21st International Geochemical Exploration Symposium
Dublin, Ireland
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# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview


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Minerals, Exploration,
BHP Billiton World Exploration Inc.


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# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview

**In regions glaciated in the Quaternary, mineral exploration can be hampered by the scarcity of bedrock outcrops and by the complex nature and thickness of the surficial glacial sediments that mantle, and often conceal, the bedrock and mineral deposits beneath.**

**In this day and age, both "Conventional" and a variety of newer "Deep Penetrating" geochemical exploration techniques are being employed for Mineral Exploration in Glaciated Terrains.**



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## Conventional Geochemistry

"Conventional" geochemical exploration techniques attempt to use the primary glacial sediments themselves (mainly till), or products derived therefrom (i.e. heavy minerals, fine fraction, etc.), in the context of their glacial depositional history – i.e. understanding the glacial sediment stratigraphy and ice movement direction(s).

Techniques involving the sampling and analyses of surficial till or secondary sediments derived therefrom, have been successful in exploration in areas of generally thin glacial drift (a few to 10s of metres).

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**Provided the glacial history and stratigraphic framework have been established, overburden drilling techniques can be successfully employed in mineral exploration in areas of thicker (several 10s to 100s of metres) glacial drift.**

**In addition, drainage sediments (i.e. lake and stream) have been successfully used to detect secondary hydromorphic dispersion associated with concealed mineralization in glaciated terrains.**

# Conventional Geochemistry

## Hope Bay Greenstone Belt, NWT, Canada

An example of working out the glacial history and stratigraphic framework of an area and using fine fraction till geochemistry to locate gold mineralization.

## Piling Project, Baffin Island, Nunavut, Canada

An example of using regional HMC and stream silt geochemistry with fine fraction till geochemistry to locate BHT-style mineralization.

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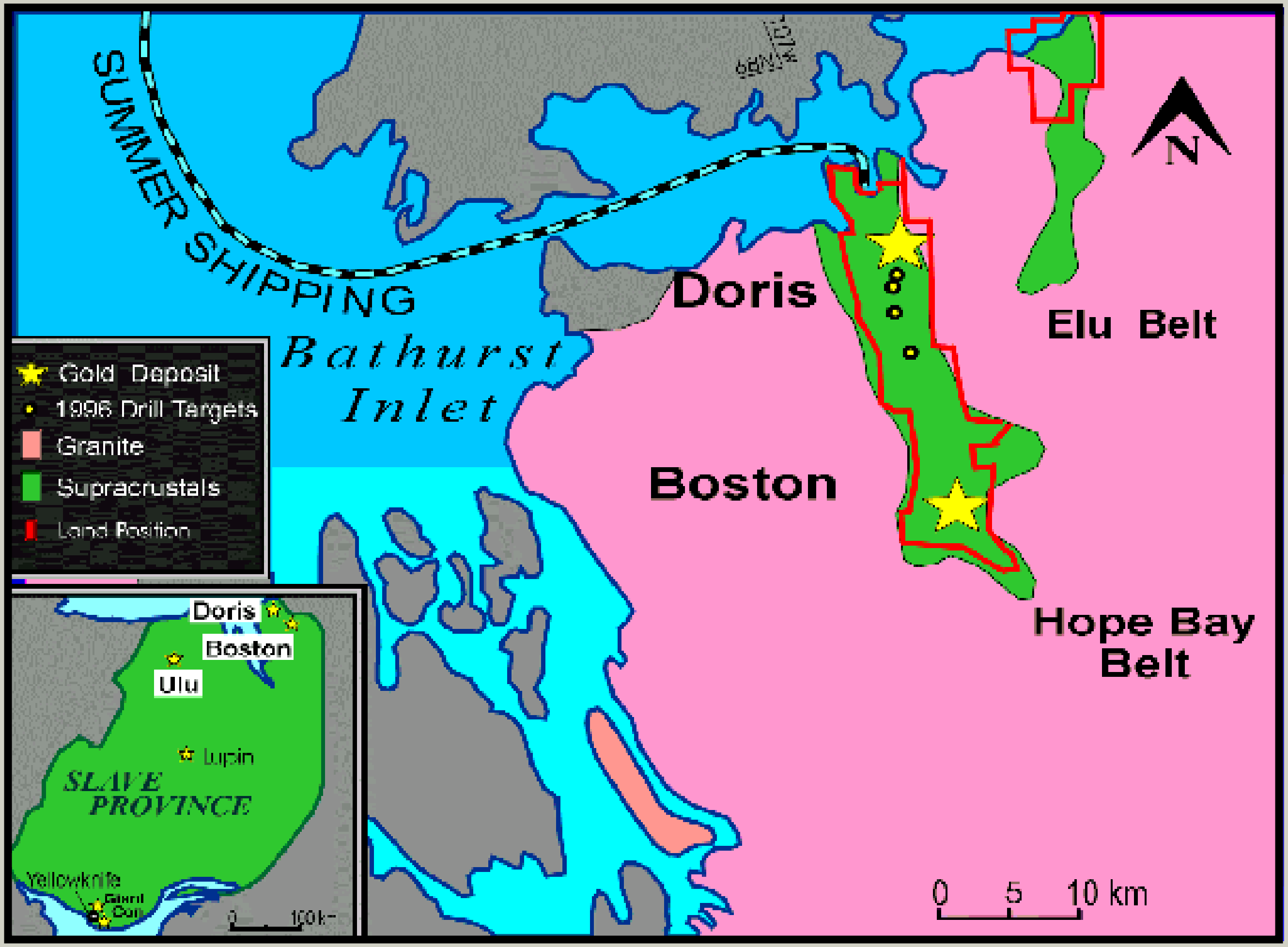
## Hope Bay Greenstone Belt, NWT, Canada



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- Unraveled ice flow history and glacial stratigraphy;

- Last ice flow was to the NNW (avg. 335°) and it smeared till along the E and SE sides of the outcrops;

- Therefore by digging through the relatively thinner glaciomarine sediments on the E and SE sides of the bedrock ridges we were able to collect till, the chemistry of which was indicative of the bedrock geology and/or mineralization in the valley to its SE.

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## Hope Bay Greenstone Belt, NWT, Canada

- Glaciomarine sediments overlying till;

- Till collected, on S-SE slopes of bedrock ridges, by digging through the glaciomarine sediments.

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- 5931 till samples were collected across the entire area;

- 500 gm to 1 kg of till were collected, coarse fragments removed, dried and sieved to -250 mesh (<63 microns);

- Au was determined by FA/AAS and an additional 32 elements by nitric/aqua regia - ICP-ES;

- QA/QC was facilitated through the analyses of reference control standards and duplicates.



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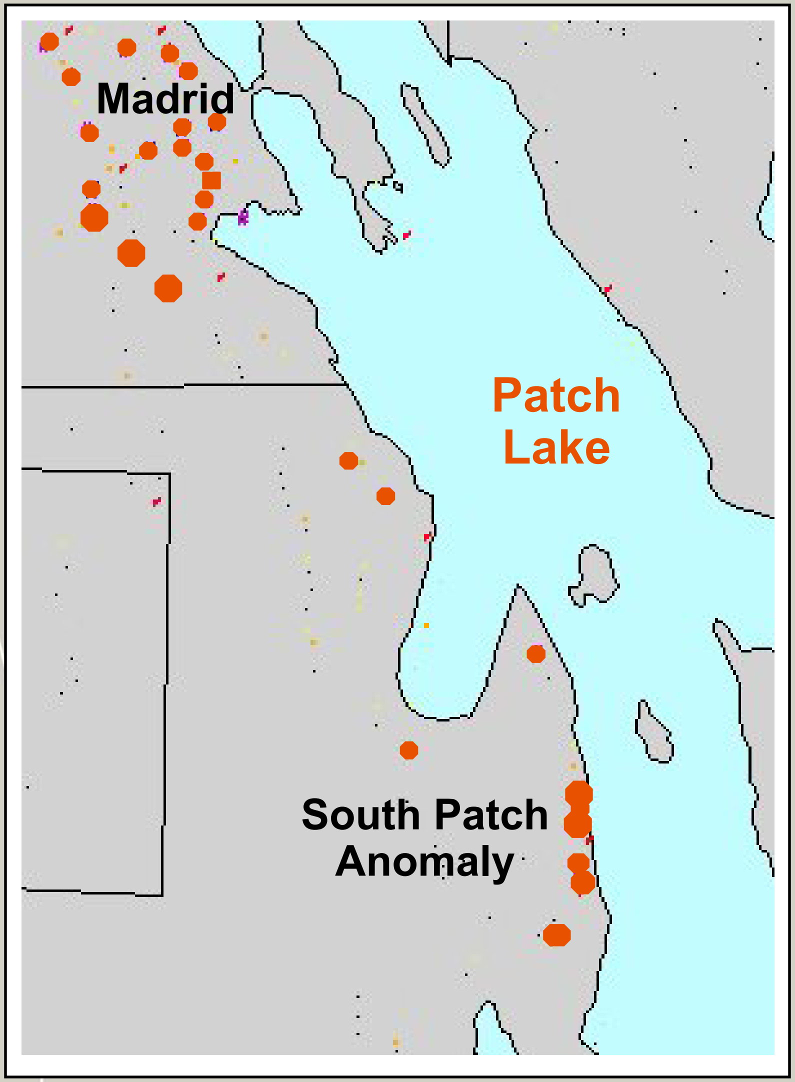


- Sampled till - SSE slopes
- Coherent till anomalies
- Several new targets in the belt
- South Patch mineralization identified by till geochemistry and proven up by drilling.

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## Piling Project, Baffin Island, Nunavut, Canada



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## *Piling Project, Baffin Island, Nunavut, Canada*

- Government geology maps, airborne geophysical data and lake sediment geochemical data used to target potential BHT province;
- BHP carries out a reconnaissance geological survey coupled with HMC and stream silt sampling which confirm area to be prospective for BHTs;
- Ground picked up and alliance formed with Falconbridge to jointly explore combined properties;
- Regional geological, till geochemistry and airborne hyperspectral surveys conducted;
- Target scale prospecting and rock sampling, till geochemistry and "Beep Mat" geophysics carried out; and,
- Initial results produced bedrock samples with 40% combined Zn / Pb with 1000 g of Ag.

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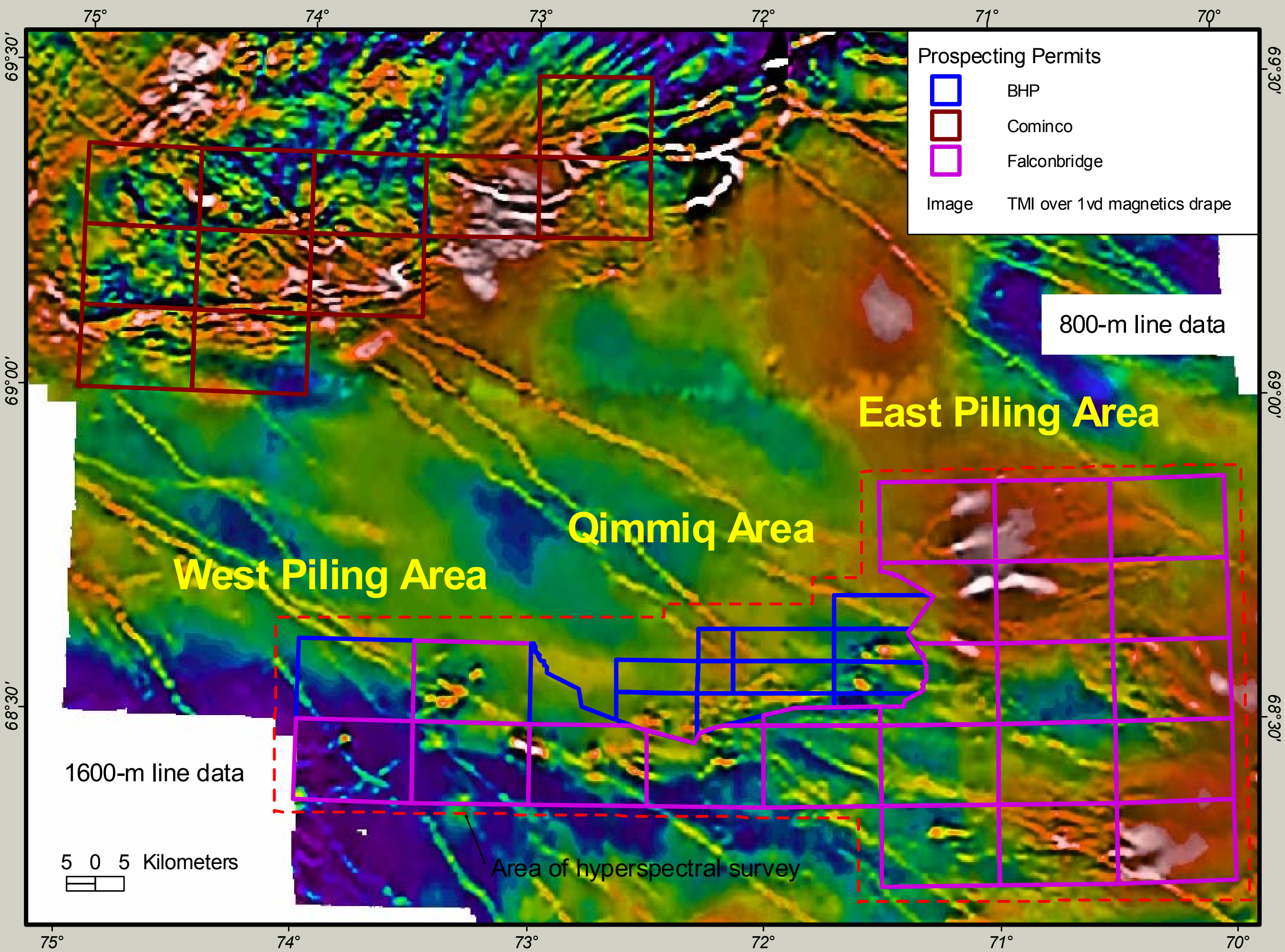
## Piling Project - TMI over 1st VD Magnetics Drape



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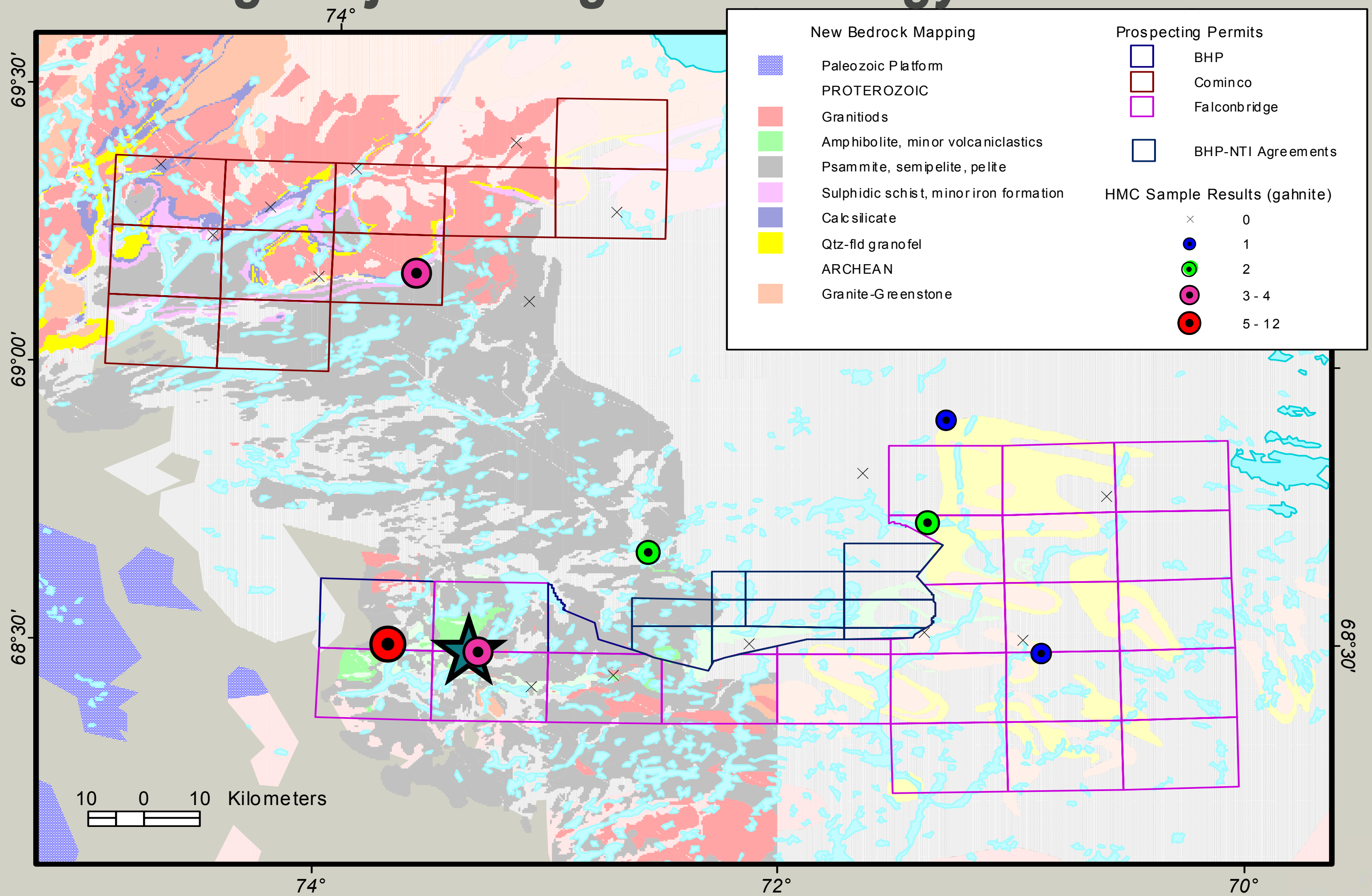
## Piling Project - Regional Geology and HMCs



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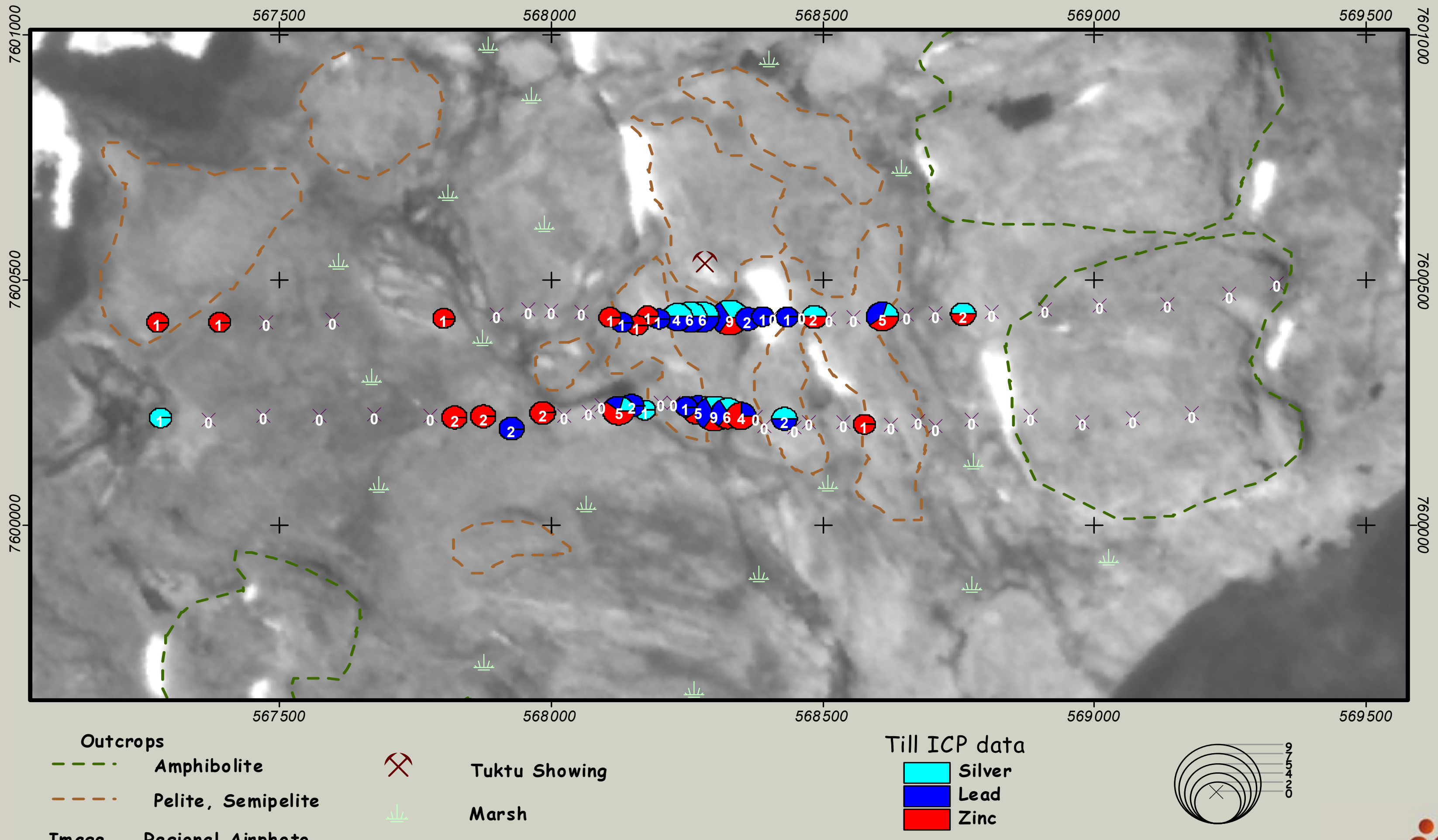
## Piling Project - Tuktu - Till Samples



