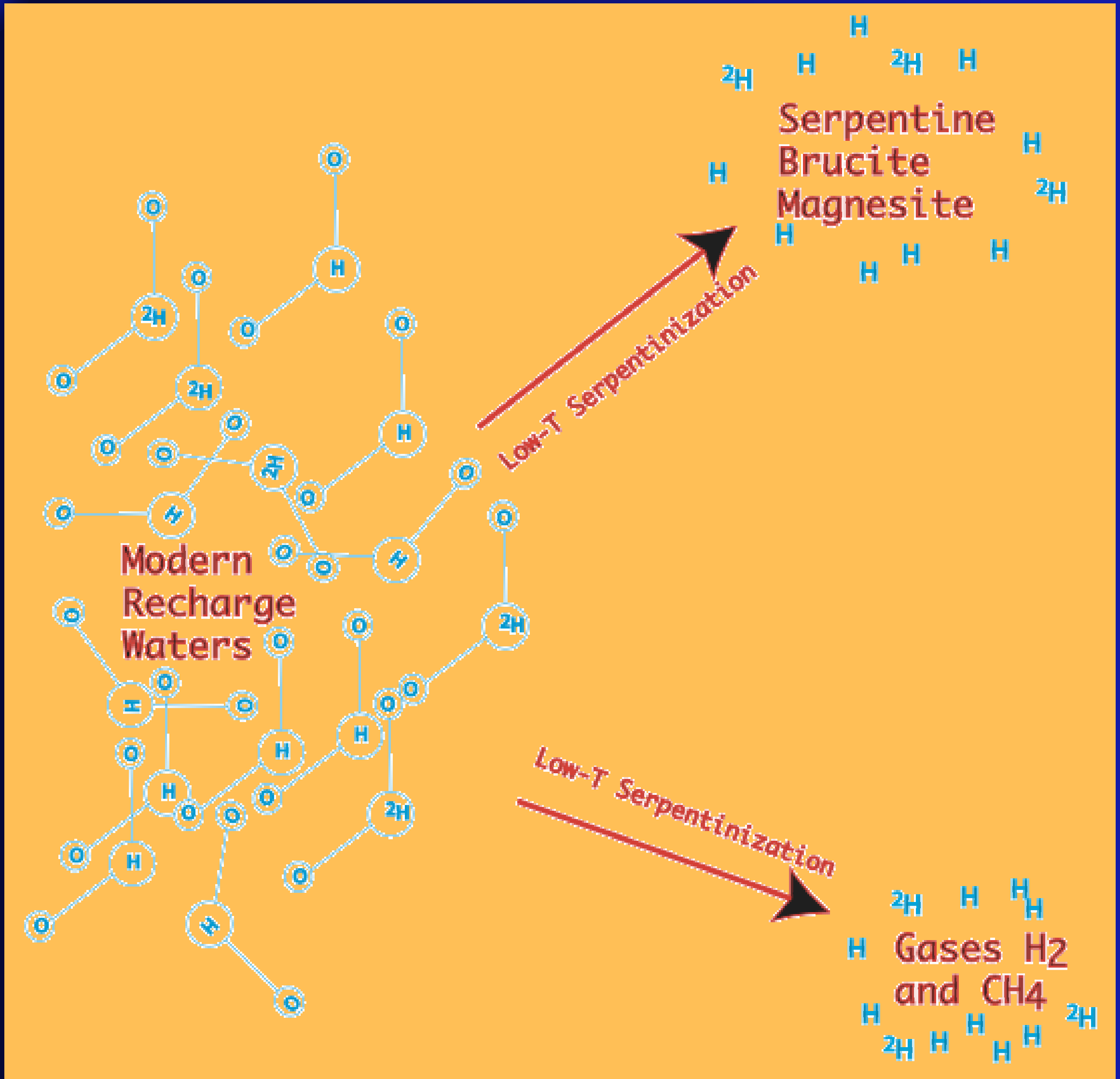
- Deviations from the Local Meteoric Water Line of high pH waters (δ^2H and $\delta^{18}O$ ratios)
- Variations in $\delta^{13}C$
- Waters demonstrate low $^{87}Sr/^{86}Sr$ ratios