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## Piling Project - Tuktu Showing

Gossan

Mineralization

**There is still a need for further evaluation of Tuktu, as well as other as yet untested, targets in this project area.**

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## Talks and Posters:

## On the

## Application of Conventional Geochemical Techniques

## In Glaciated Terrains

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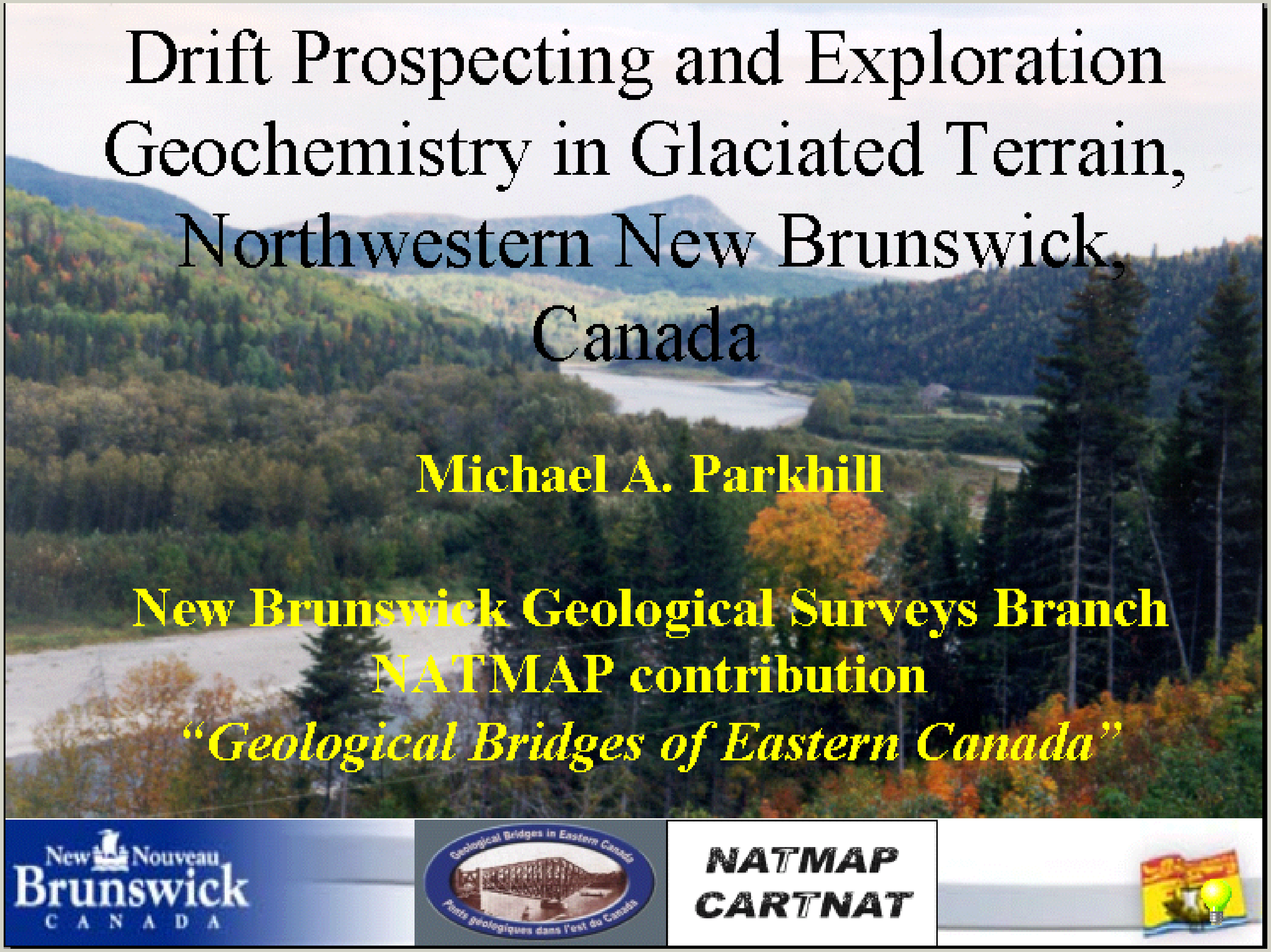




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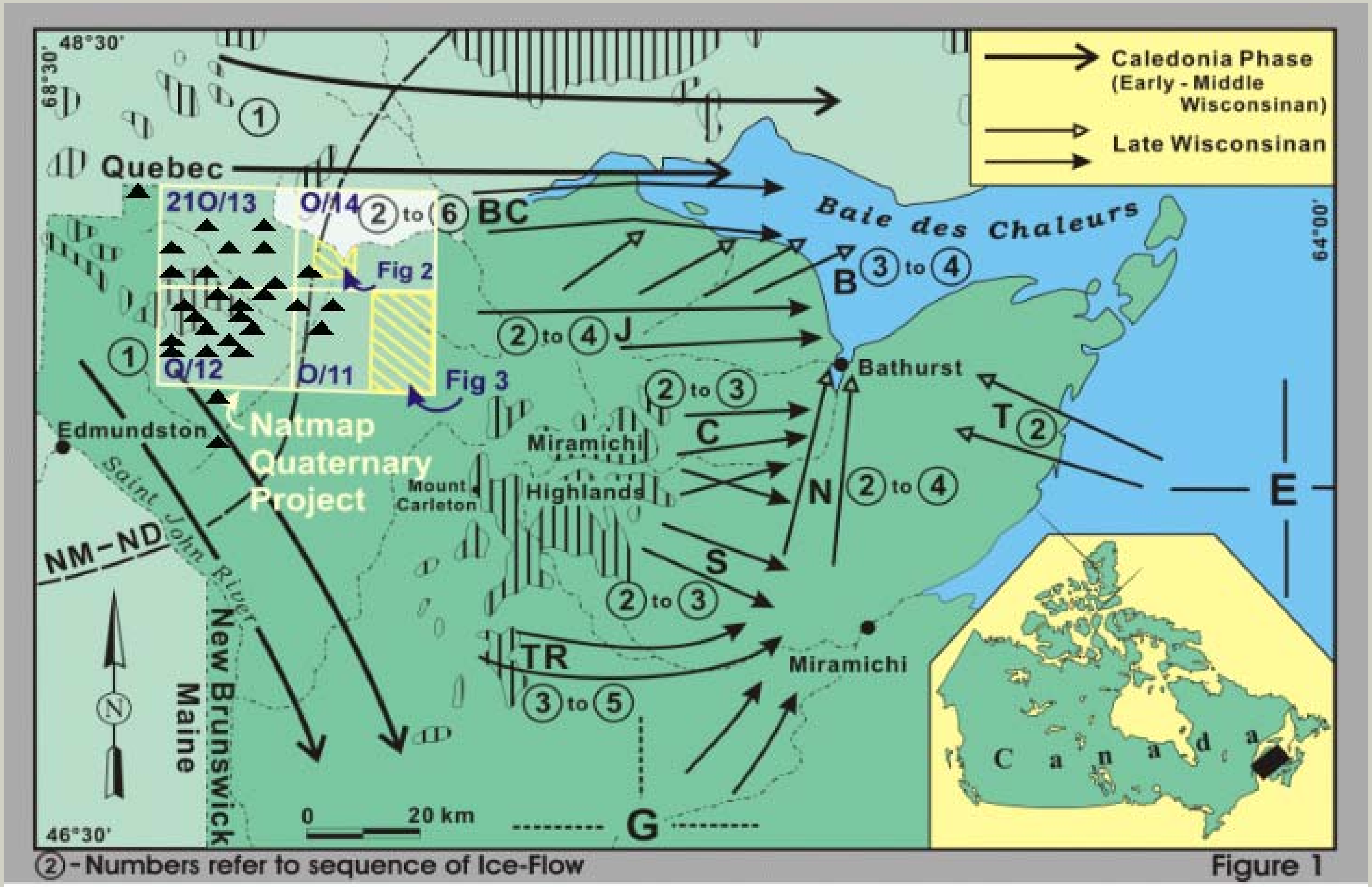


Distribution of Appalachian and Laurentide erratics and Ice flow sequence



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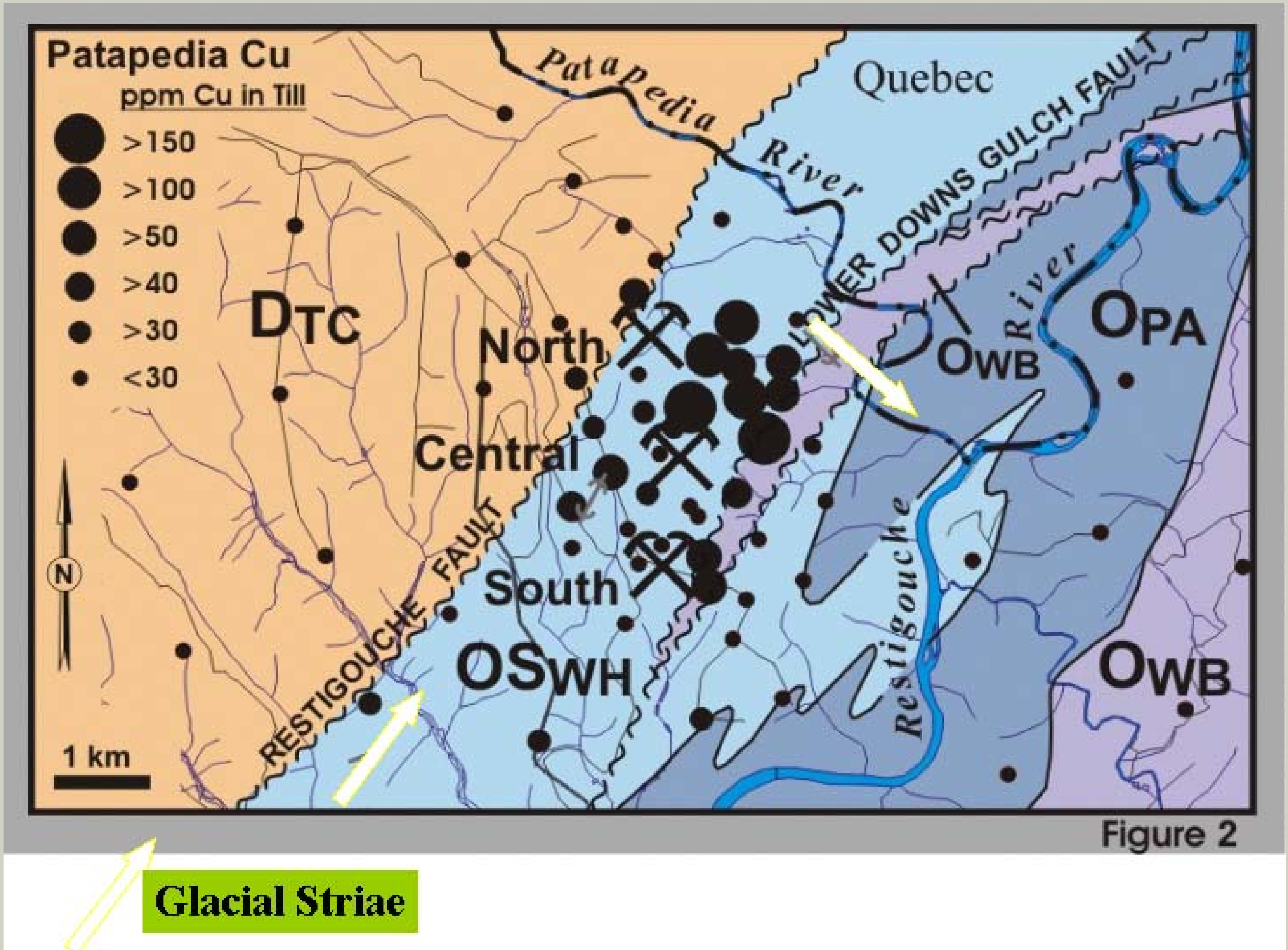




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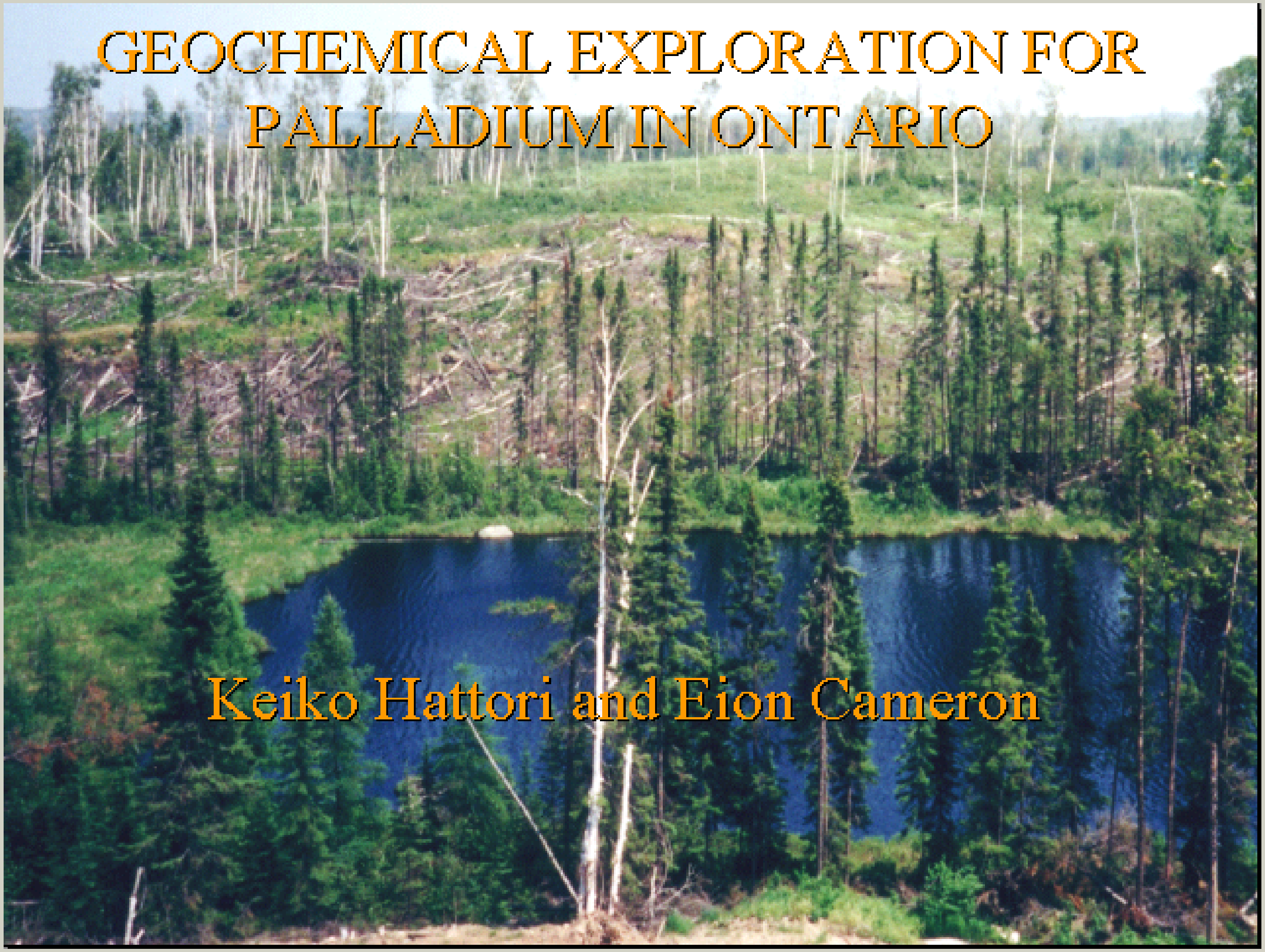

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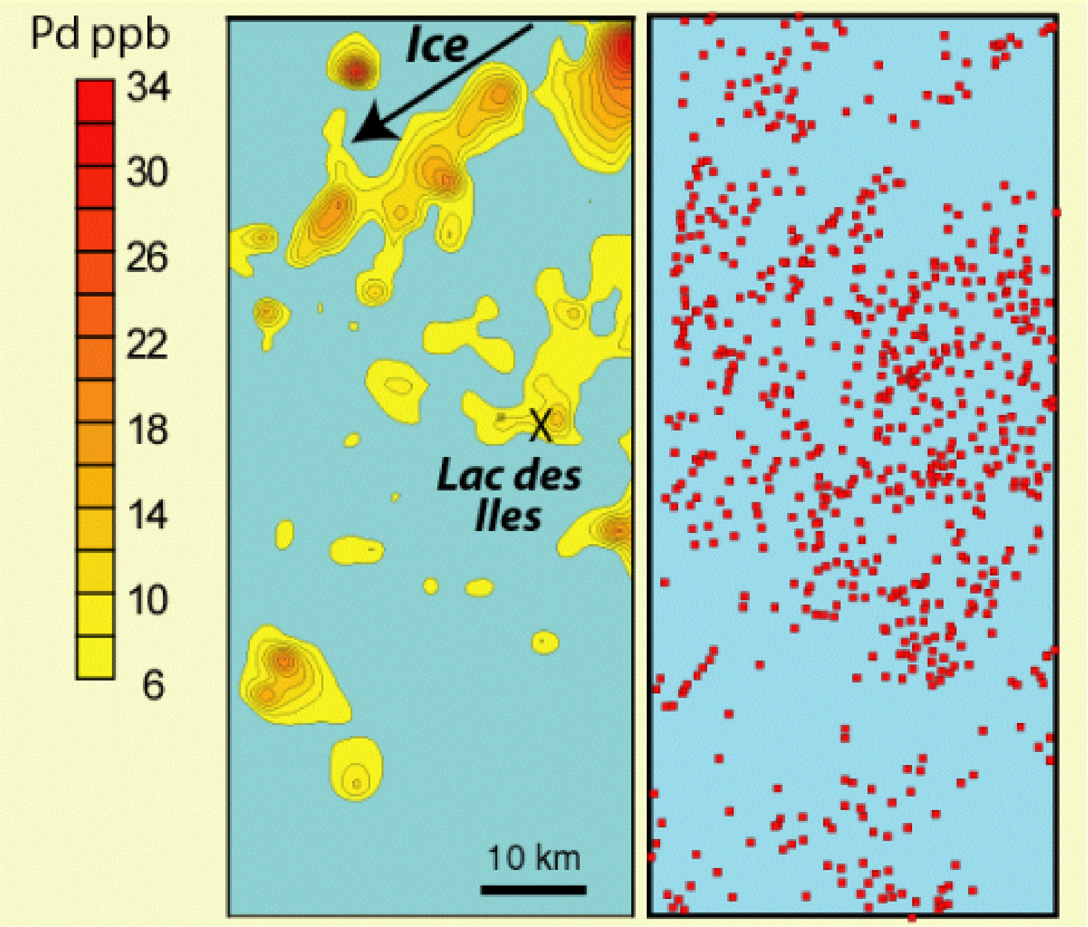
## Regional Lake Sediment Surveys (OGS)




2800 km²
675
samples

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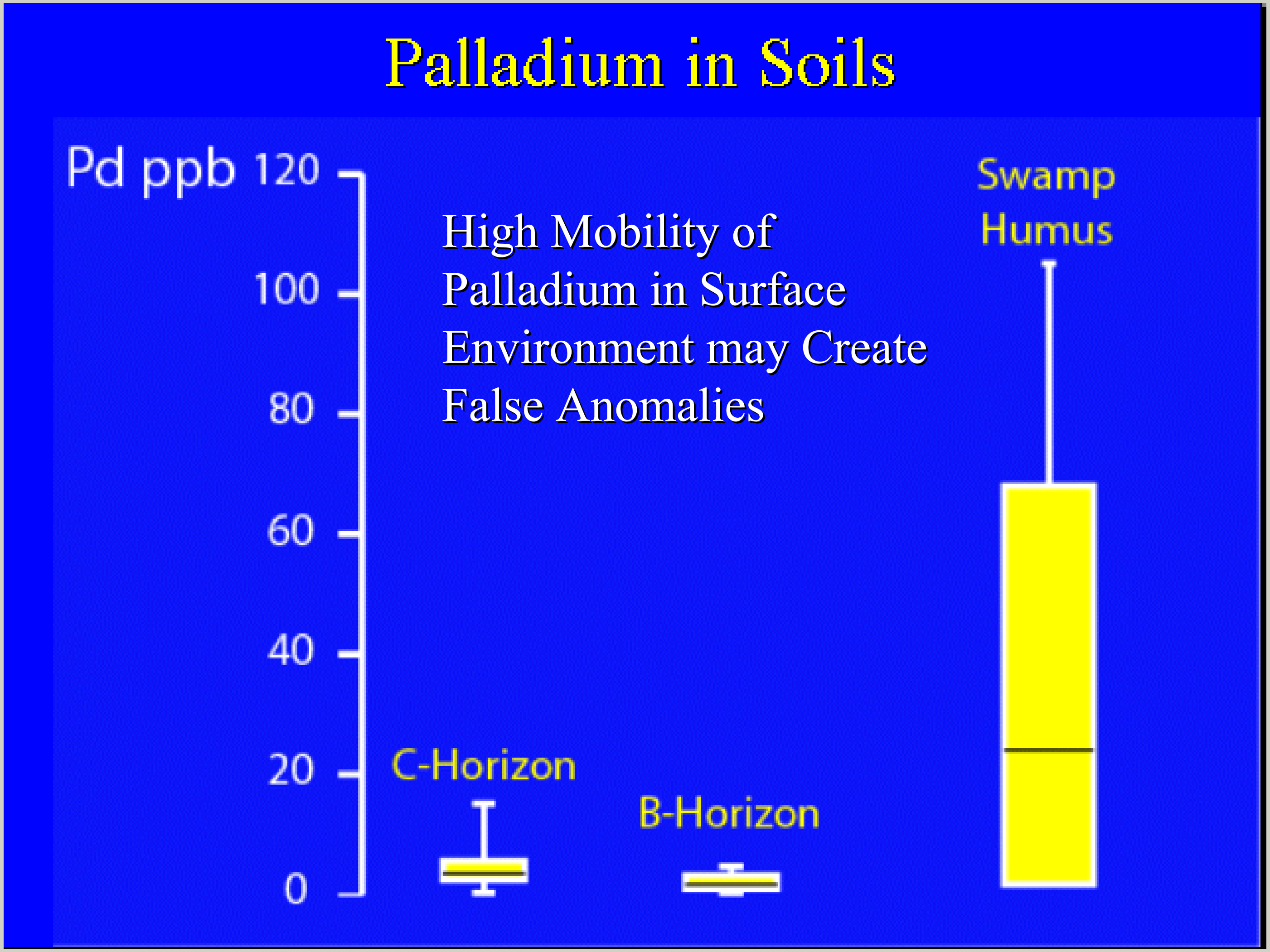




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# Geochemical and Mineralogical Dispersion Models in Till: Physical Process Constraints and Impacts on Geochemical Exploration Interpretation

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- The ***Exponential and Linear Dispersion Models*** are numerically inconsistent with the physical model for which they are ascribed
- An alternative ***Aggradational Dispersion Model*** is proposed that has both physical justification and explains both observed dispersion patterns (‘*pseudo-exponential*’ *and* ‘*pseudo-linear*’)

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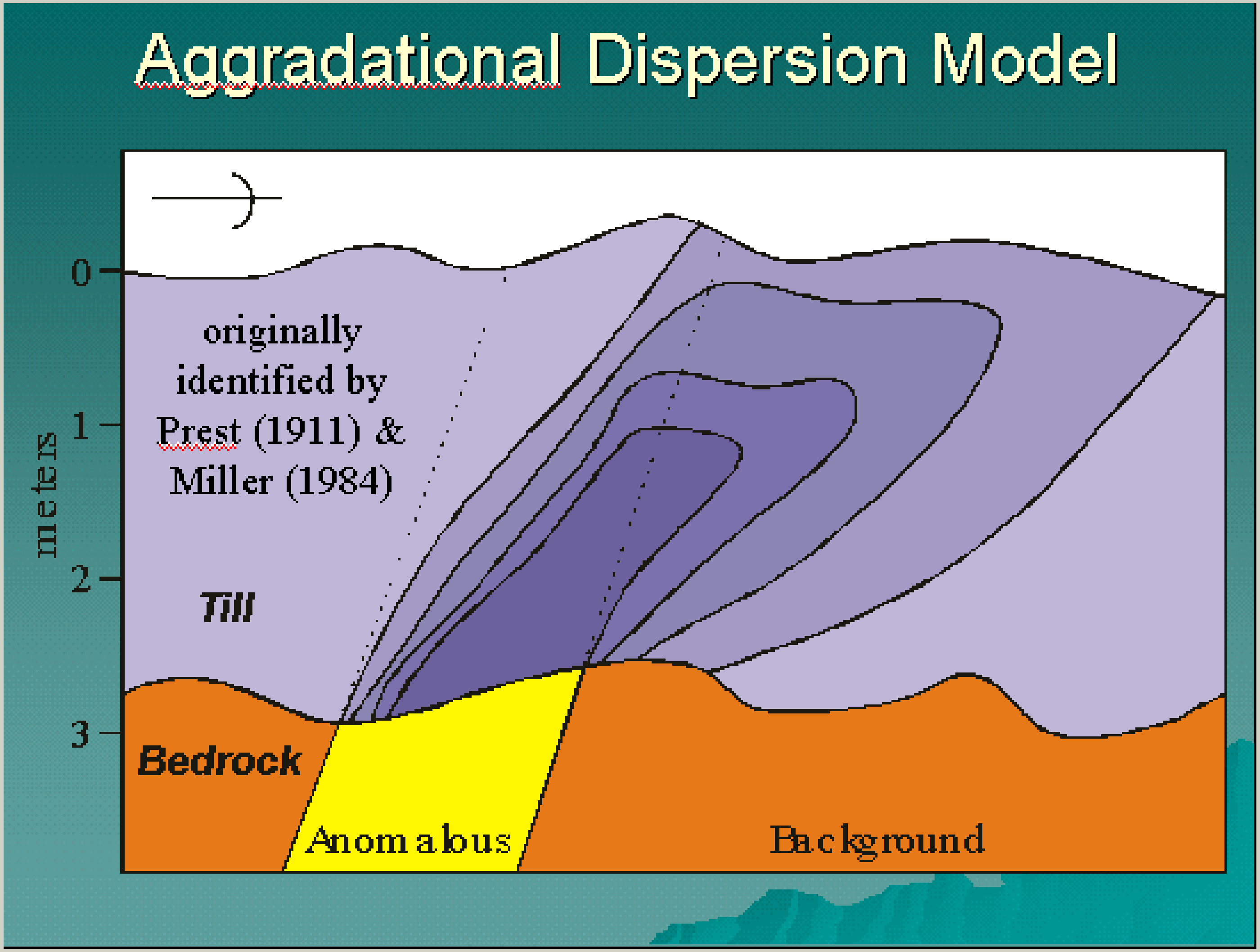

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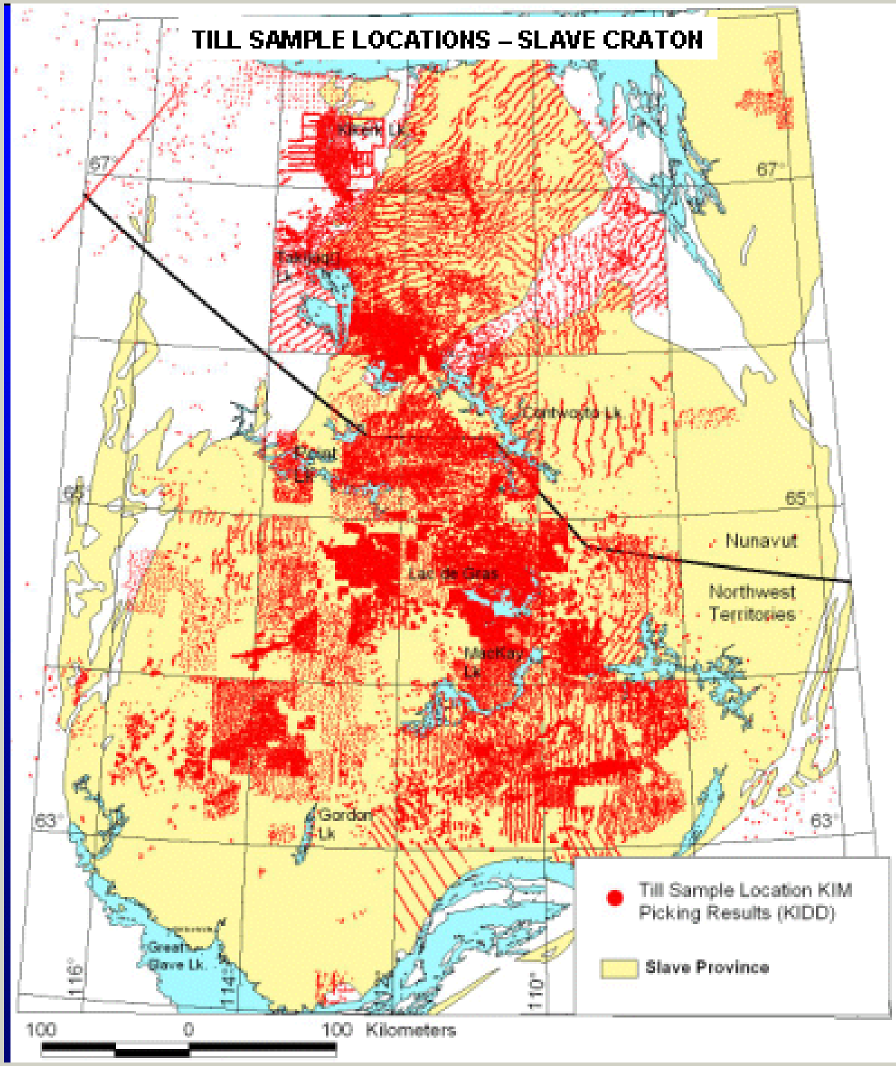
## PUBLIC DOMAIN COMPILATIONS OF KIMBERLITE INDICATORS AND THEIR MINERAL CHEMISTRY FROM AN EMERGING DIAMOND REGION: ARCHEAN SLAVE CRATON, NORTHERN CANADA

John P. Armstrong, C.S. Lord Northern Geoscience Centre,
DIAND NWT GEOLOGY DIVISION, Yellowknife NT Canada

- Since 1991 over 350 kimberlites have been discovered in the region underlain by the Archean Slave Craton, northern Canada
- 2 producing diamond mines
- Exploration data generated by exploration companies is filed with the Federal Government to maintain mineral claims
- Data for diamond exploration has consisted of glacial till sampling and kimberlite indicator mineral (KIM) picking results, electron microprobe analyses of indicator minerals, airborne magnetic and electromagnetic surveys, and diamond drilling
- This hard copy data has been digitized and compiled into a series of GIS compatible products

# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview




Till Samples > 125 000

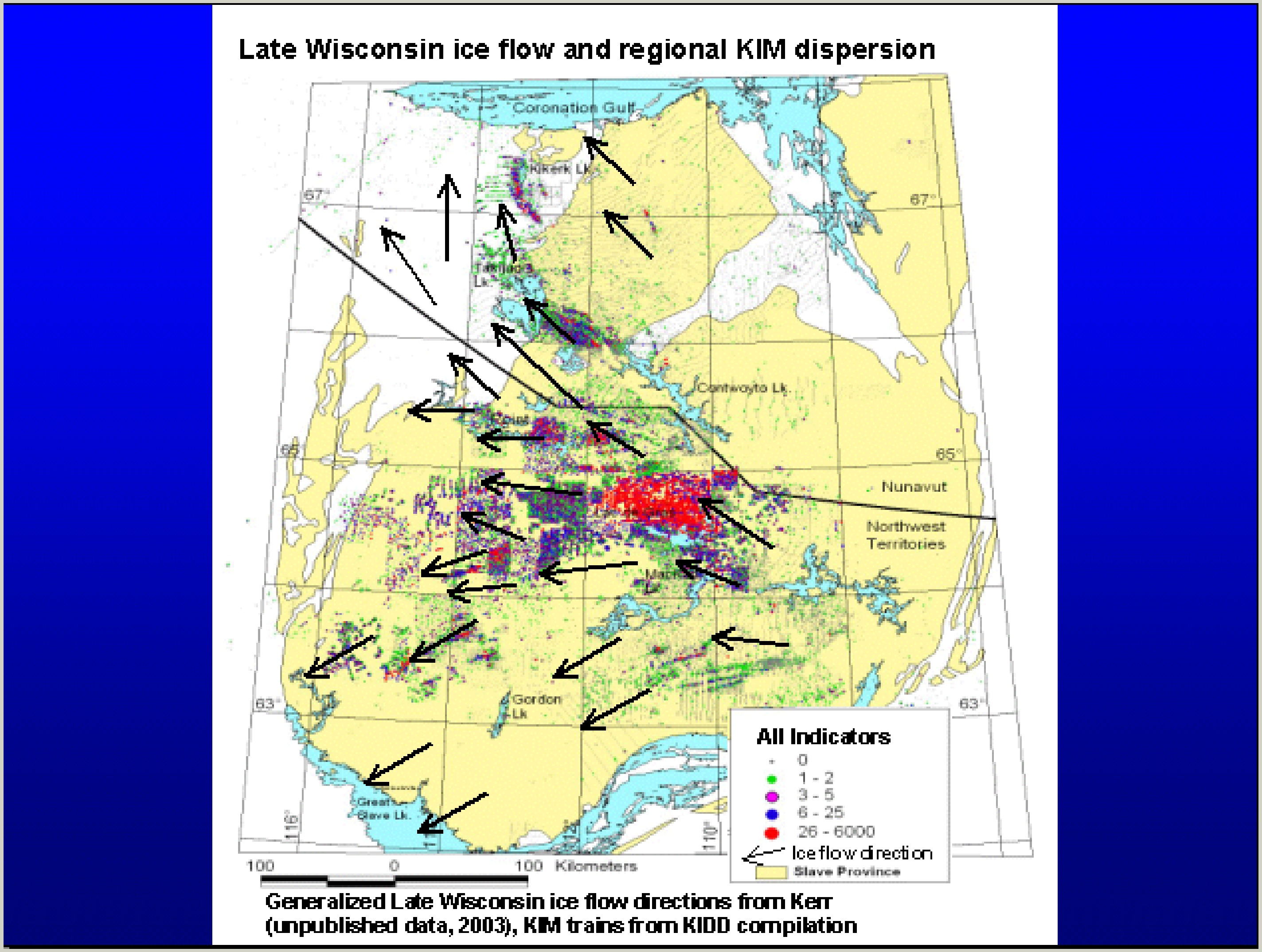
Mineral Chemical Analyses >110 000

Drill Logs > 1600 with over 500 kimberlite intersections

Total Field Magnetic Images > 1500 maps scanned and geo-referenced

Compilations are designed in such a manner that allows for quick integration with clients existing GIS datasets

# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview



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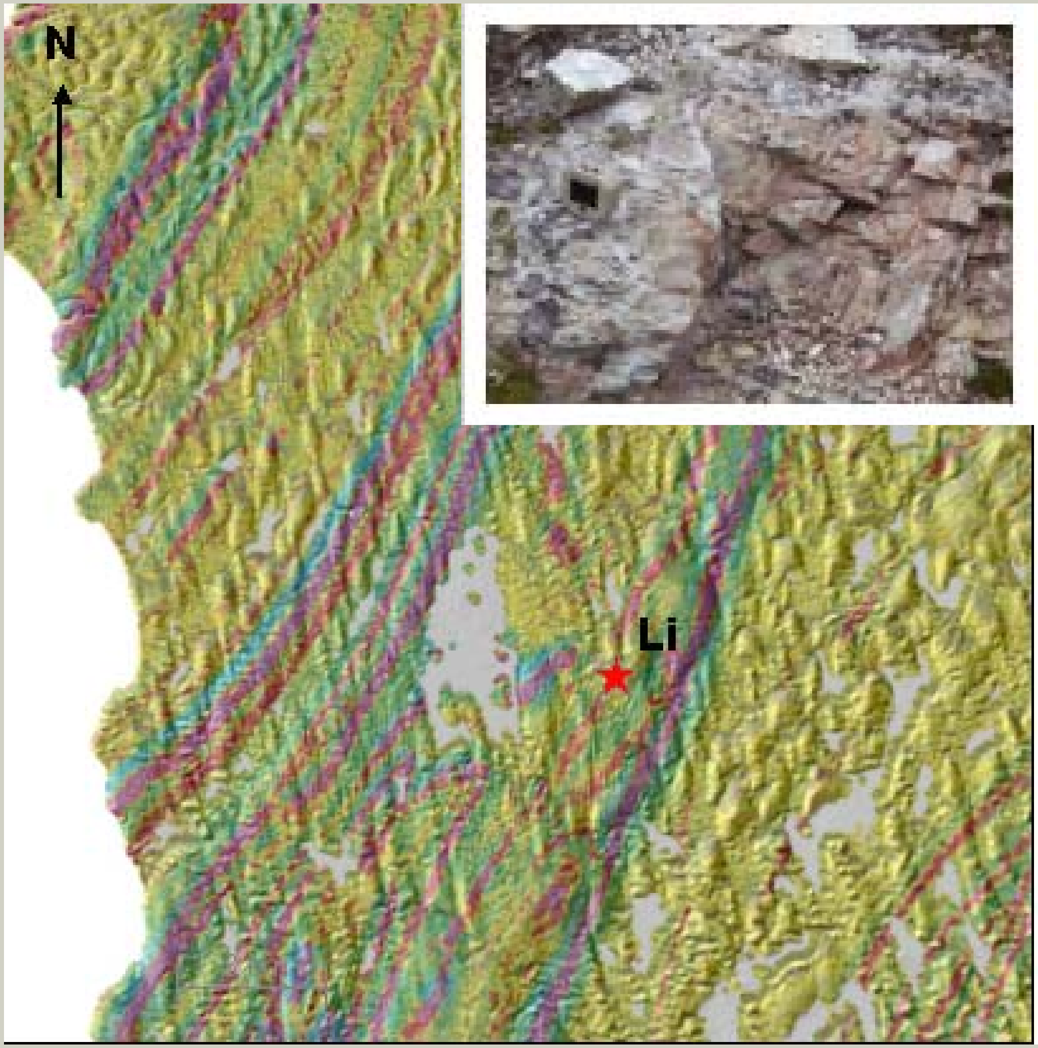
## GEOCHEMICAL PROSPECTING IN ICE MARGINAL SETTINGS: INSIGHTS FROM RARE-METAL PEGMATITE EXPLORATION IN THE BRAZIL LAKE AREA, SOUTHWESTERN NOVA SCOTIA

Andrea Locke, Cliff Stanley, Ian Spooner
ACADIA UNIVERSITY

ACADIA UNIVERSITY

# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview




- 2nd derivative aeromagnetic map
- NE-SW trending syncline
- Shaded relief model
- N-S trending glacial features

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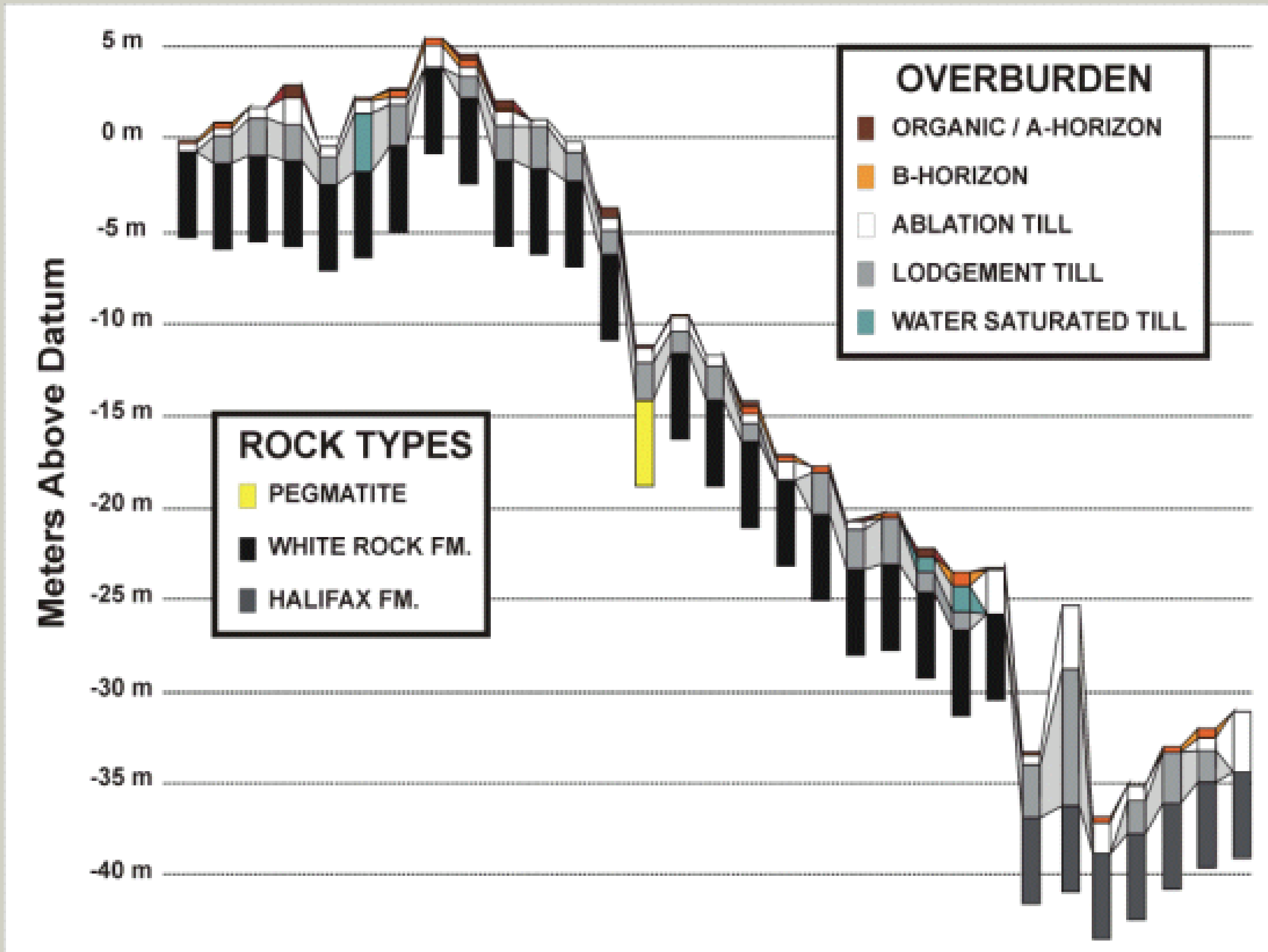

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## Subglacial Till:
## The “Upwardly Mobile Sediment”

by

Mark Tarplee

Queen Mary,
University of London

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Galaxy Structure –skeleton grains spiraling outward (anticlockwise)

# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview

## Deep Penetrating Geochemistry

In recent years, considerable effort has been focused on the development of surficial geochemical techniques to "see through" thicker, compositionally complex, sedimentary (glacial, marine, etc.) sequences.