H and O isotopes

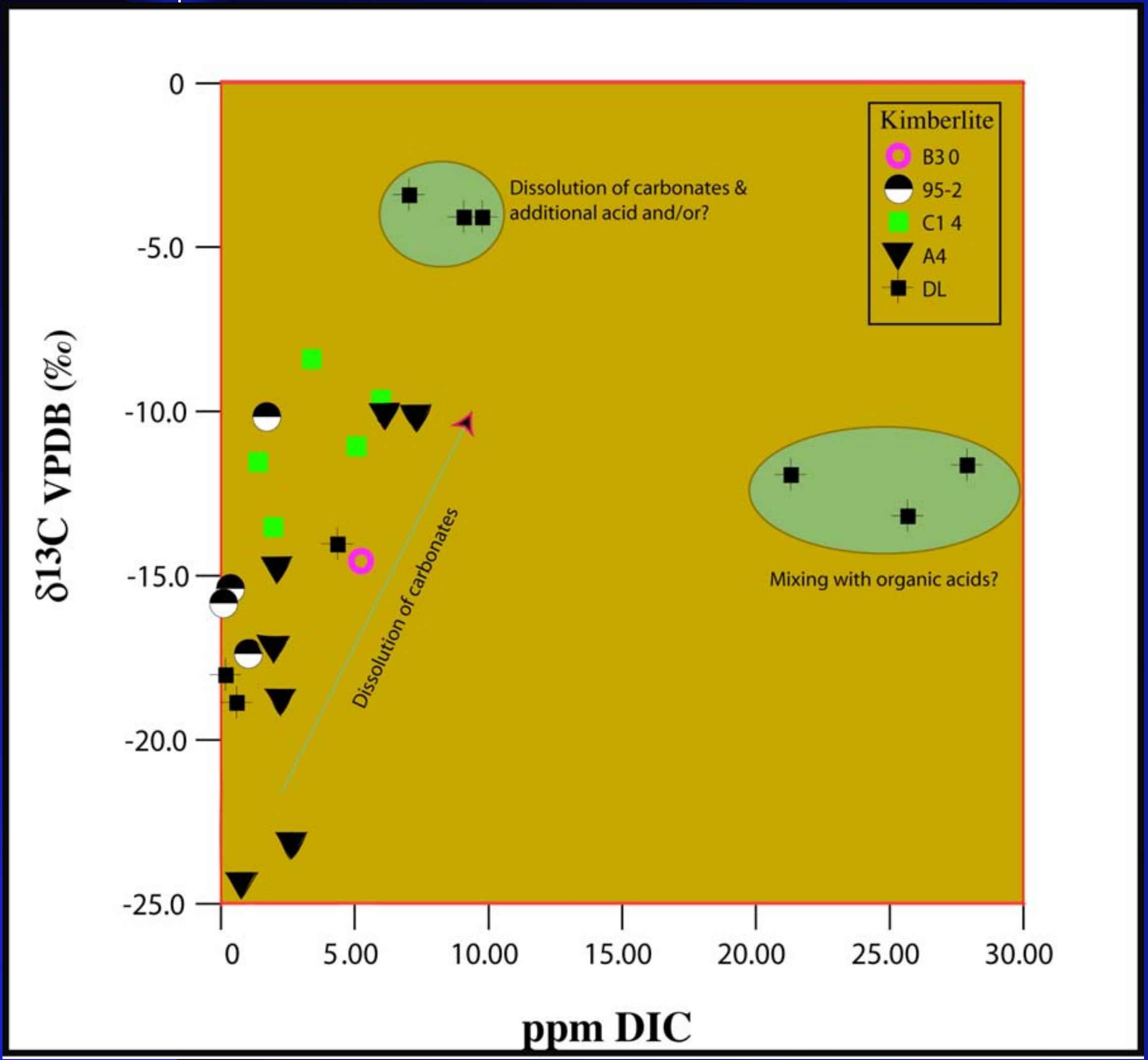




Rayleigh Distillation of δ^2H

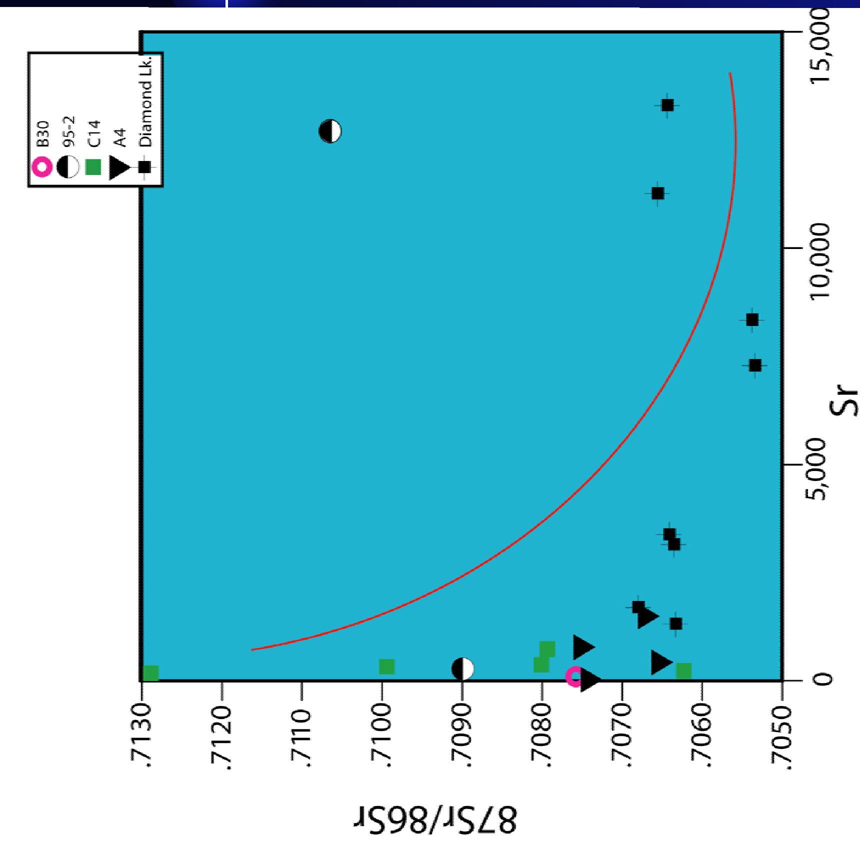


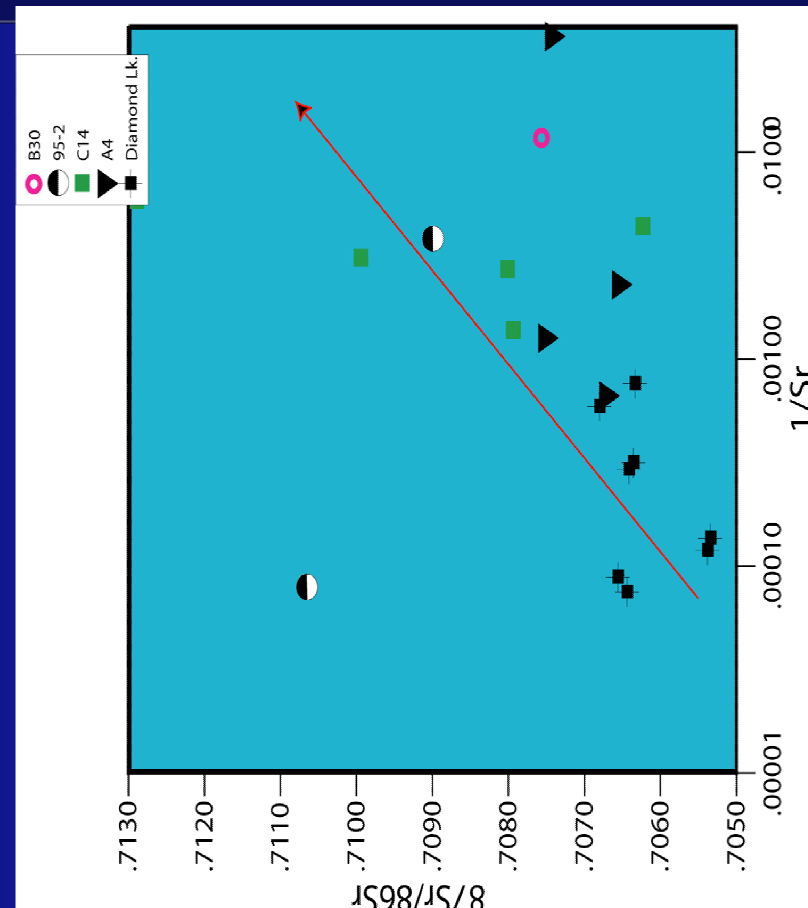
δ^{13}C Variations in waters



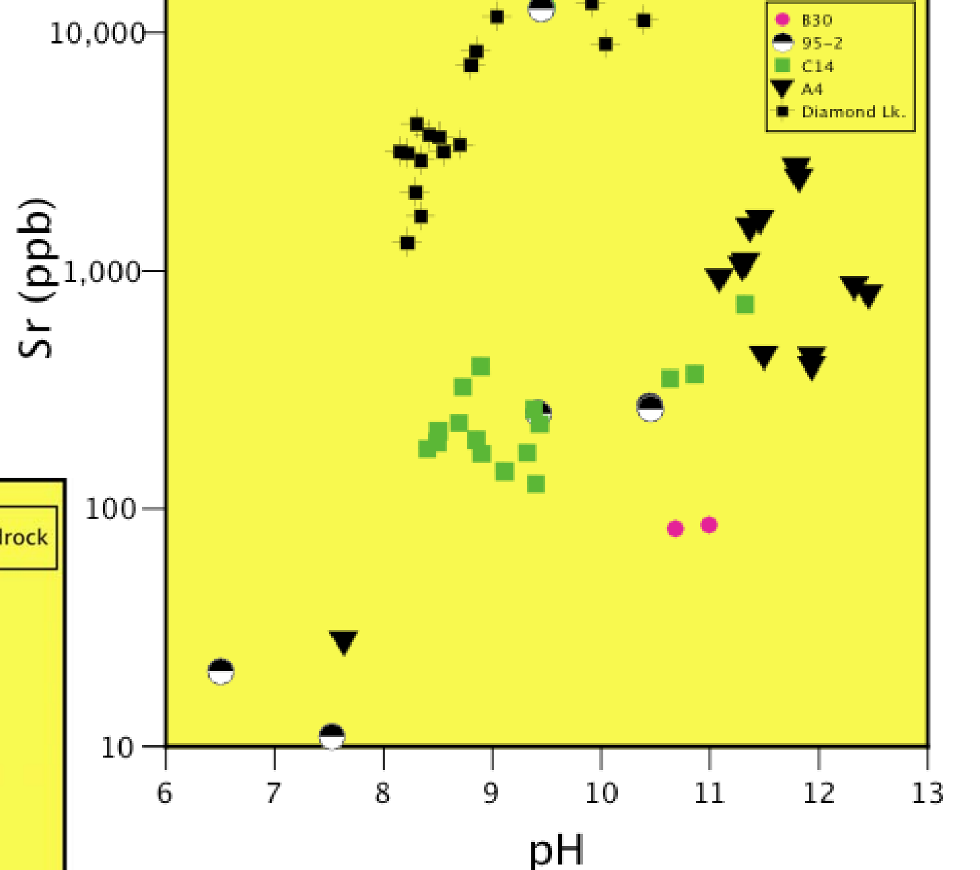
- δ^{13}C isotopes in waters demonstrate mixing of C from various sources.
- Paleozoic limestone, mantle carbon and alteration of ratios due to biogenic processes are the main sources.