In this context, i.e. discovery of economic mineral deposits concealed beneath thick cover, a number of modern "Deep Penetrating" surficial geochemical techniques, that focus on giving an *in situ* response vertically above the target mineralization, have been developed.

# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview

These techniques include a variety of selective extraction, soil gas, physiochemical, electrochemical and biological (bacterial and microbial, etc.) methods.

The key to the successful application of these targeting techniques for "*seeing through thick cover*" is understanding the processes controlling the elements/compounds "*vertical redistribution*" to the near surface and their modification / redistribution within the near surface environment.

## What are selective extractions:

Analysis of a sample to selectively release the metals associated with a specific component of the sample.

## Why are they Used in Exploration:

- Areas with cover, in particular exotic overburden;
- Particular fraction of sample desired (Carbonate, Mn Oxide, Fe Oxide, Clay, Organic);
- Measure a component of the chemically rather than mechanically transported elements; and,
- Separate recent chemical signature from background geological signature of the parent material.

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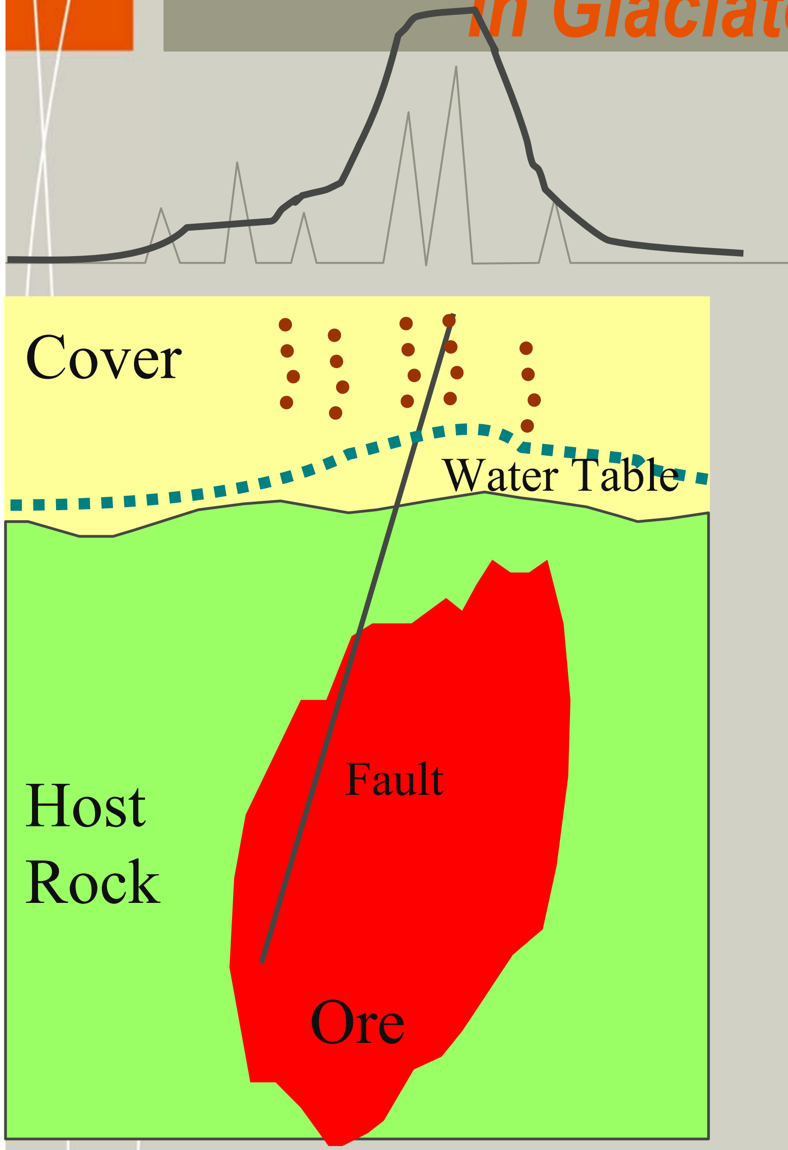
## Emphasize secondary chemical processes

- Hydromorphic Dispersion
- Evapotranspiration
- Electrochemical dispersion
- Gaseous Diffusion
- Seismic Pumping
- Organic/Bacteria/Microbial Activity

\+ Others?

## Limit chemical contribution from resident surficial medium sampled

# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview




1. **Ore forming** primary geochemical signature during ore formation
2. **Release** of elements during ore weathering (e.g. oxidation)
3. **Transport** of elements through cover to the surface
4. **Accumulation** of elements at surface

Geochemical signature at the surface varies according to the deposit type, type and depth of cover, surface environment.

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## Examples:

- Water-Bound Ions (MMI)
- Cyanide Extraction (BCL)
- Carbonate Extraction (Na Acetate)
- *Organic Extraction (Organomet )*
- *Amorphous Mn Oxides (Allegro)*
- Amorphous Mn Oxides (Enzyme Leach)
- *Amorphous Fe Oxides (Foxy)*
- Crystalline Mn or Fe Oxides
- Sulphides (Aqua Regia)
- Near Total Extraction (3 or 4 -acid)
- Total (Fusion)



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Climate and geomorphology are radically different throughout the world resulting in a range of processes at work in transport through cover and in the media where dispersed elements will be trapped at the near surface.

In geochemical exploration, recognition of the nature of the local (soil) cover is particularly important as this provides a useful indication of both the potential mobility of elements of interest in the surficial environment and of the potential effectiveness of specific (soil) components (horizons) as geochemical sample media.

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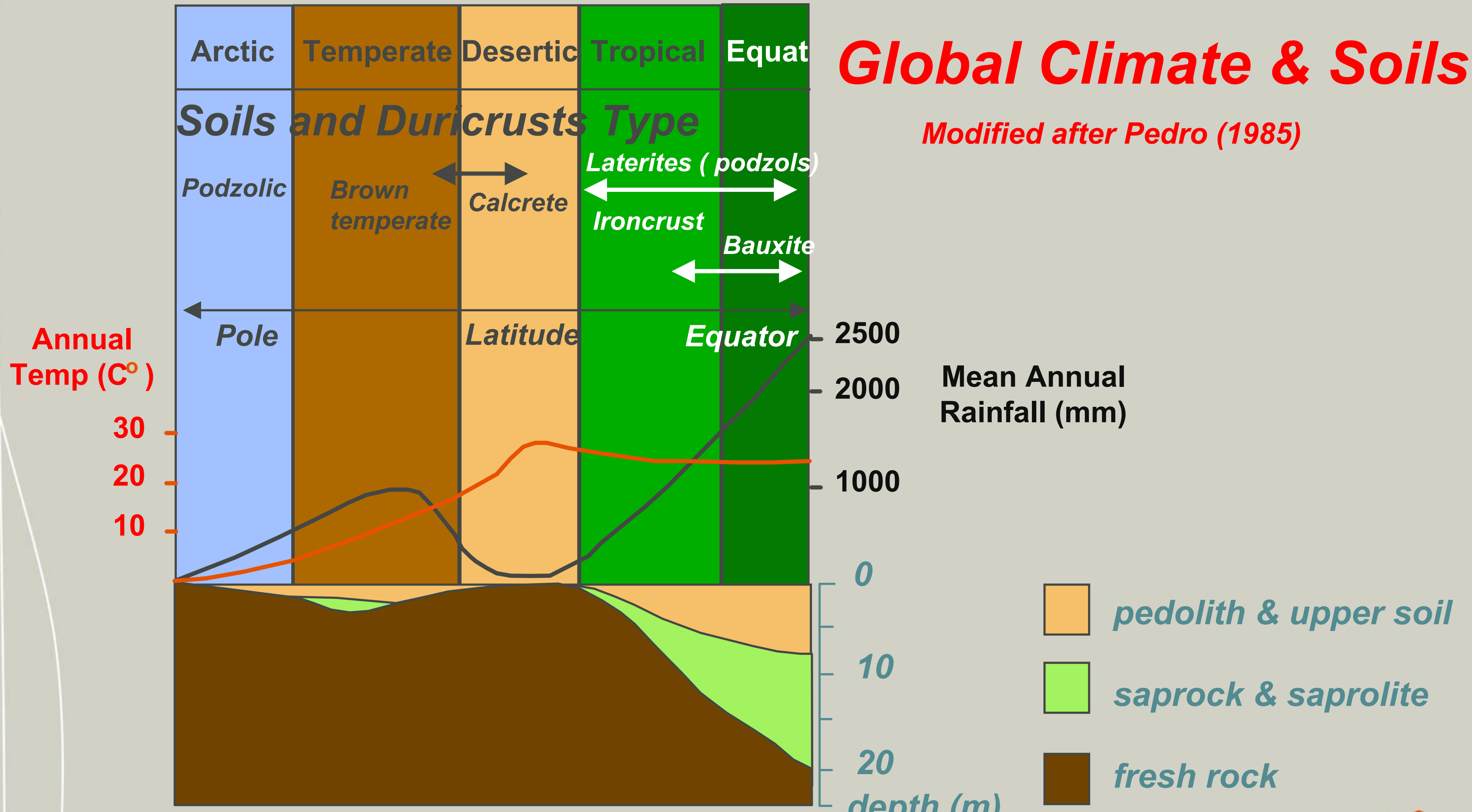
## Global Climate & Soils

Modified after Pedro (1985)



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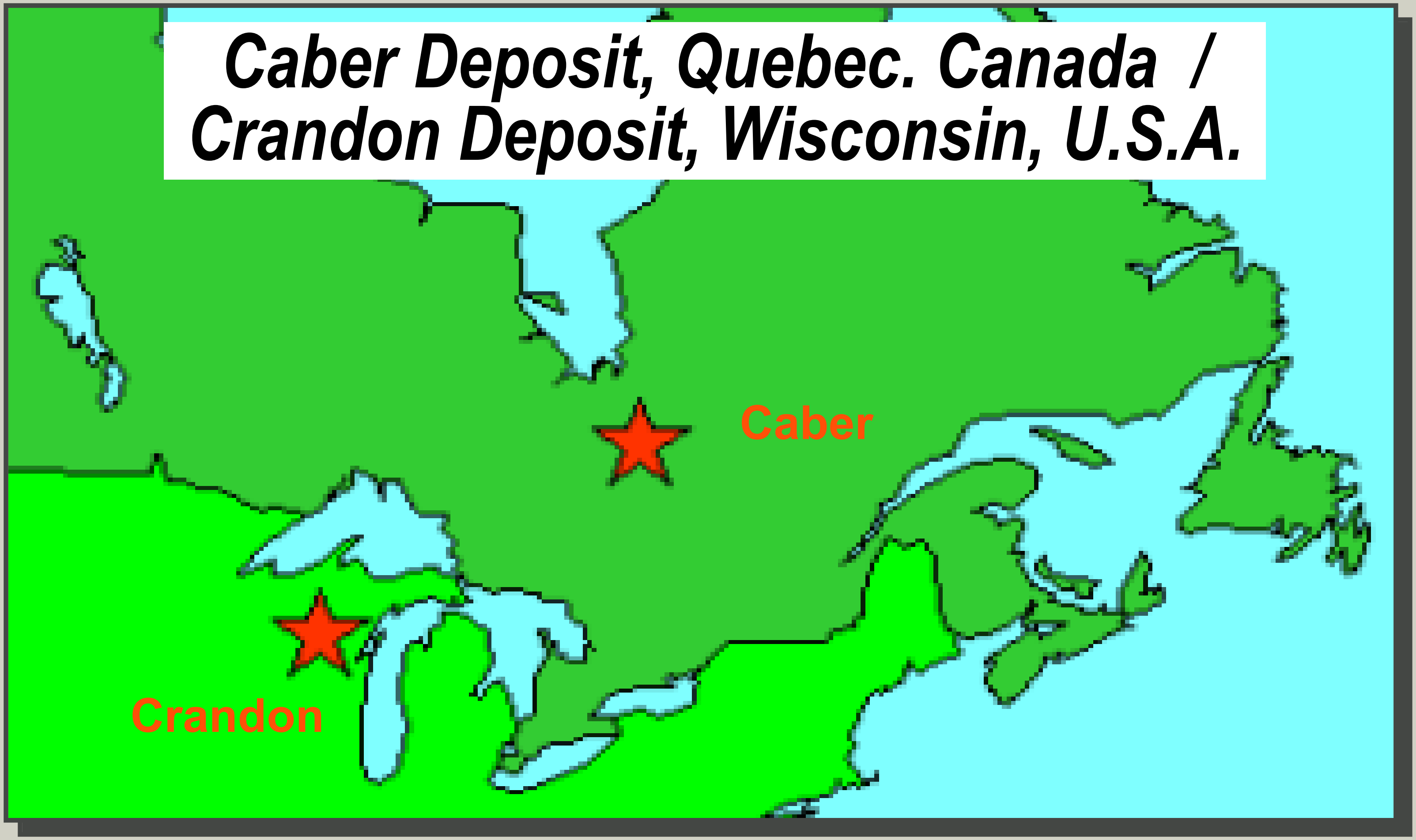




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# *Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview*

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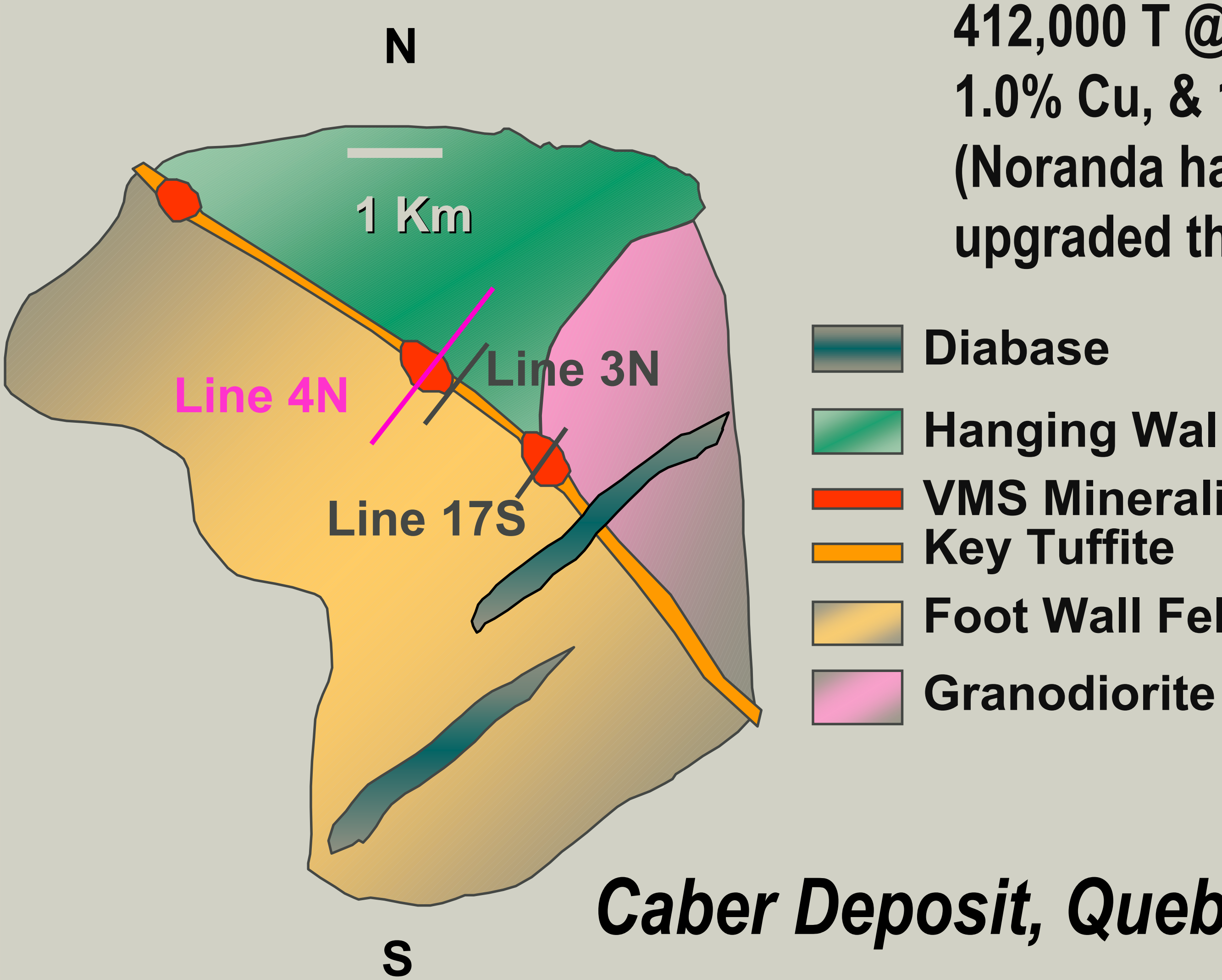


**412,000 T @ 12.4% Zn 1.0% Cu, & 15.0 g/t Ag (Noranda has since upgraded this resource)**

***Caber Deposit, Quebec. Canada***

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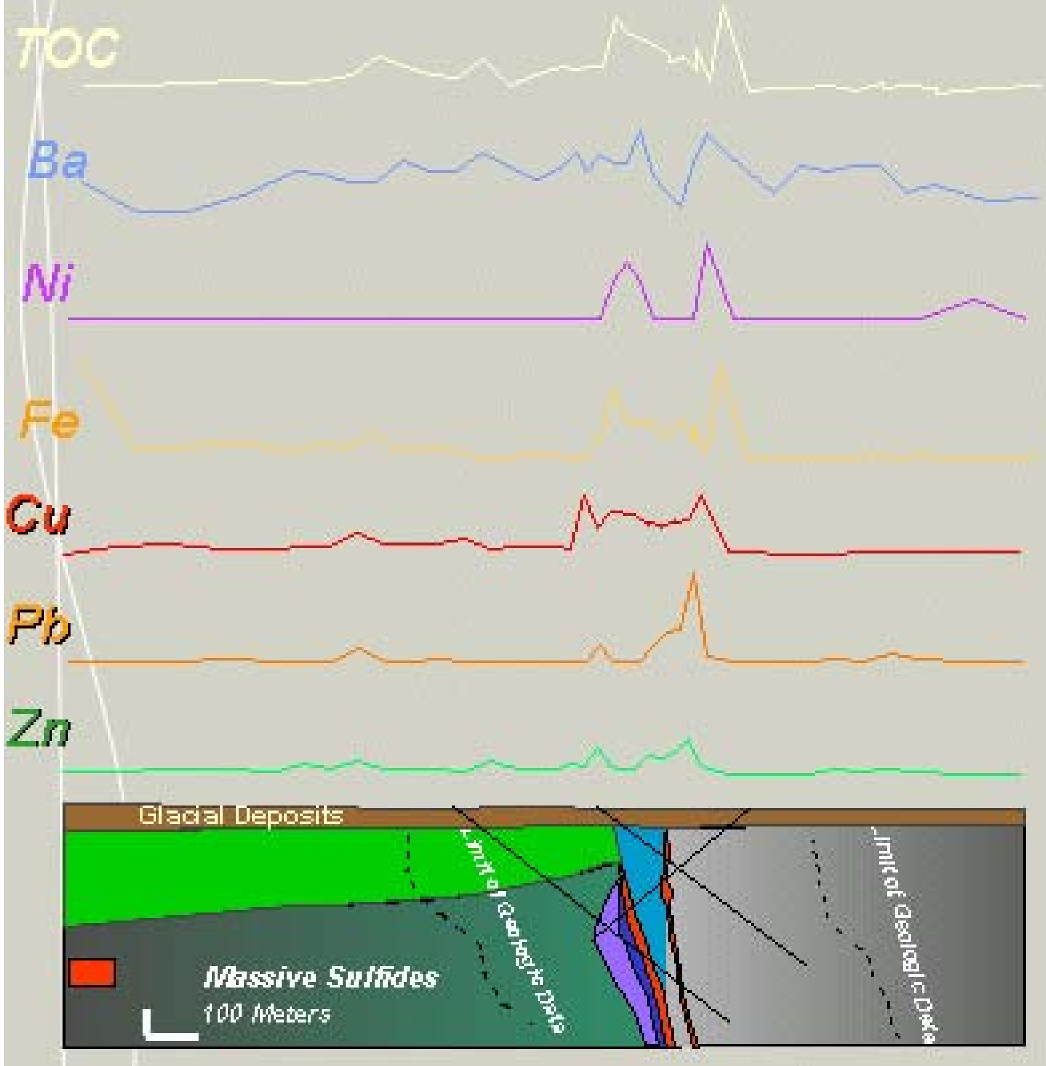


- Extremely valuable tool in areas of thick overburden;
- A selective extraction (**OrganoMet**) used on 100% organic sample medium (**humus**);
- Analyses by (ICP-ES/MS);
- Extremely low background, but high contrast anomalies
- **Multi-element anomalies directly over mineralization at Caber.**

# Crandon Deposit, Wisconsin, U.S.A.

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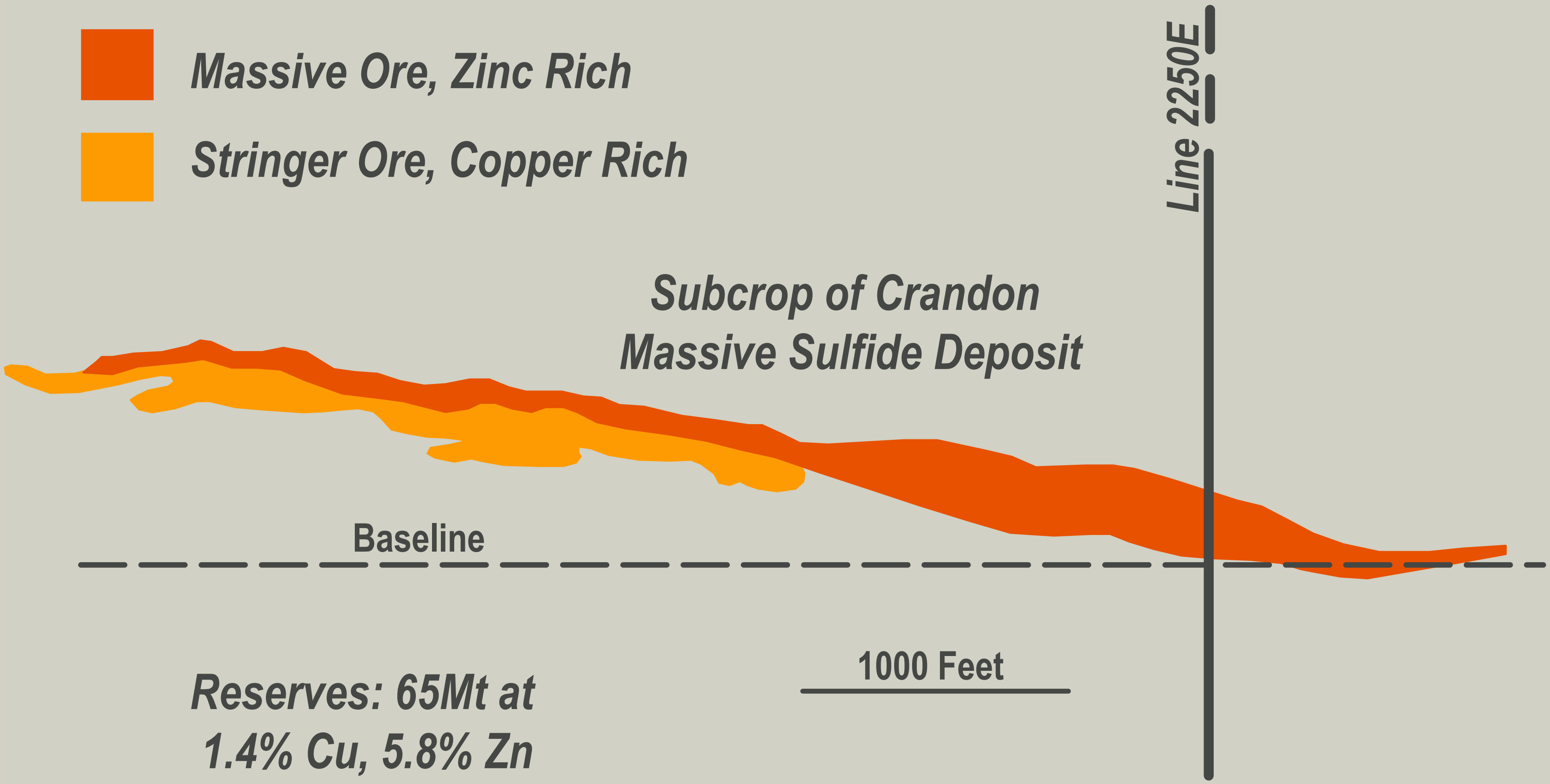


***Reserves: 65Mt at 1.4% Cu, 5.8% Zn***

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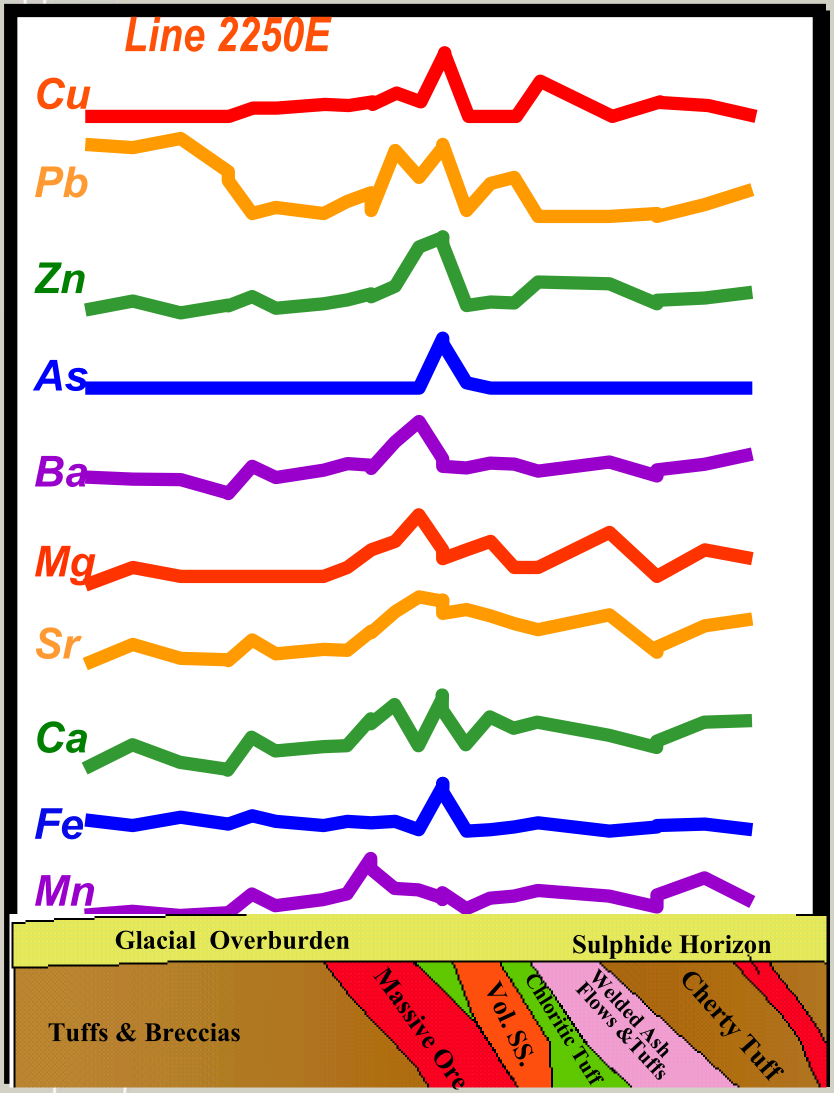


- Extremely valuable tool where you have thick overburden;
- A selective extraction (OrganoMet) used with a 100% organic sample medium (humus);
- Analyses by (ICP-ES/MS);
- Extremely low background, but high contrast, anomalies; and,
- **Multi-element anomalies directly over mineralization at Crandon.**



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# Kimberlite Detection

# Ekati Area, N.W.T., Canada

21st IGES, Dublin, Ireland - Aug. 28th to Sept. 3rd, 2003

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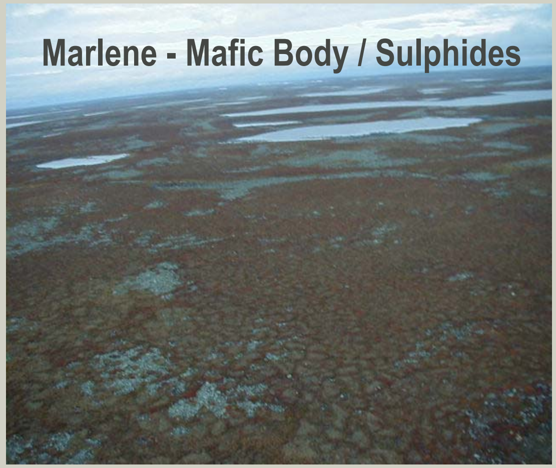
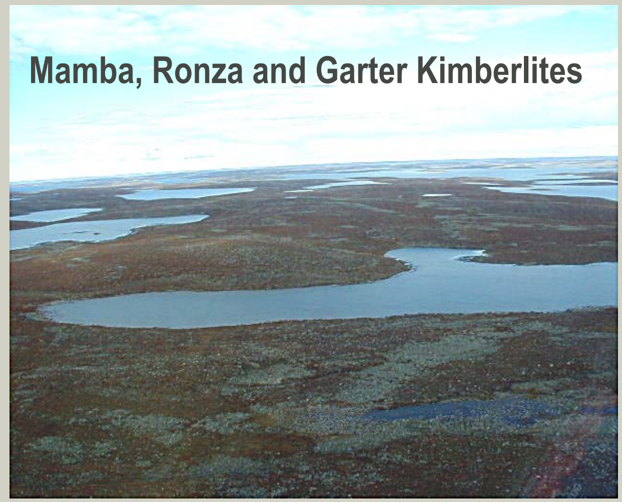
Impala Kimberlite Pipe


Marlene - Mafic Body / Sulphides


D54 - Ultramafic Body


Big Horn Kimberlite Pipe


Jenelle - Metaseds / Sulphides


Mamba, Ronza and Garter Kimberlites

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Local Till


Mottled Collivium/Till

# Land Based Targets:

# Geophysical Expressions

# Geochemical Expressions

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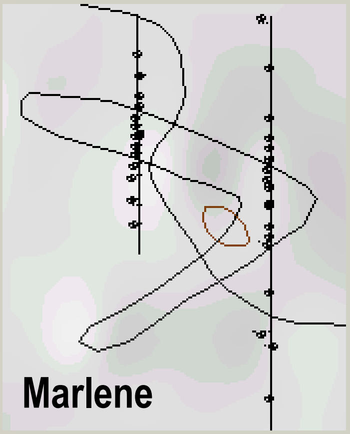


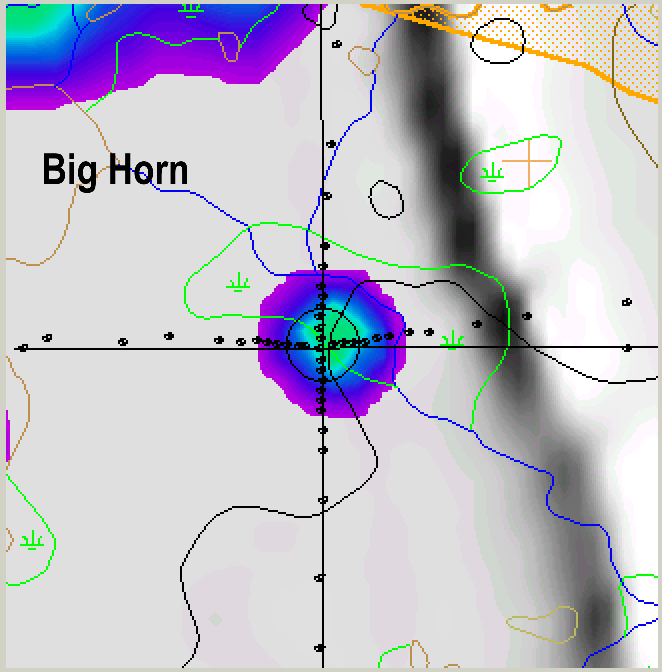


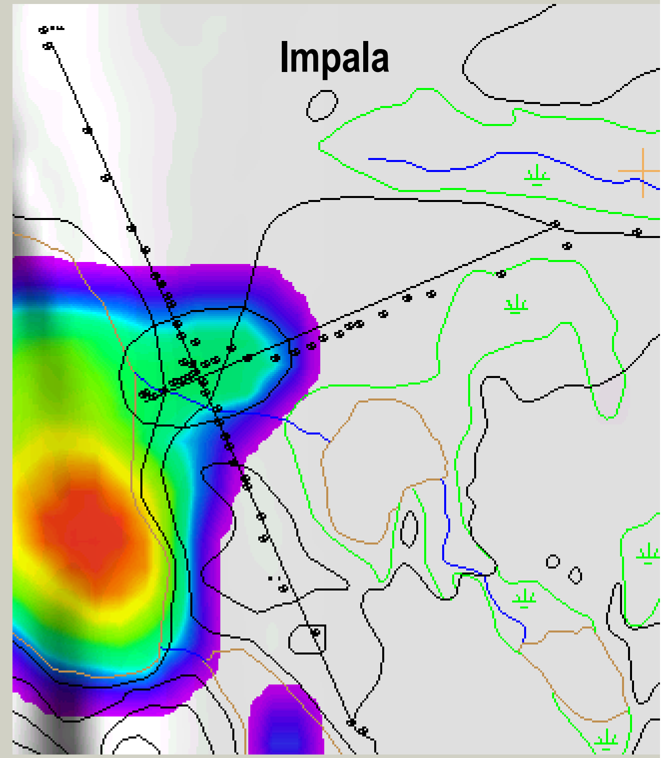


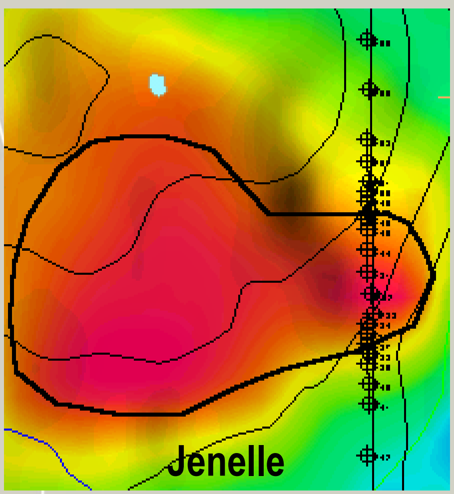


## *Geophysics:*

## *EM Colour Drape on Magnetics*

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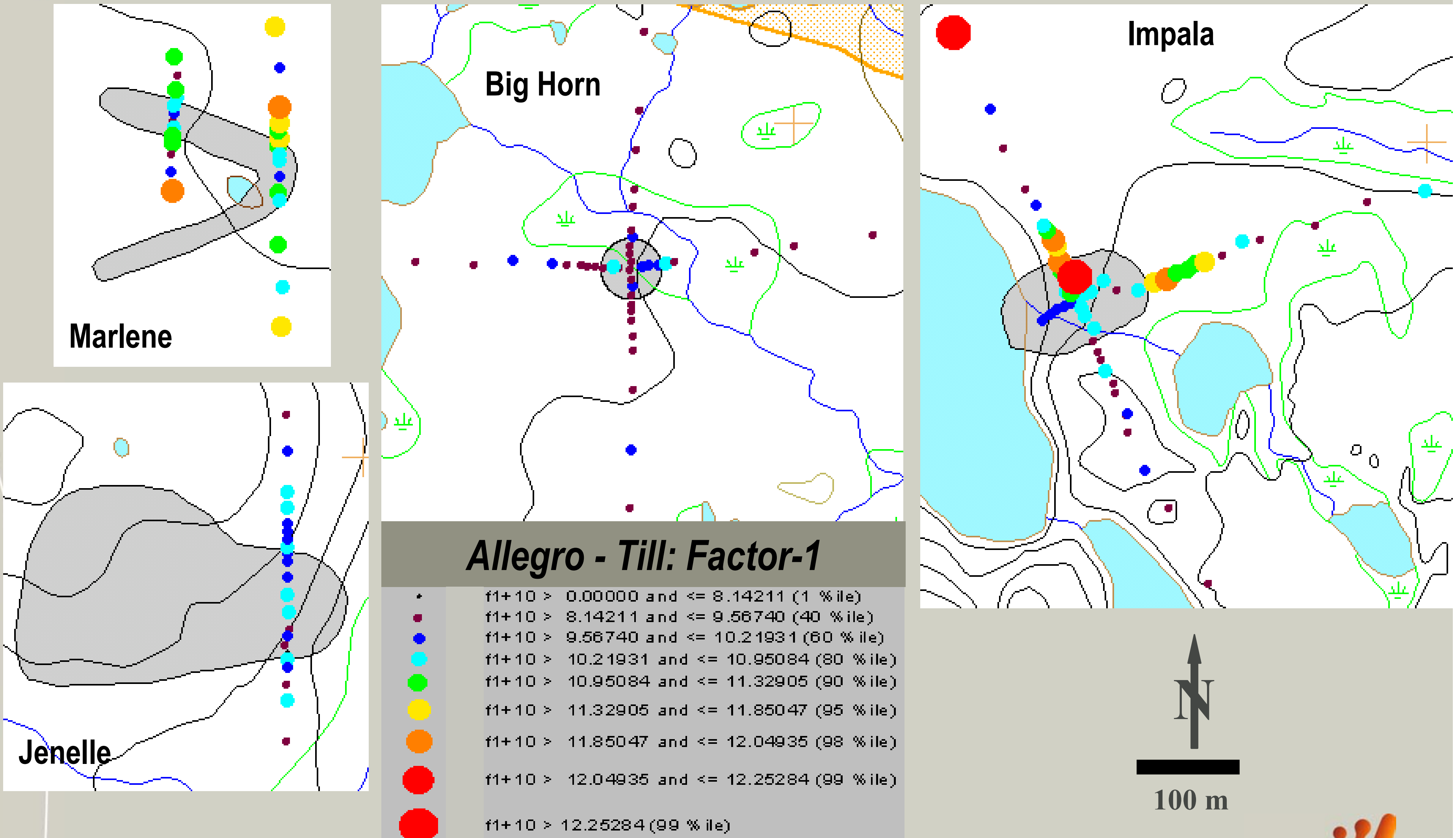




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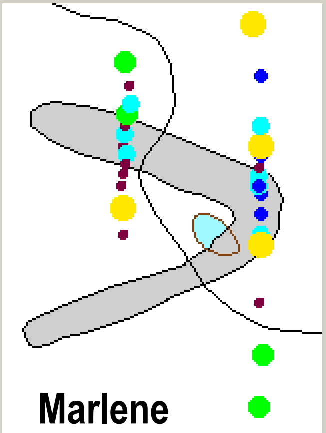