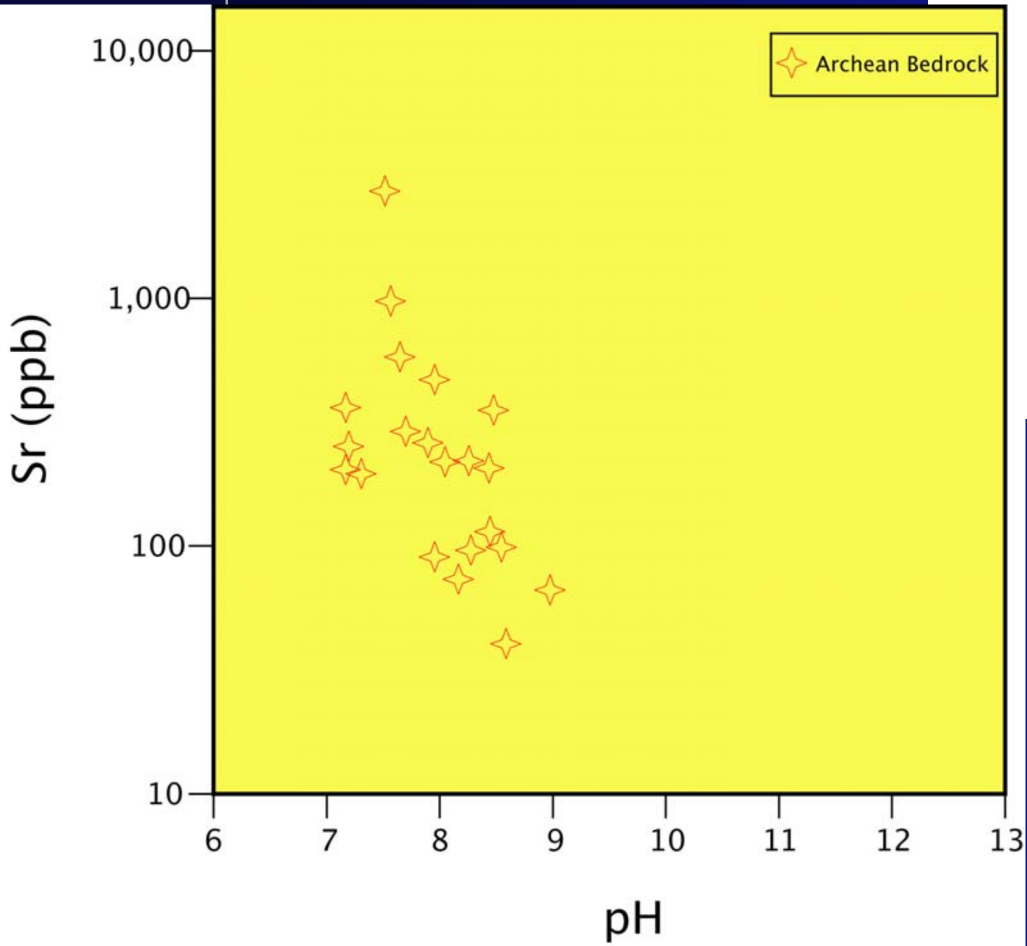
$^{87}Sr/^{86}Sr$ isotopic ratios

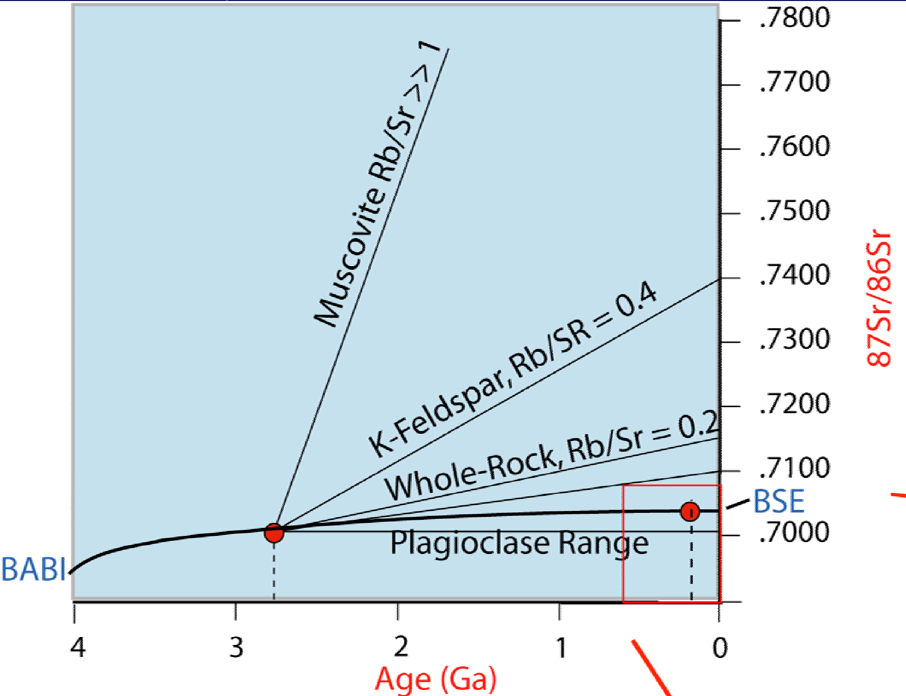




- Kimberlitic waters contain low $^{87}Sr/^{86}Sr$ ratios for most samples (average of 0.7065).
- Both graphs indicate that kimberlitic waters are mixing with waters from the Archean host rocks.

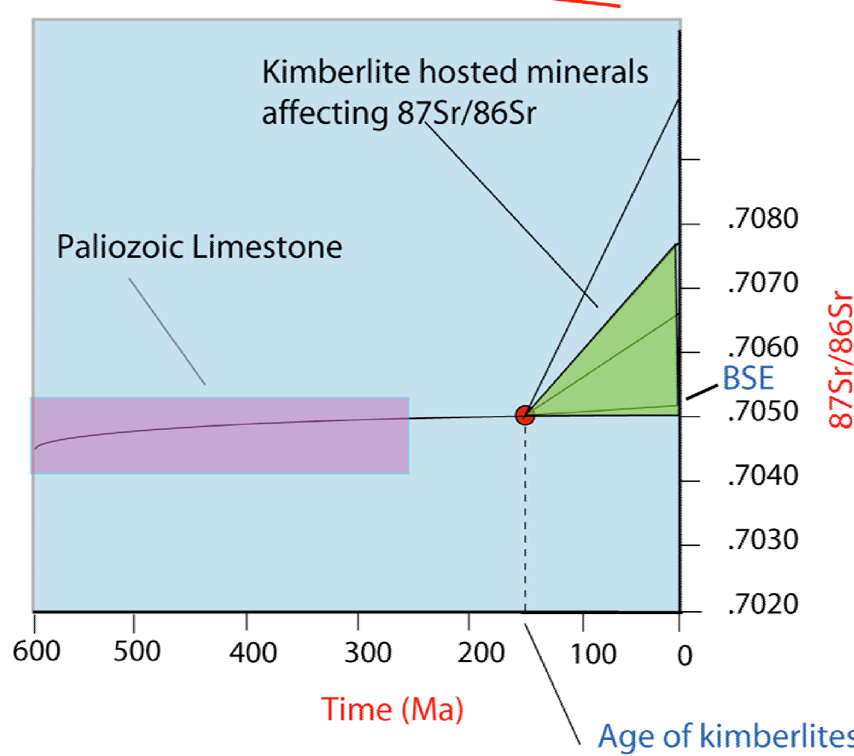

B30
95-2
C14
A4
Diamond Lk.
10,000
1,000
100
10
Sr (ppb)
6
7
8
9
10
11
12
13
pH


Archean Bedrock
10,000
1,000
100
10
Sr (ppb)
6
7
8
9
10
11
12
13
pH



The major components of a granitic rock and the growth of 87Sr/86Sr over time.

Modified from McNutt et al., 1989.

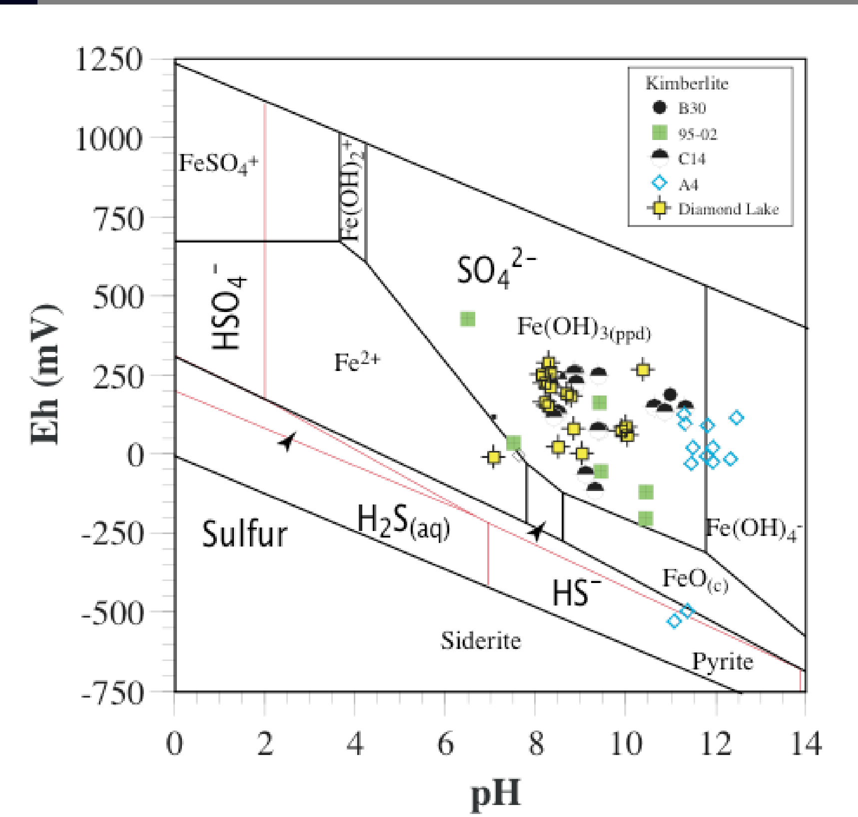


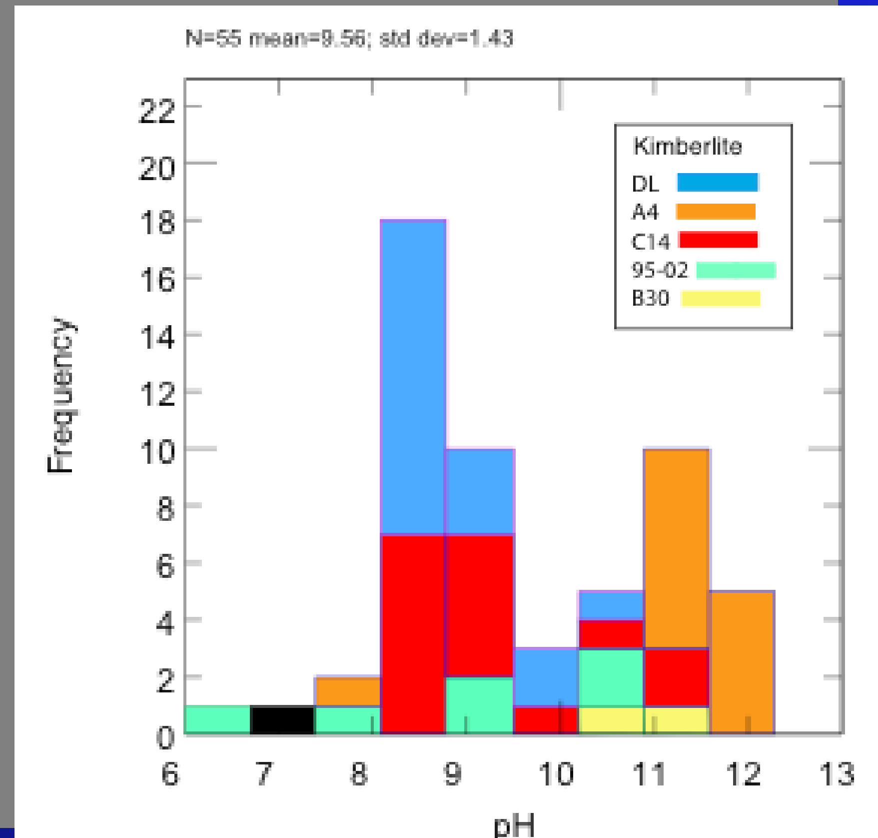
Components affecting the Sr ratio in groundwaters in kimberlites.

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.