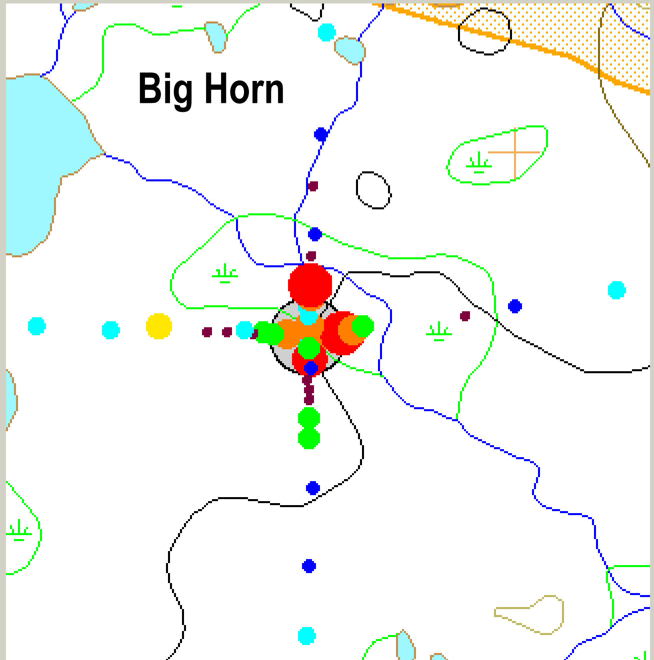


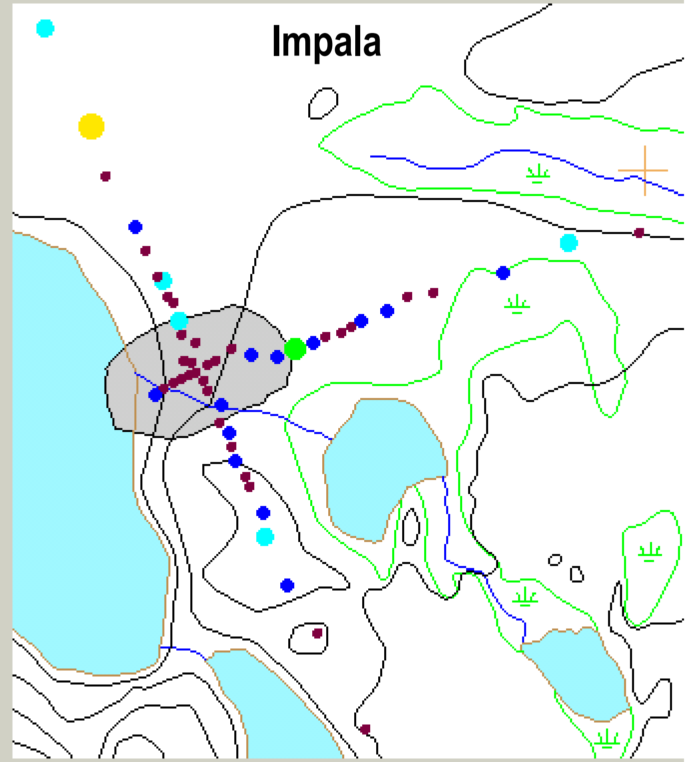


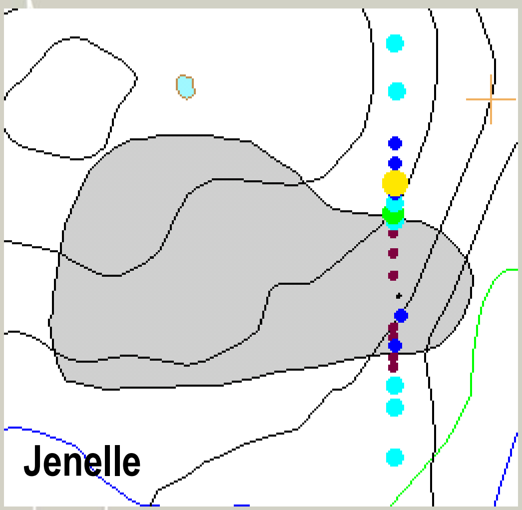


## *Allegro - Till: Factor-2*

- f2+10 > 0.00000 and <= 8.57276 (1 %ile)
- f2+10 > 8.57276 and <= 9.55716 (40 %ile)
- f2+10 > 9.55716 and <= 9.85842 (60 %ile)
- f2+10 > 9.85842 and <= 10.34560 (80 %ile)
- f2+10 > 10.34560 and <= 11.16905 (90 %ile)
- f2+10 > 11.16905 and <= 12.04680 (95 %ile)
- f2+10 > 12.04680 and <= 13.44473 (98 %ile)
- f2+10 > 13.44473 and <= 13.64386 (99 %ile)
- f2+10 > 13.64386 (99 %ile)

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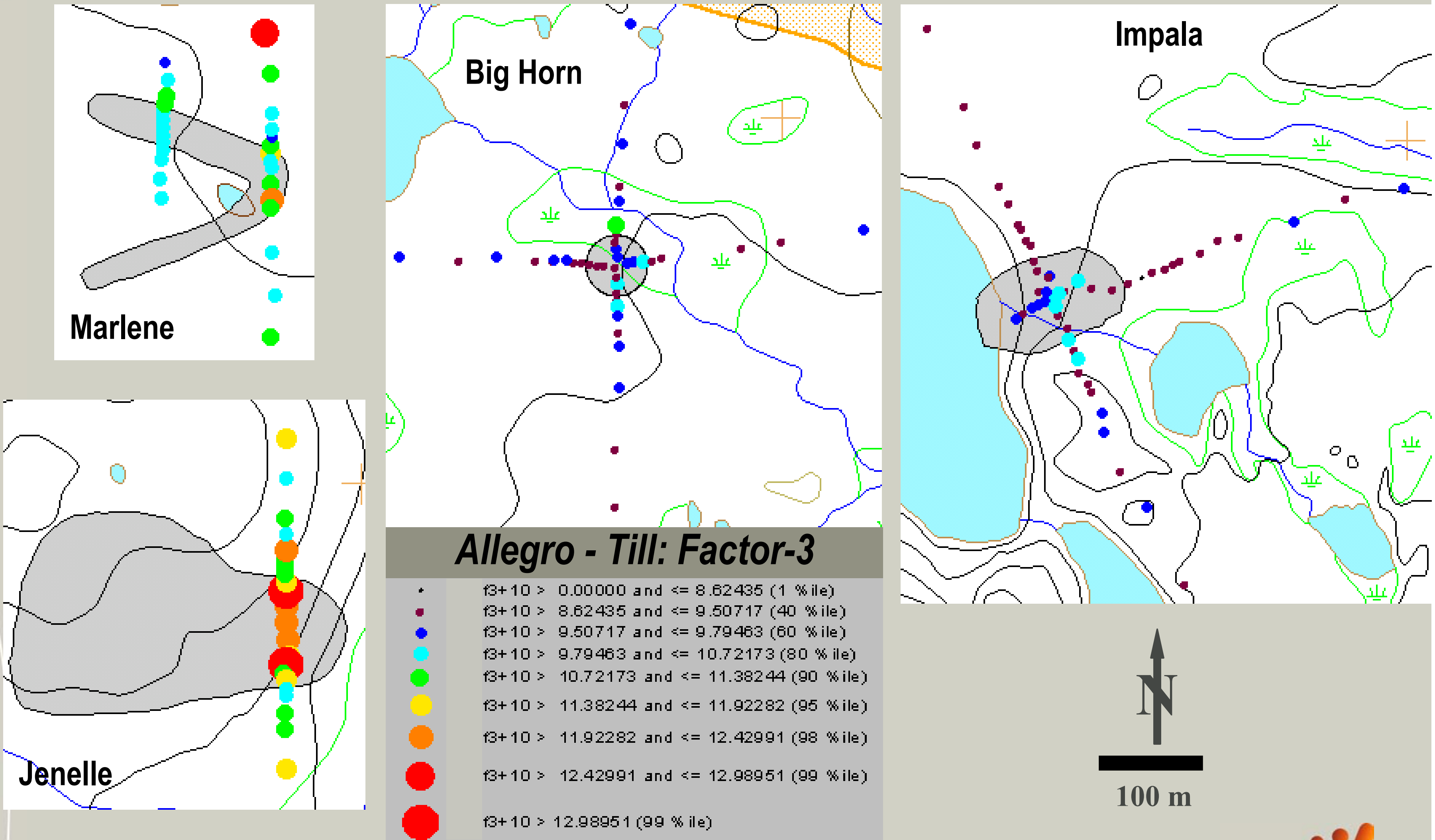




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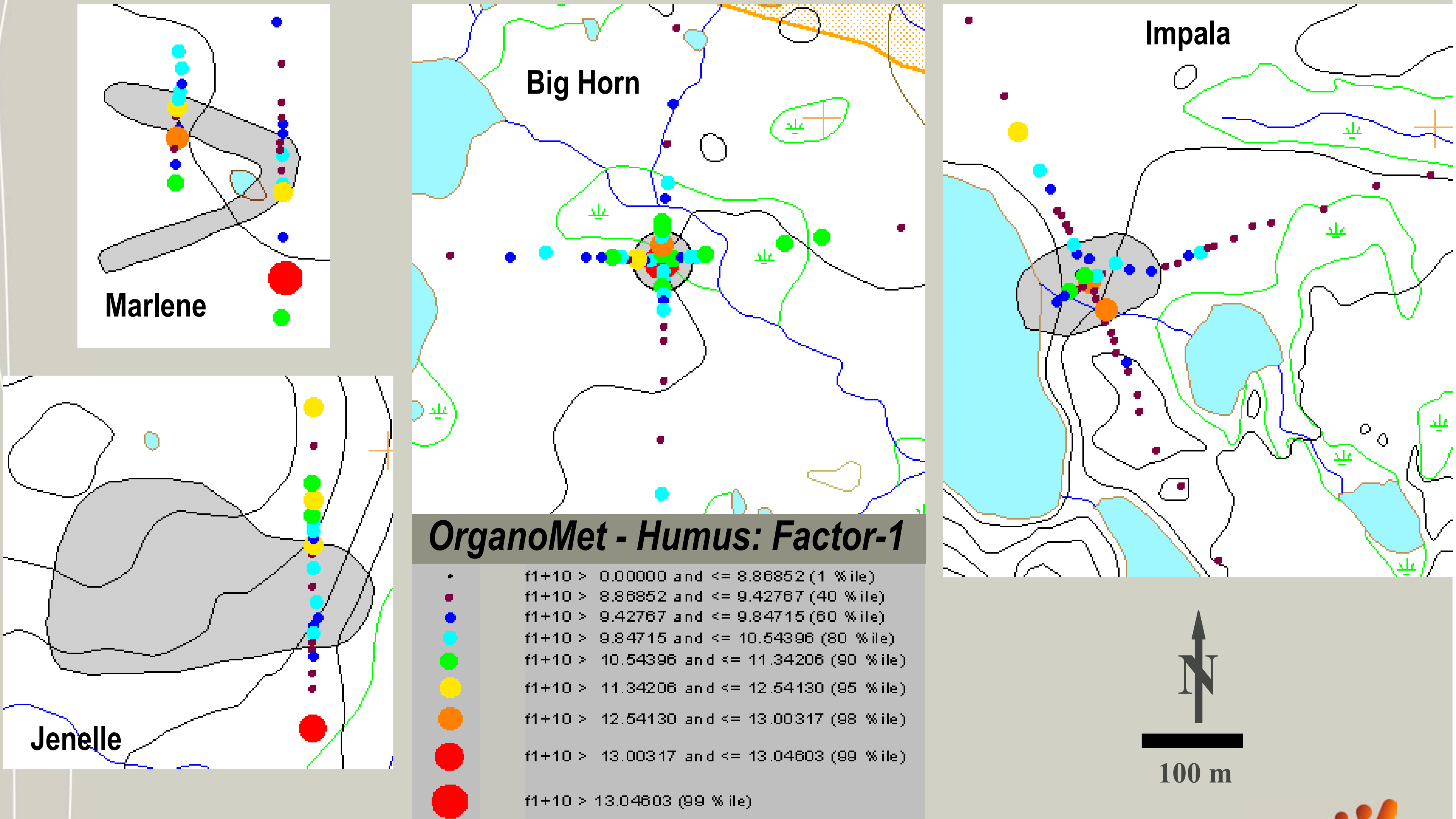
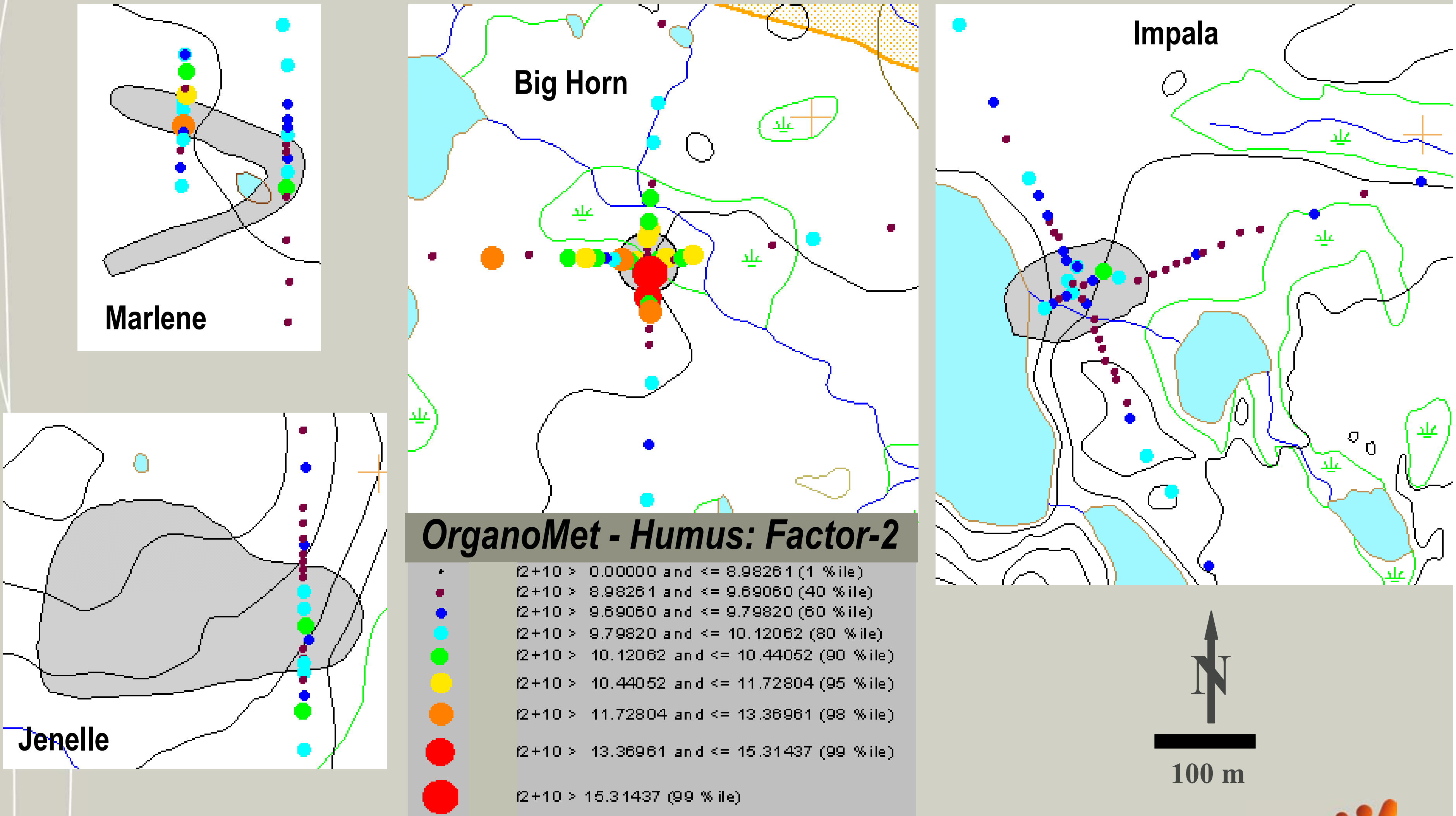


# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview



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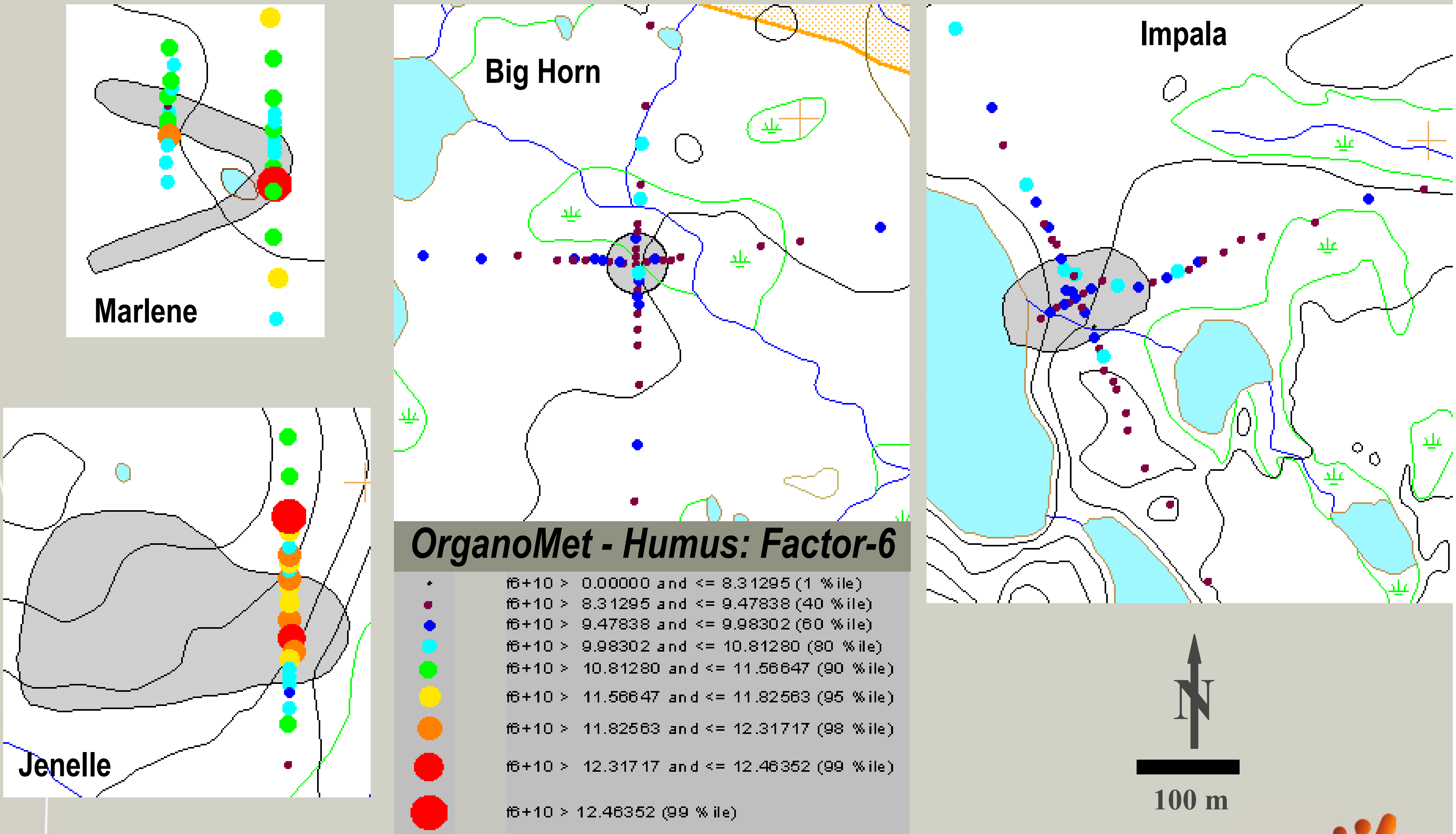




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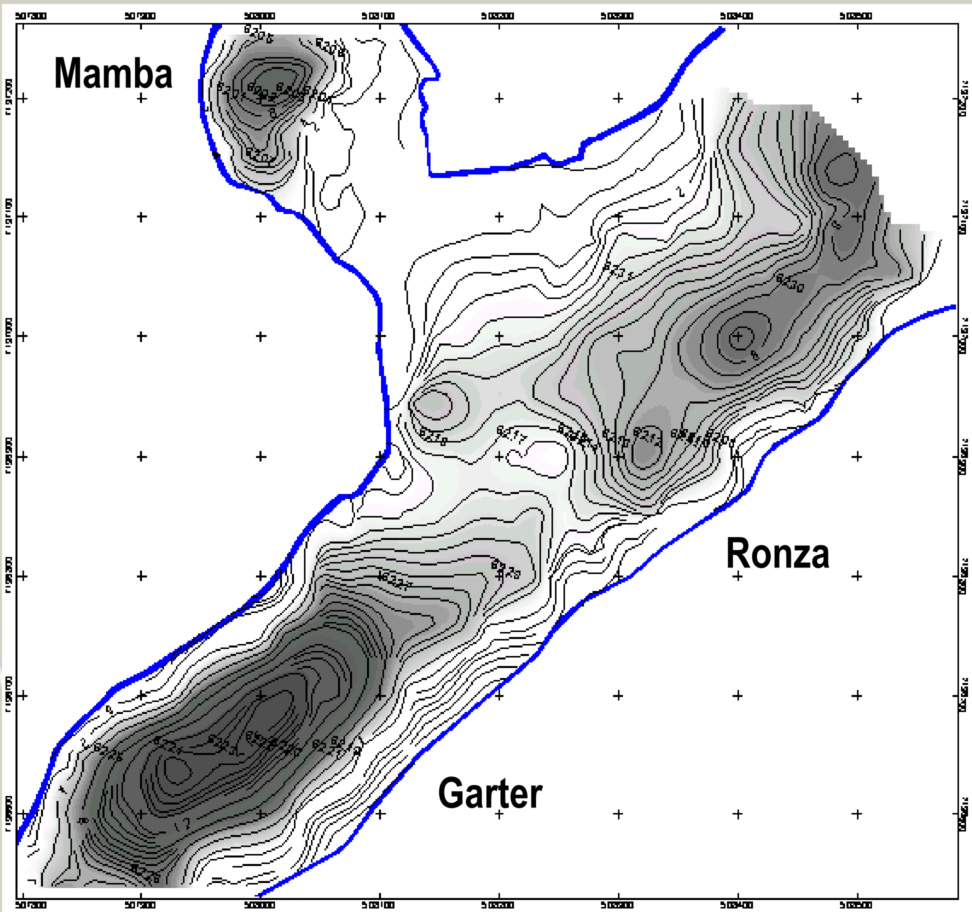
# Lakes:

## Bathymetry

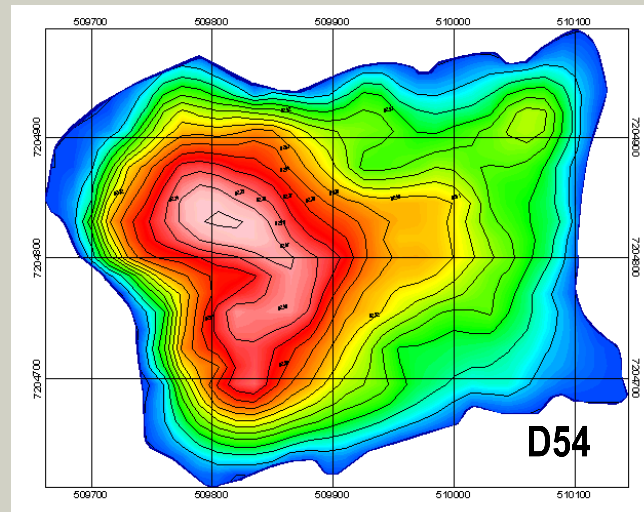
## Geophysical Expressions

## Geochemical Expressions

# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview




## Bathymetry

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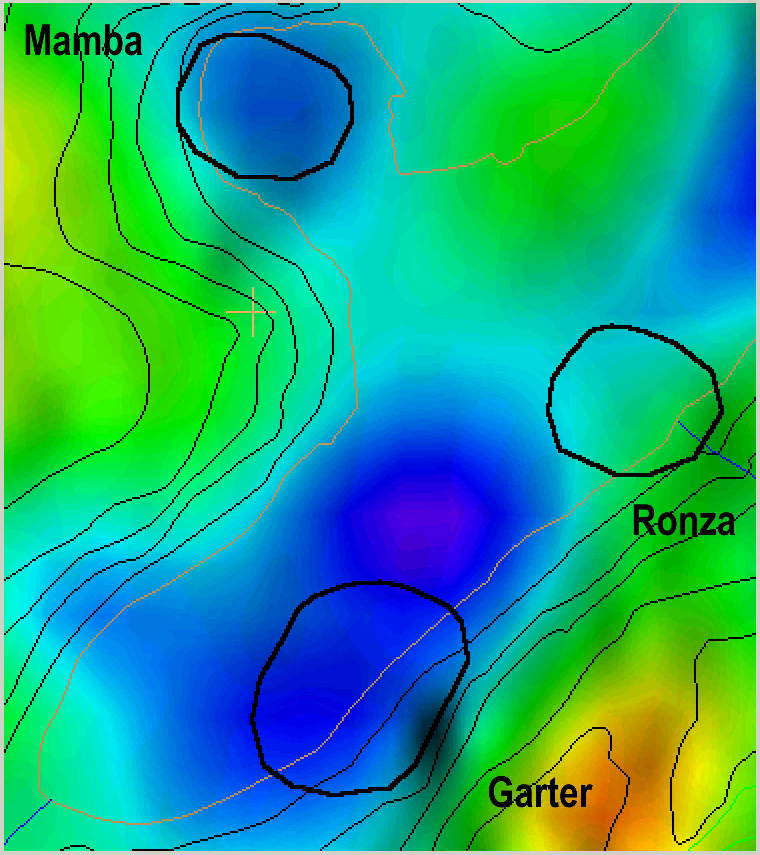
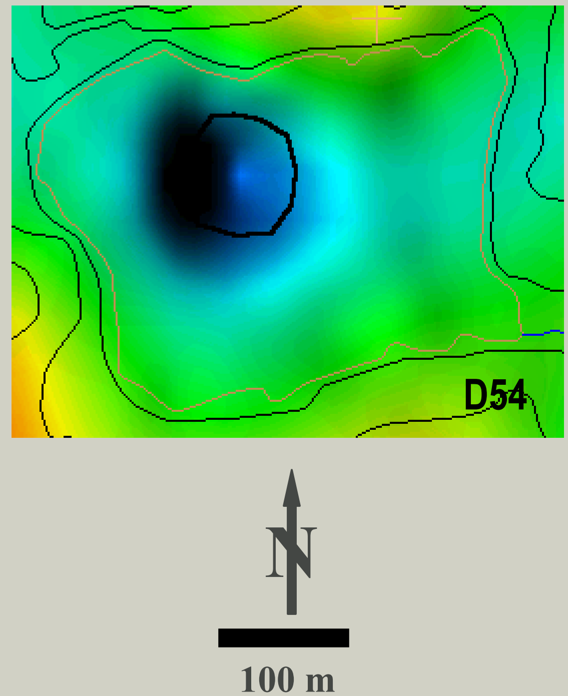



## Geophysics:

## Gravity Colour Drape on Magnetics



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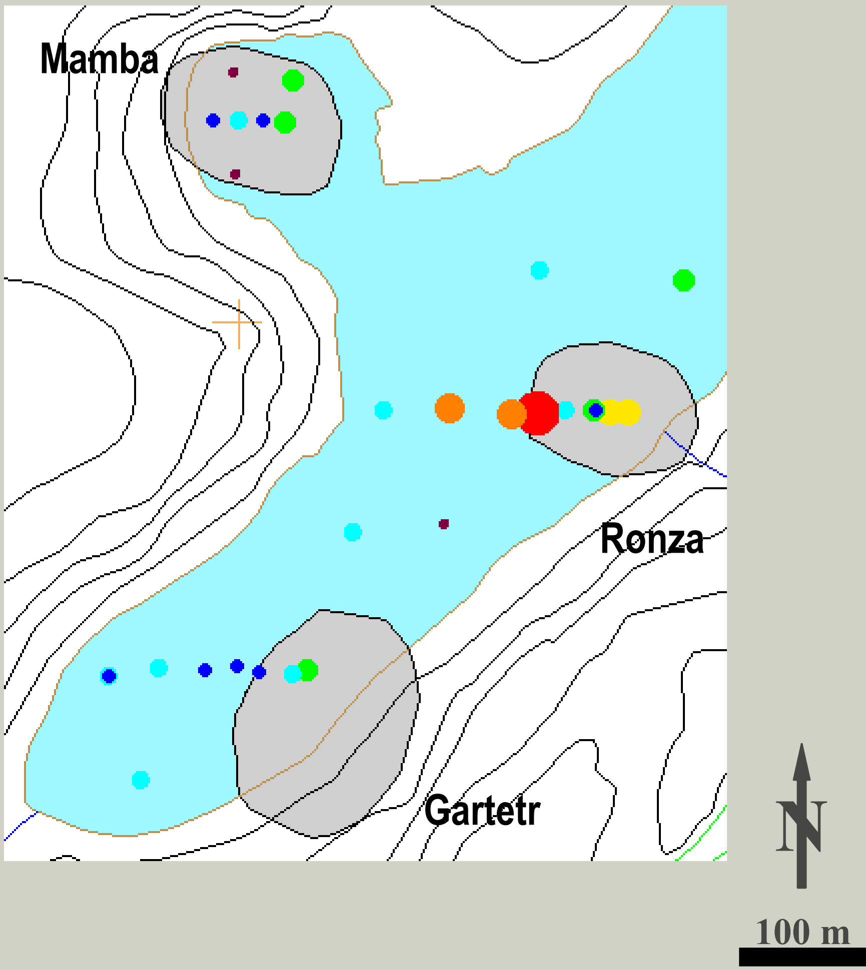
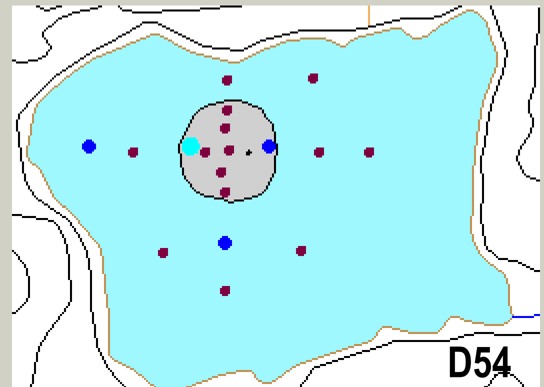
# *Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview*




## *Lake Sediments: Factor-1*

- f1+10 > 0.000 and <= 8.120 (1 %ile)
- f1+10 > 8.120 and <= 9.764 (40 %ile)
- f1+10 > 9.764 and <= 10.109 (60 %ile)
- f1+10 > 10.109 and <= 10.583 (80 %ile)
- f1+10 > 10.583 and <= 11.236 (90 %ile)
- f1+10 > 11.236 and <= 11.699 (95 %ile)
- f1+10 > 11.699 and <= 12.185 (98 %ile)
- f1+10 > 12.185 and <= 12.692 (99 %ile)
- f1+10 > 12.692 (99 %ile)

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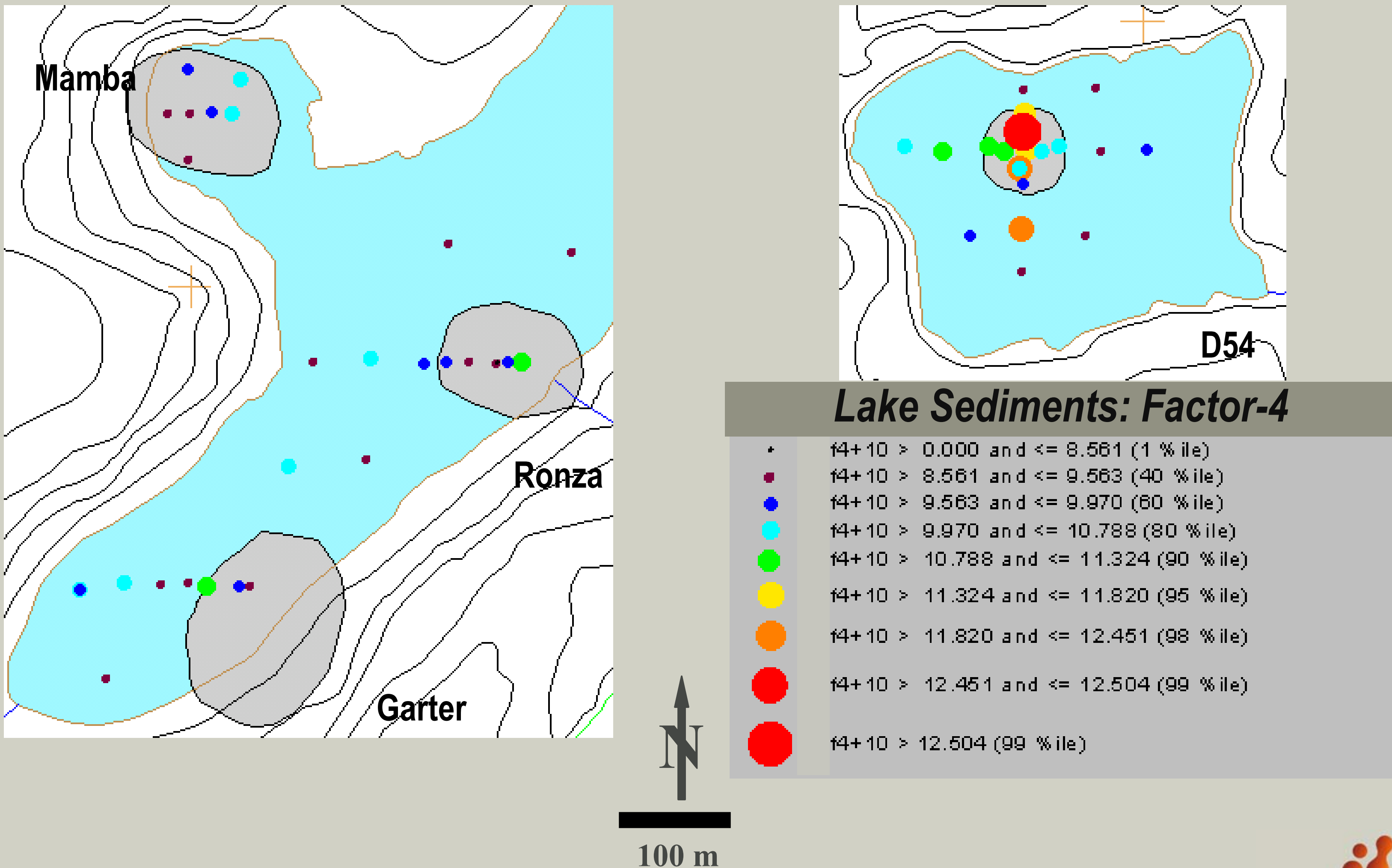




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## Conclusions and Recommendations

There is a distinct geochemical expression in soils/tills and lake sediments over kimberlite pipes compared to other geological and/or geophysical targets in the northern environment around the Ekati area, NWT, Canada. Surficial geochemistry can be effective for prioritization and discrimination of geological and/or geophysical expressions which are variably related to kimberlites, mafic bodies, metasedimentary units, etc..

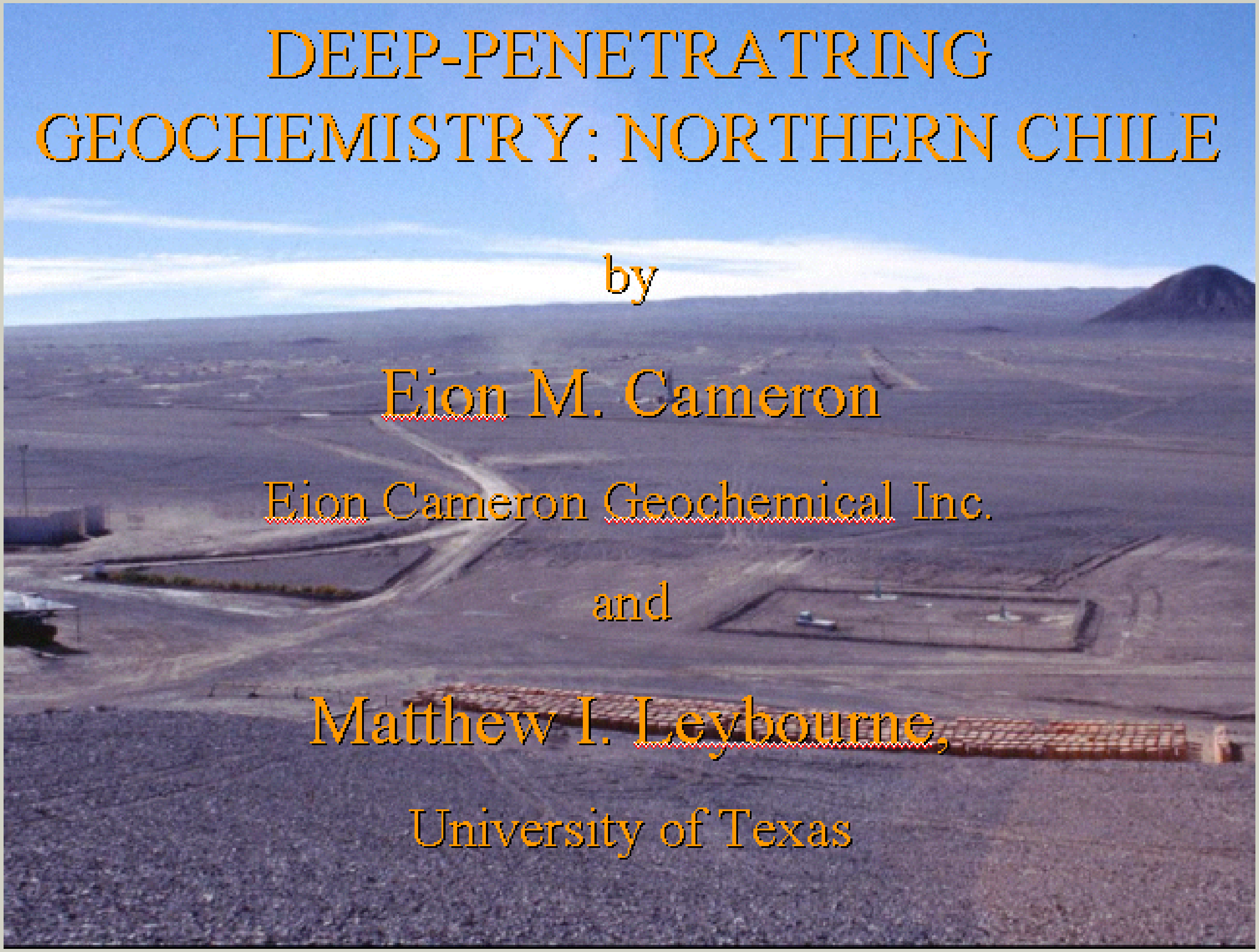
# Talks and Posters:

# On the

# Application of Deep Penetrating Geochemical Techniques

# In Glaciated Terrains

# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview



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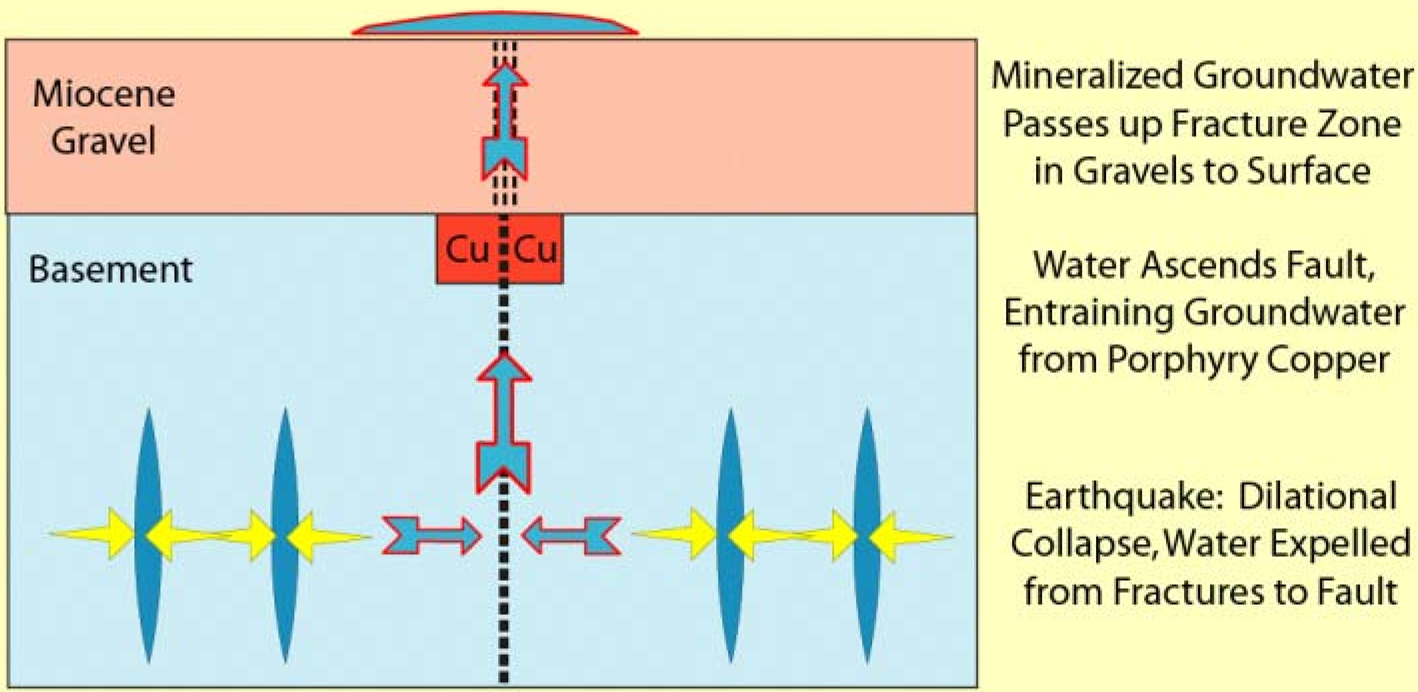
## Surface Flooding by Seismic Pumping



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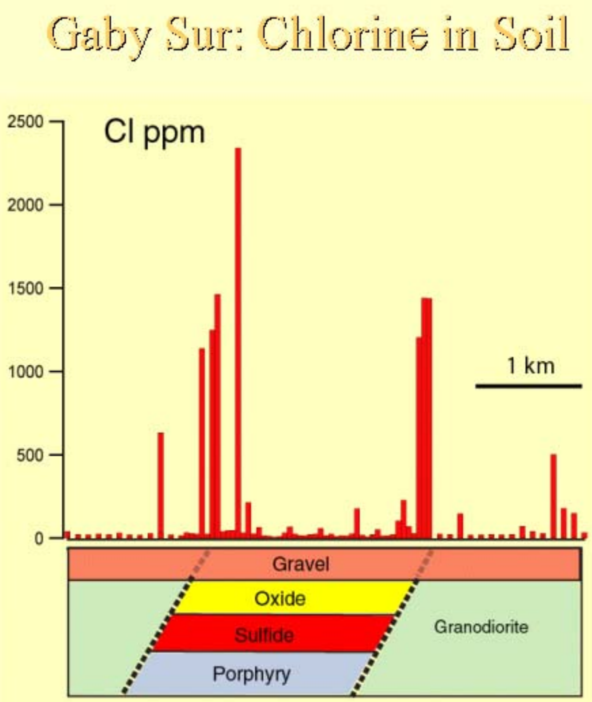