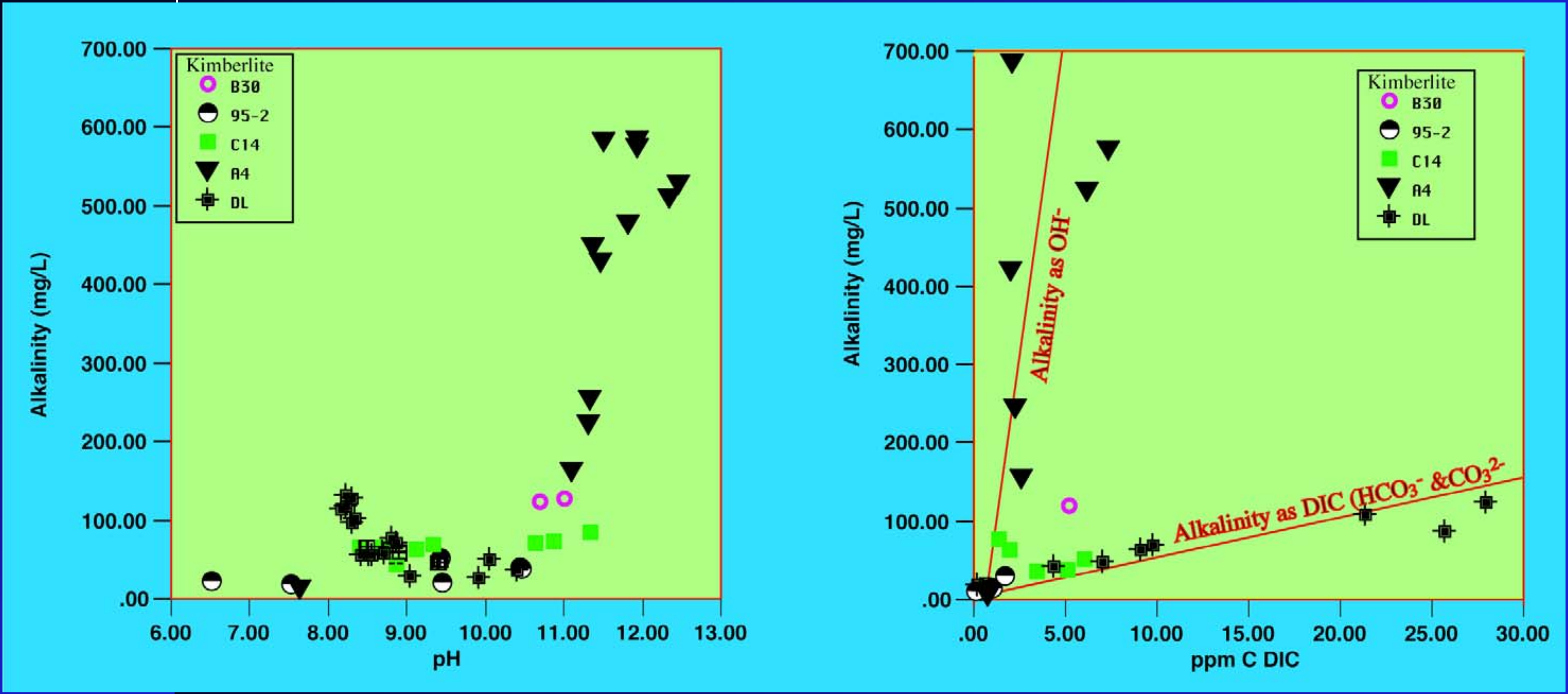
Strongly Reducing Waters





- High pH and low Eh in kimberlitic waters contribute to unusual geochemical characteristics in this area of the Superior province.

Alkalinity and pH



K Concentrations With respect to Mg, Ca and Rb

- Low temperature serpentinization is responsible for the the unusual elemental concentrations in the waters.

- Olivine + H_2O + C (or CO_2) = magnesite + serpentine + CH_4 + brucite + H_2

(Sherwood Lollar et al., 1993)

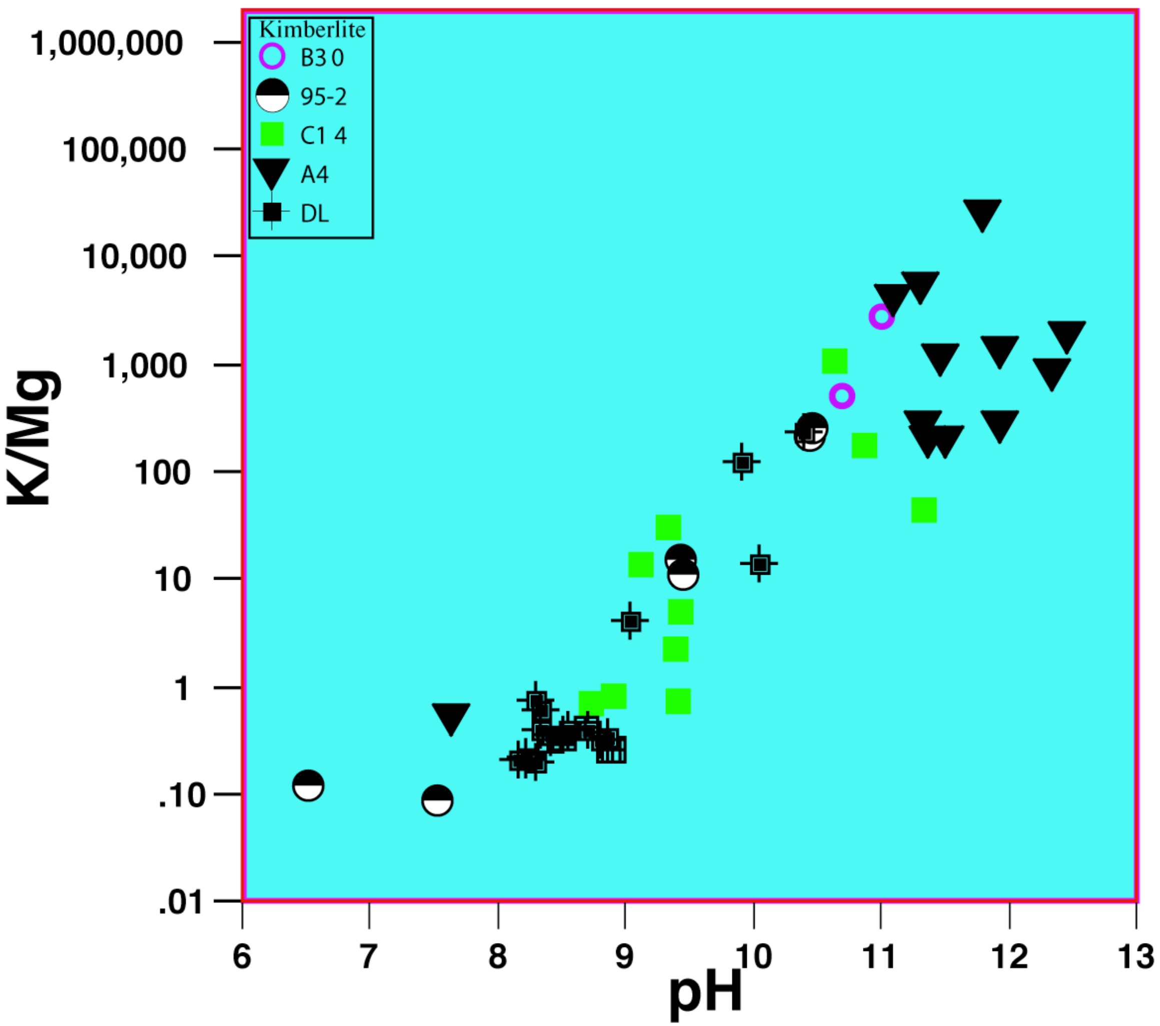
- $5Mg_2SiO_4 + Fe_2SiO_4 + 9H_2O = 3Mg_3Si_2O_5(OH)_4$

(olivine) (serpentine)

$+ Mg(OH)_2 + 2Fe(OH)_2$

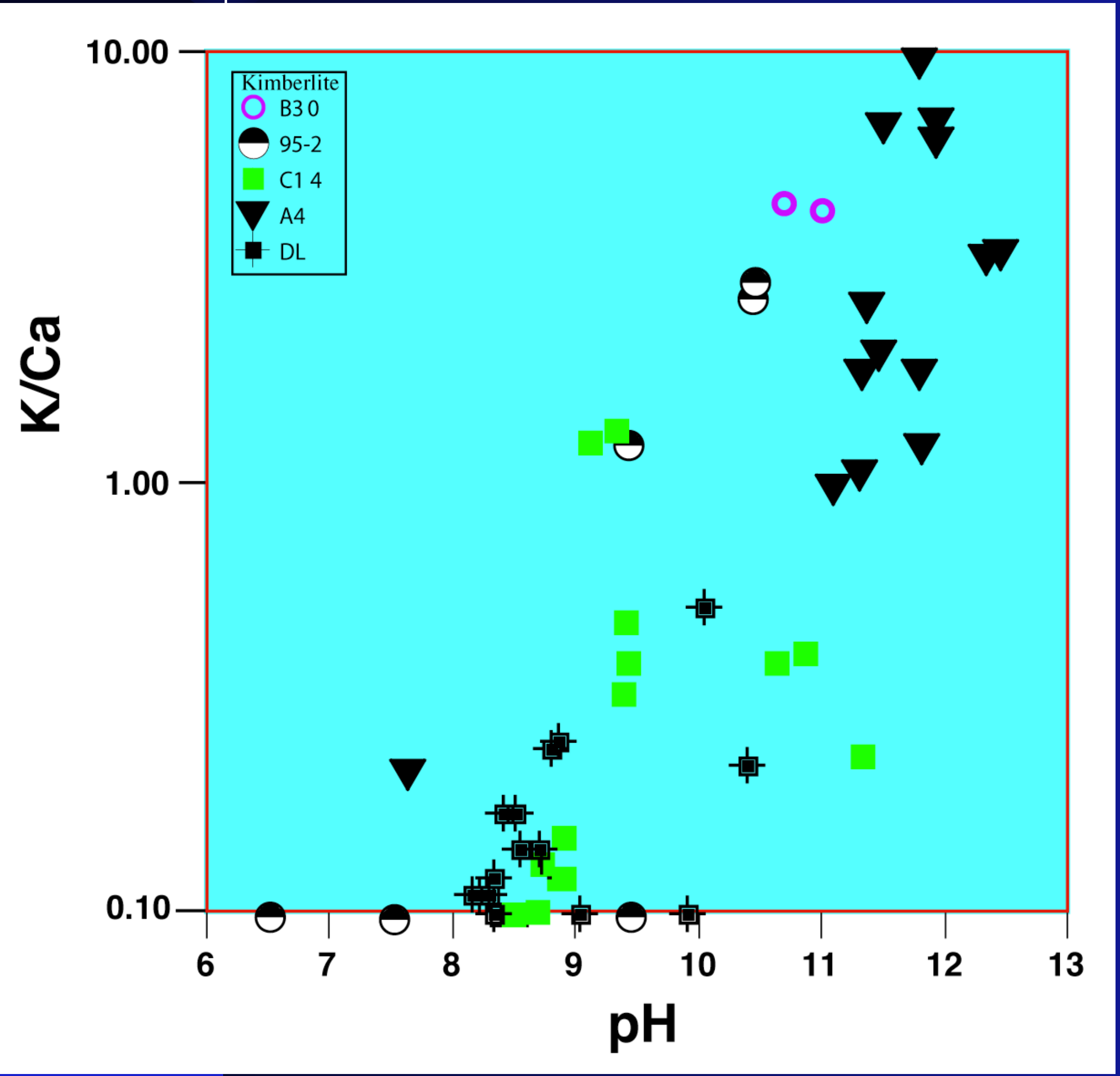
(brucite) (ferrous hydroxide)

The ratio of K to Mg



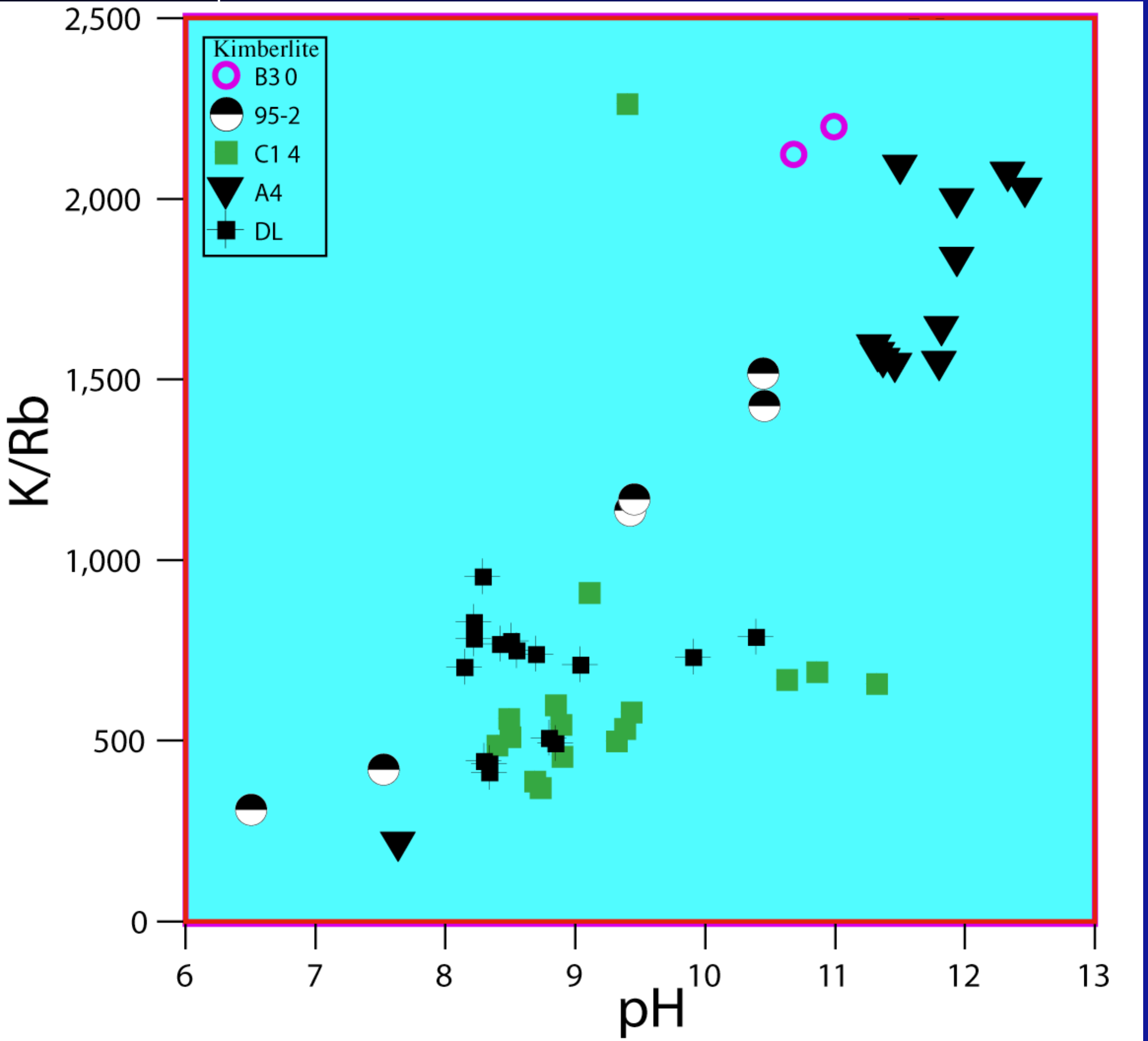
- The ratio of K to Mg increases with pH.
- Mg is becoming increasingly buffered out of the waters when pH becomes high.

The ratio of K to Ca



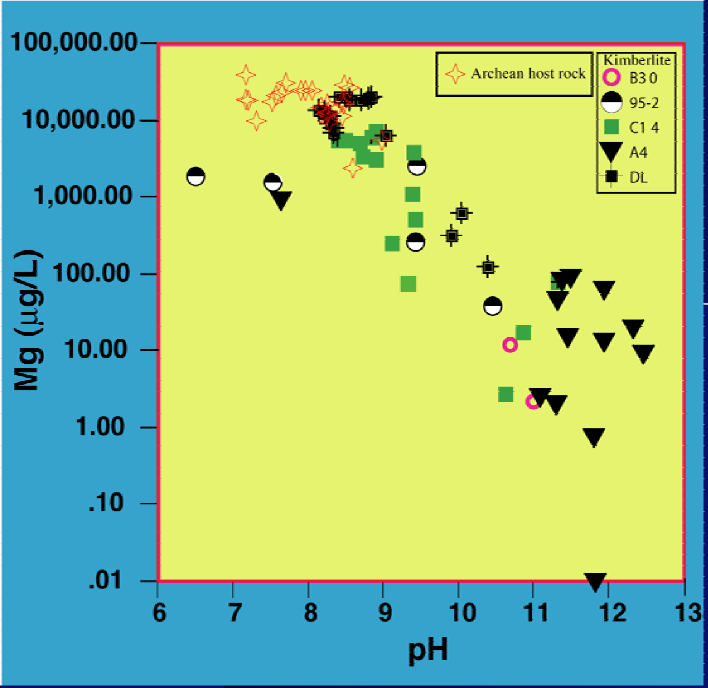
- The Ca is also buffered out of the water with increasing pH when the K remains in the waters.

The ratio of K to Rb

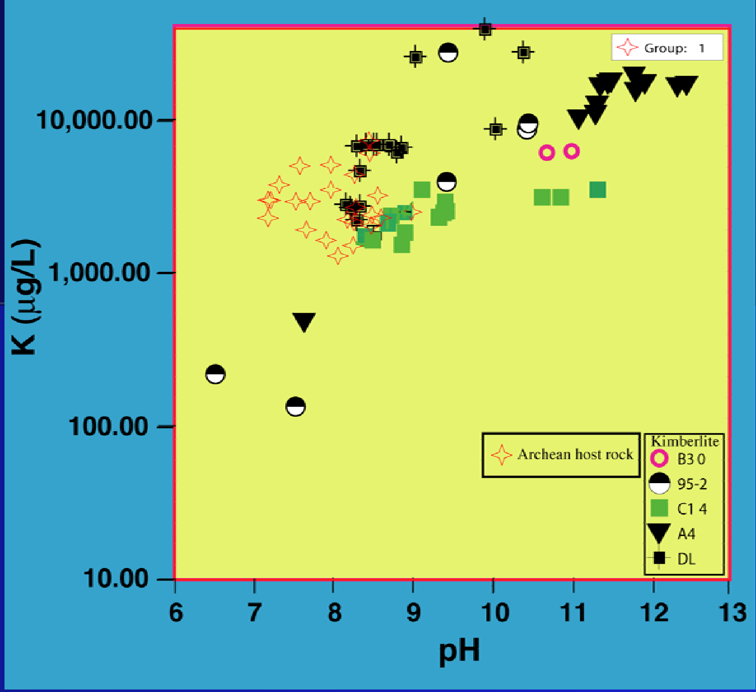


- The Rb is buffered out of the waters compared to K with increasing pH.
- There is question as to why Rb is buffered but not K (ionic radius of the two are almost exact).

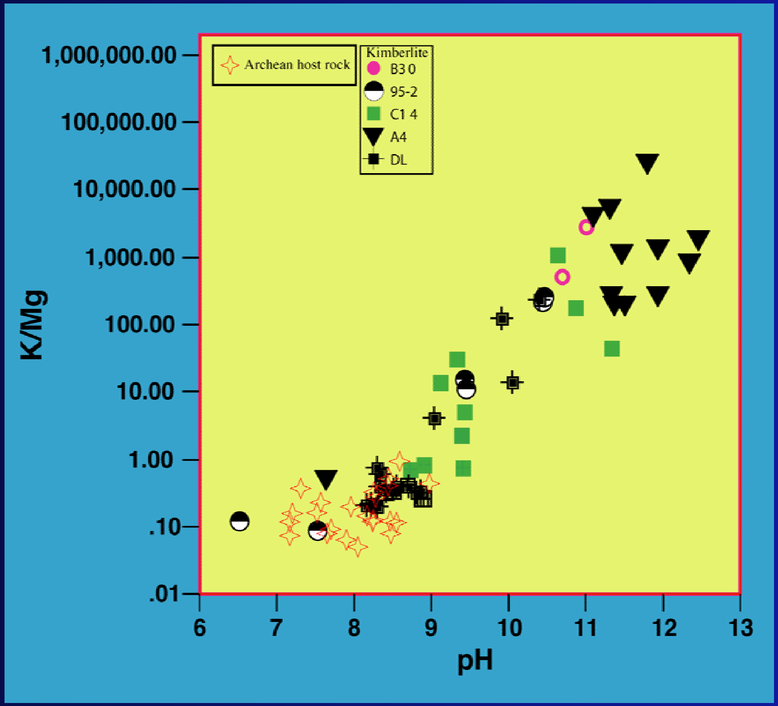
Comparisons with Archean host-rock waters



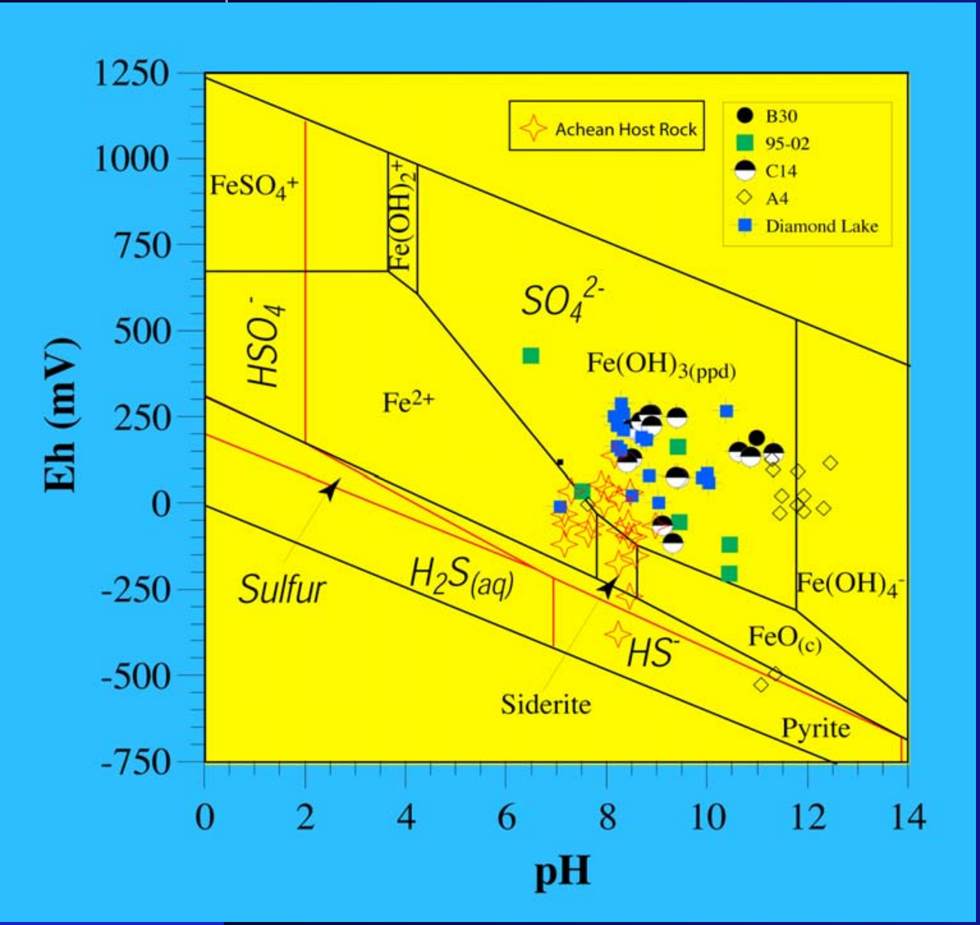
Mg (µg/L)
pH
Archean host rock
Kimberlite
B3 0
95-2
C1 4
A4
DL

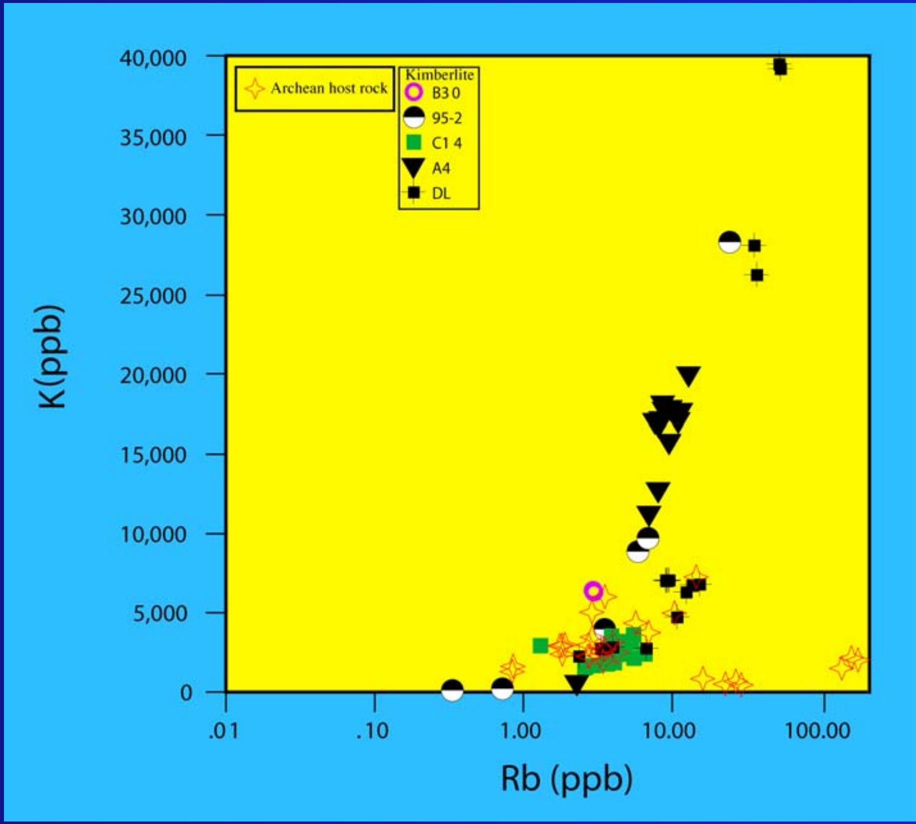


K (µg/L)
pH
Group: 1
Archean host rock
Kimberlite
B3 0
95-2
C1 4
A4
DL

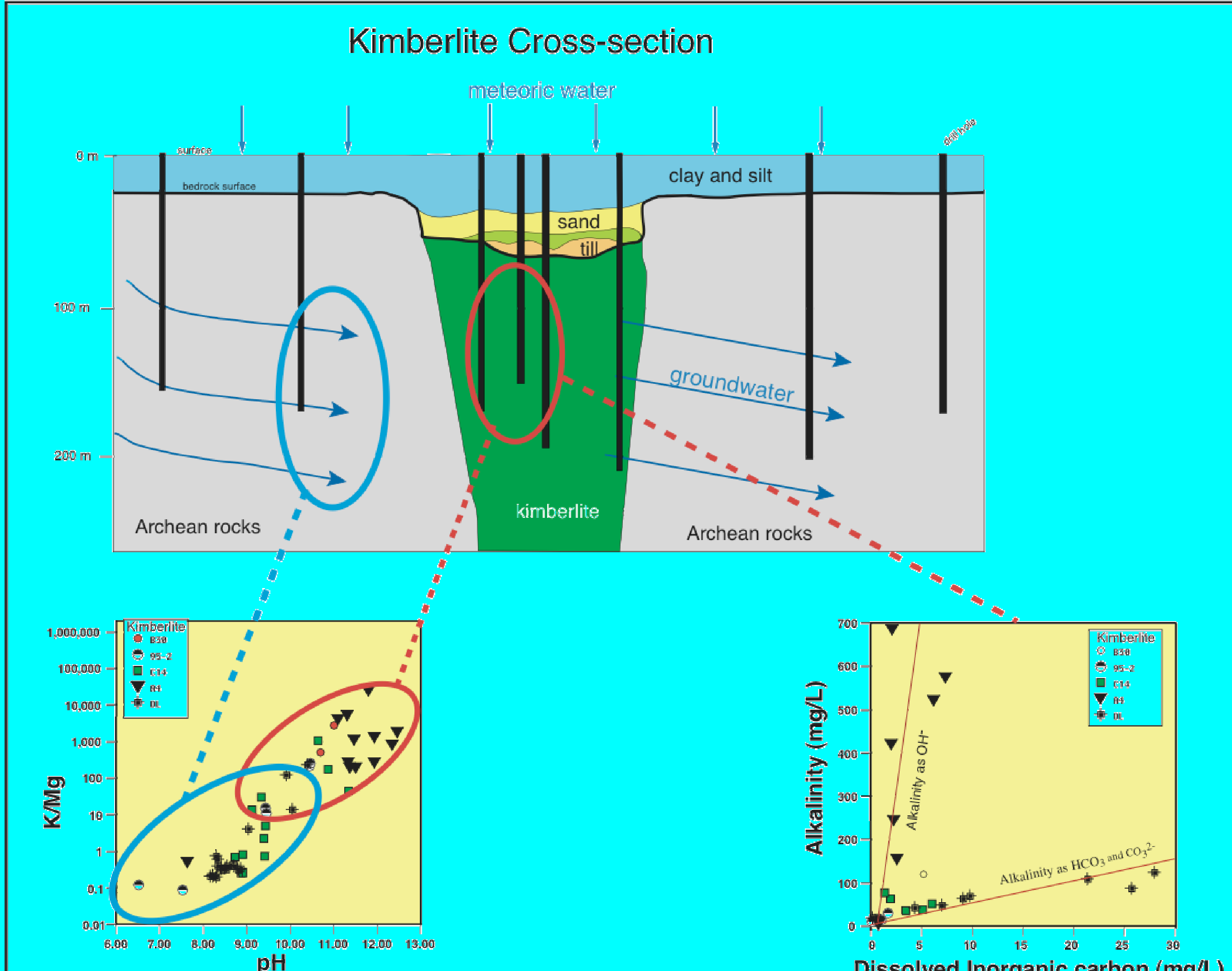


K/Mg
pH
Archean host rock
Kimberlite
B3 0
95-2
C1 4
A4
DL


Achean Host Rock
B30
95-02
C14
A4
Diamond Lake
FeSO4+
Fe(OH)2+
HSO4-
SO4 2-
Fe2+
Fe(OH)3(ppd)
Sulfur
H2S(aq)
HS-
Siderite
FeO(c)
Fe(OH)4-
Pyrite
Eh (mV)
pH
1250
1000
750
500
250
0
-250
-500
-750
0
2
4
6
8
10
12
14


Archean host rock
Kimberlite
B3 0
95-2
C1 4
A4
DL
K(ppb)
Rb (ppb)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
.01
.10
1.00
10.00
100.00

Flow model - Exploration



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 δ^2H - 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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