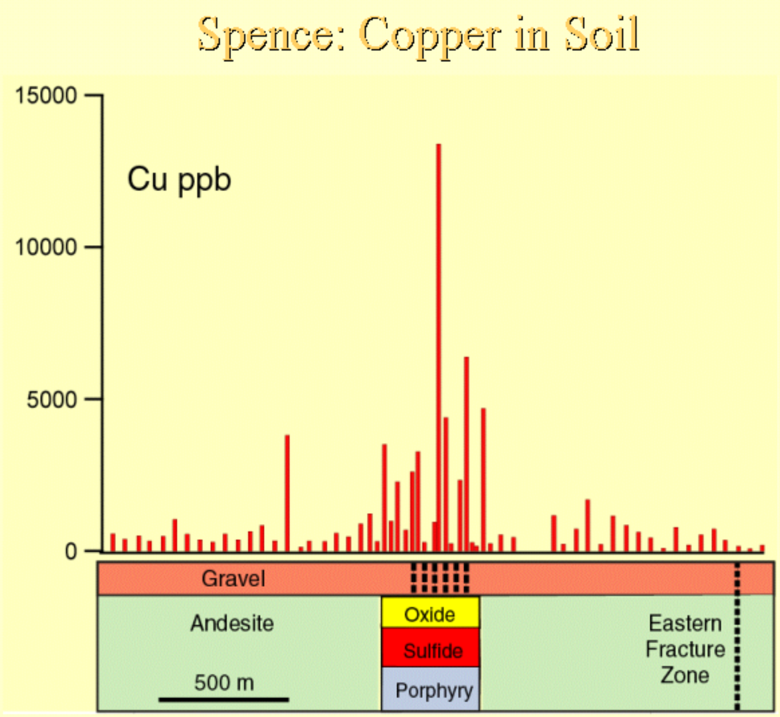




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# Electrochemical Transport of Metals Due to Redox Gradients: Highly Predictive and Somewhat Problematic

## - But Whose Problem Is It ?


Stewart Hamilton (Ontario Geological Survey)

Gwendy Hall (Geological Survey of Canada)

Beth McClenaghan (Geological Survey of Canada)

Eion Cameron (Eion Cameron Geochemical)

Keiko Hattori (University of Ottawa)


Ontario Geological Survey

OMET

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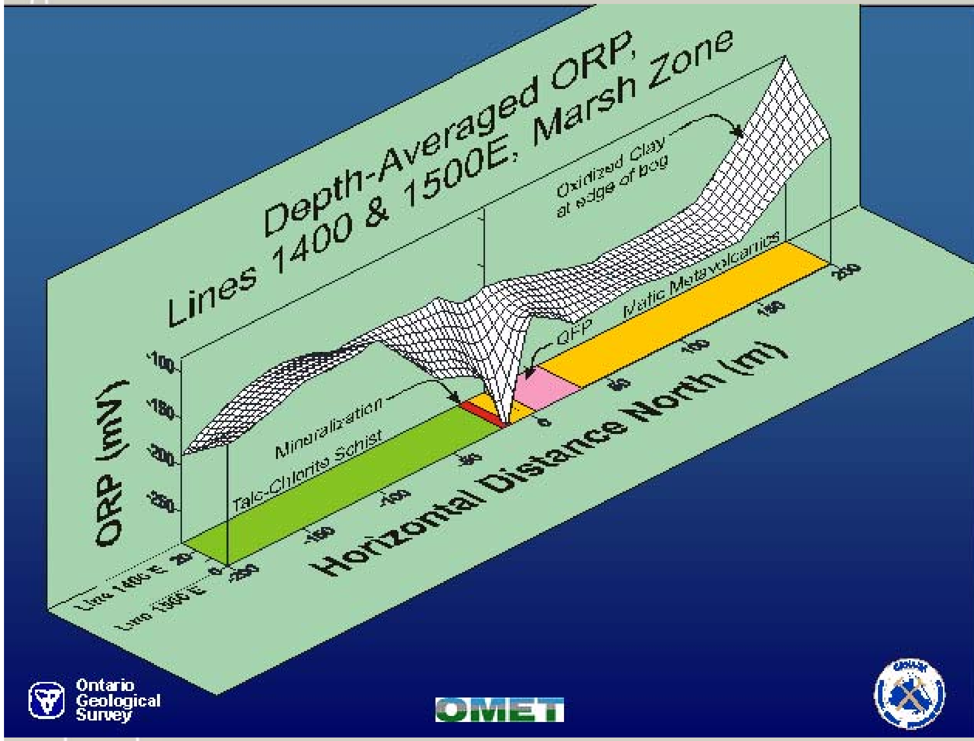


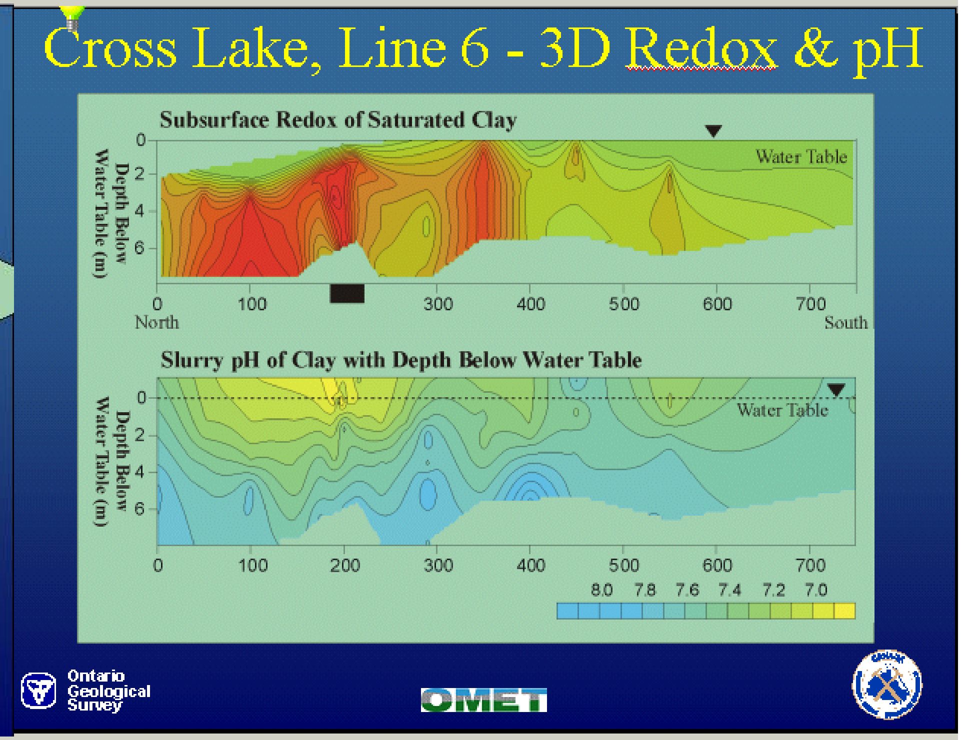




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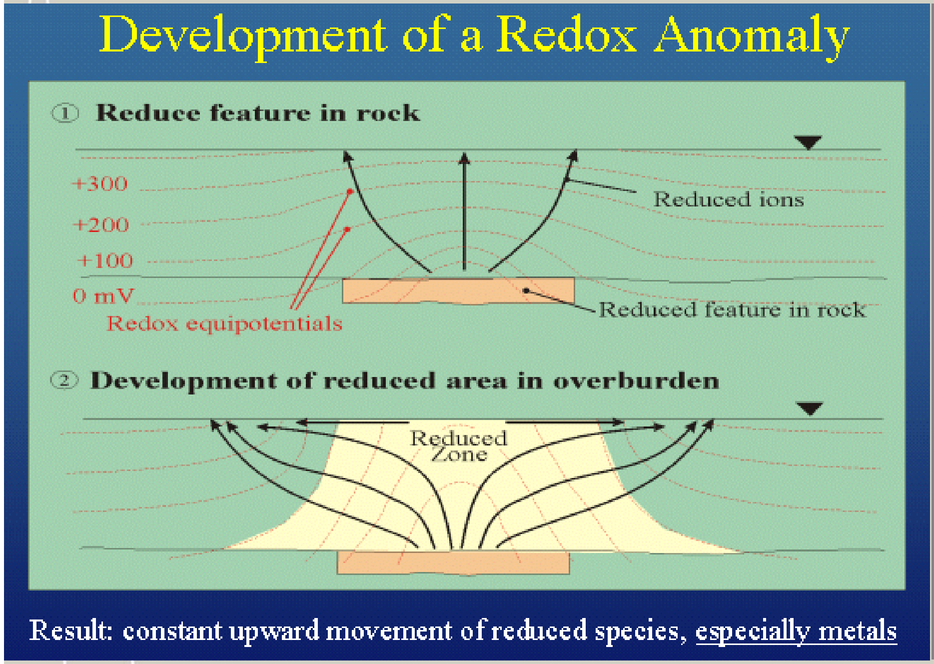


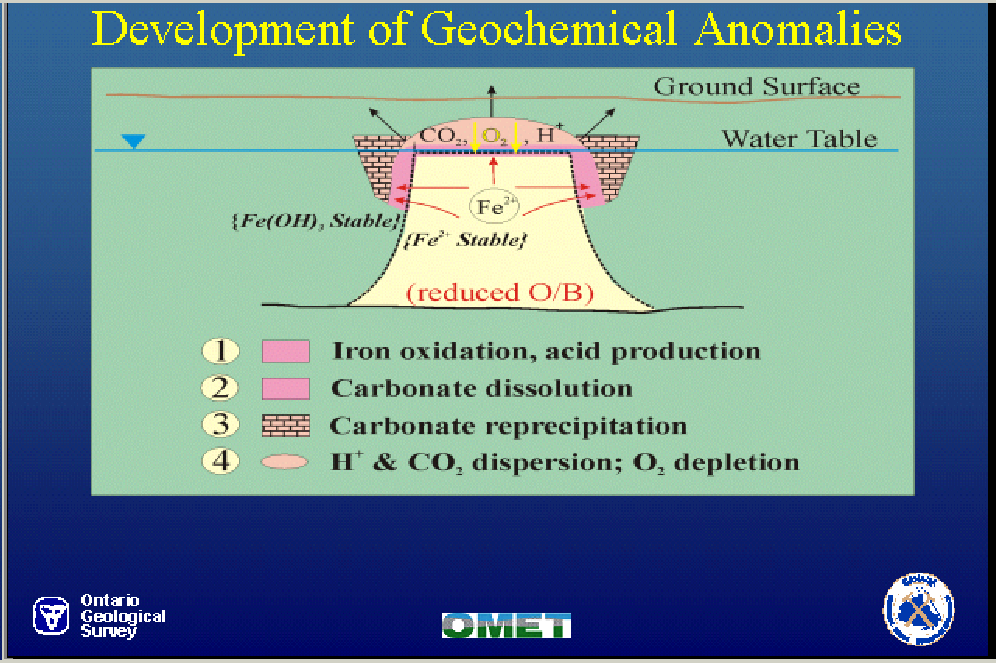

# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview

**"SEEING THROUGH THICK GLACIAL OVERBURDEN WITH GEOCHEMISTRY"**

Gwendy Hall (GSC)
Beth McClenaghan (GSC)
Stew Hamilton (OGS)
Eion Cameron (EC Geochemical Inc.)
Bahram Daneshfar (Ottawa U)

funded by
OMET (Ontario Mineral Exploration Technology Pgm),
GSC and OGS

**Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview**

# Location in the Abitibi Greenstone Belt




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# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview

## "3D Geochemistry in the Abitibi: Development of Geochemical Exploration Methods"

- Builds on previous work under Camiro's DPG project (Eion Cameron) by examining in 3D geochemical signatures in soil, overburden, groundwater and gaseous media to identify:
  - (1) element migration pathways to surface,
  - (2) resident sites of these hitherto labile elements,
  - (3) those elements redistributed by acidic 'low'
  - (4) optimum sampling and analytical methods
- The focus is on the Zn-Cu-Pb VMS Cross Lake deposit and the syenite-hosted Au deposit at Marsh Zone, both east of Timmins, ON, Canada



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# Mechanism for Vertical Ionic Migration

**A.W. Mann, T.F. Foster, D.A. Mann**

MMI Technology,
Perth, Western Australia

# Main Points of Model

- Sulphide oxidation reactions are exothermic
- That heat has to be dissipated
- Density differences will be caused in the saturated water column
- Ions in the water will ascend with the convective flow
- They will then be subjected to the effects of capillary rise above the water table
- Model applies to situations with high water tables and ore-bodies undergoing oxidation

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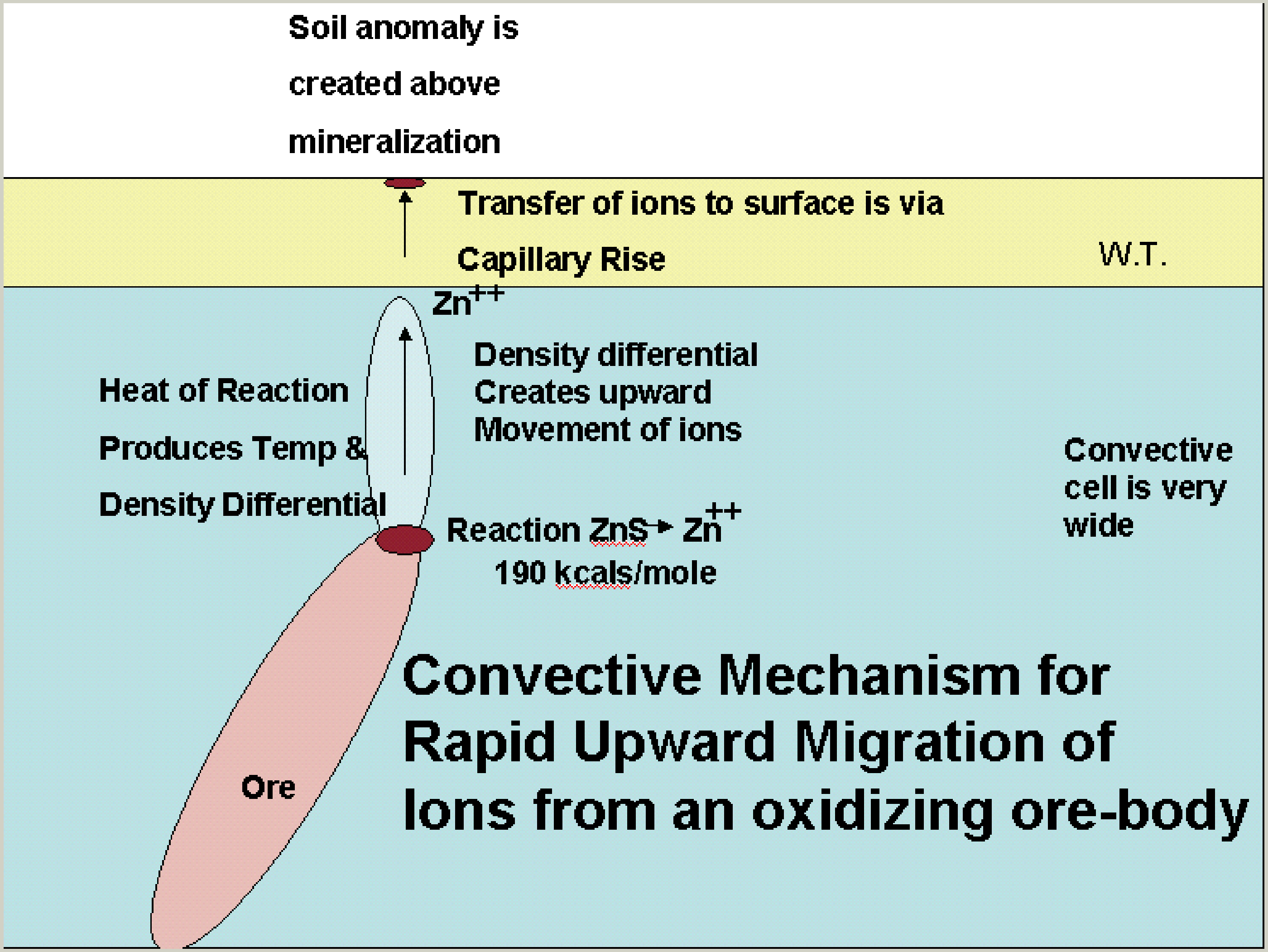




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*Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview*

SDP Pty Ltd

Soil-Gas Geochemistry

# Detection of Concealed Kimberlites: A Preliminary Evaluation of SDP Soil Gas Geochemistry


D.S.Thiede

W.B.Coker

S.J.Windle


21st IGES, Dublin
August 2003



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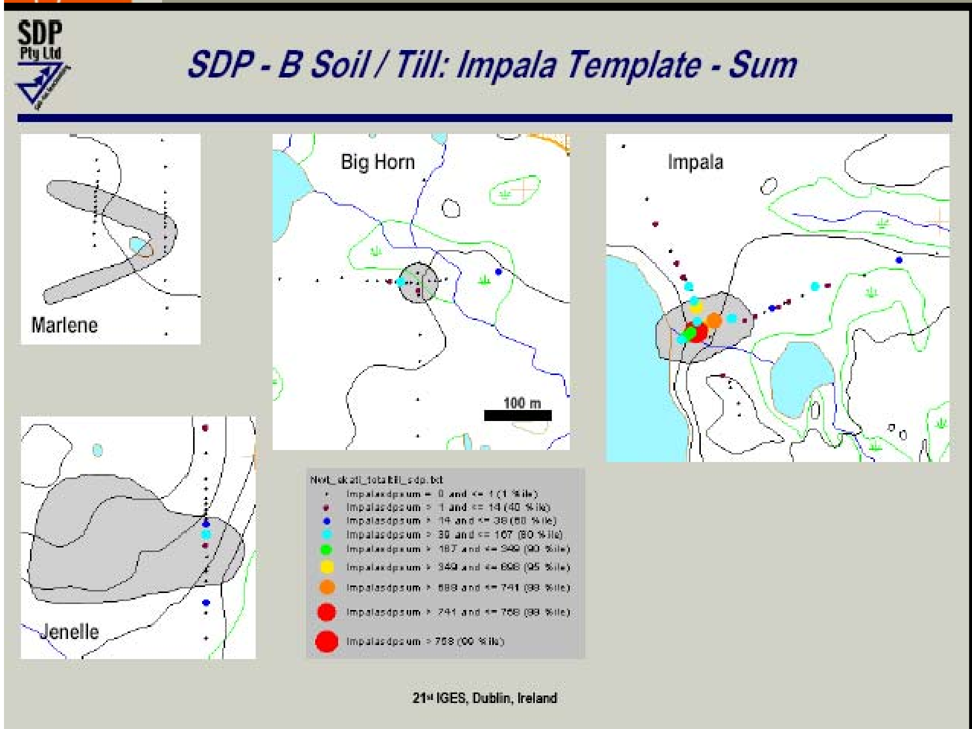


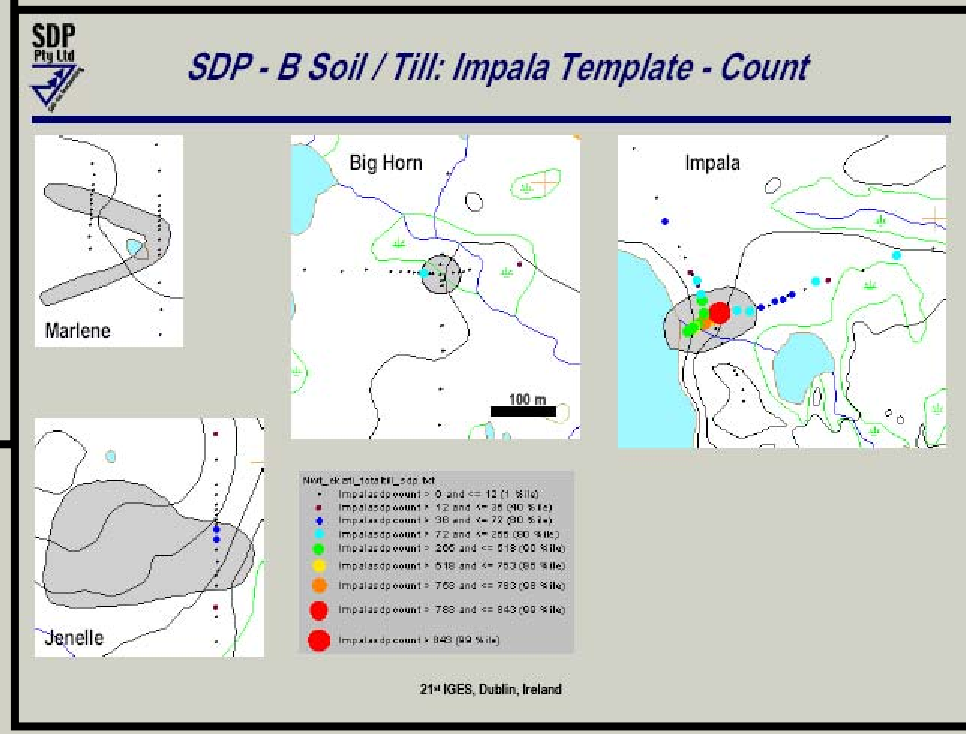

SDP Pty Ltd

## SDP - B Soil / Till: Summary

SDP data give a clear response over and somewhat peripheral to Impala which clearly distinguishes this kimberlite pipe from all of the other bodies studied.

There is no response at Big Horn, Marlene or Jenelle.

This technique definitely shows promise for discrimination of kimberlite pipes from other types of geophysical and/or geological features. However, there needs to be some further study of the situation at Big Horn.





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# Crandon Orientation

Highsmith, Jaacks, Closs, Klusman

- Proterozoic Ladysmith-Rhinelander Volcanic Complex: Flambeau and Lynne Deposits
- Early Proterozoic Zn-Cu VMS Deposit
- 65MT at 5.8% Zn and 1.4% Cu
- Lower Greenschist Facies Metamorphism
- Temperate Forest Environment
- Subcrops beneath 100-200 feet of mixed glacial deposits



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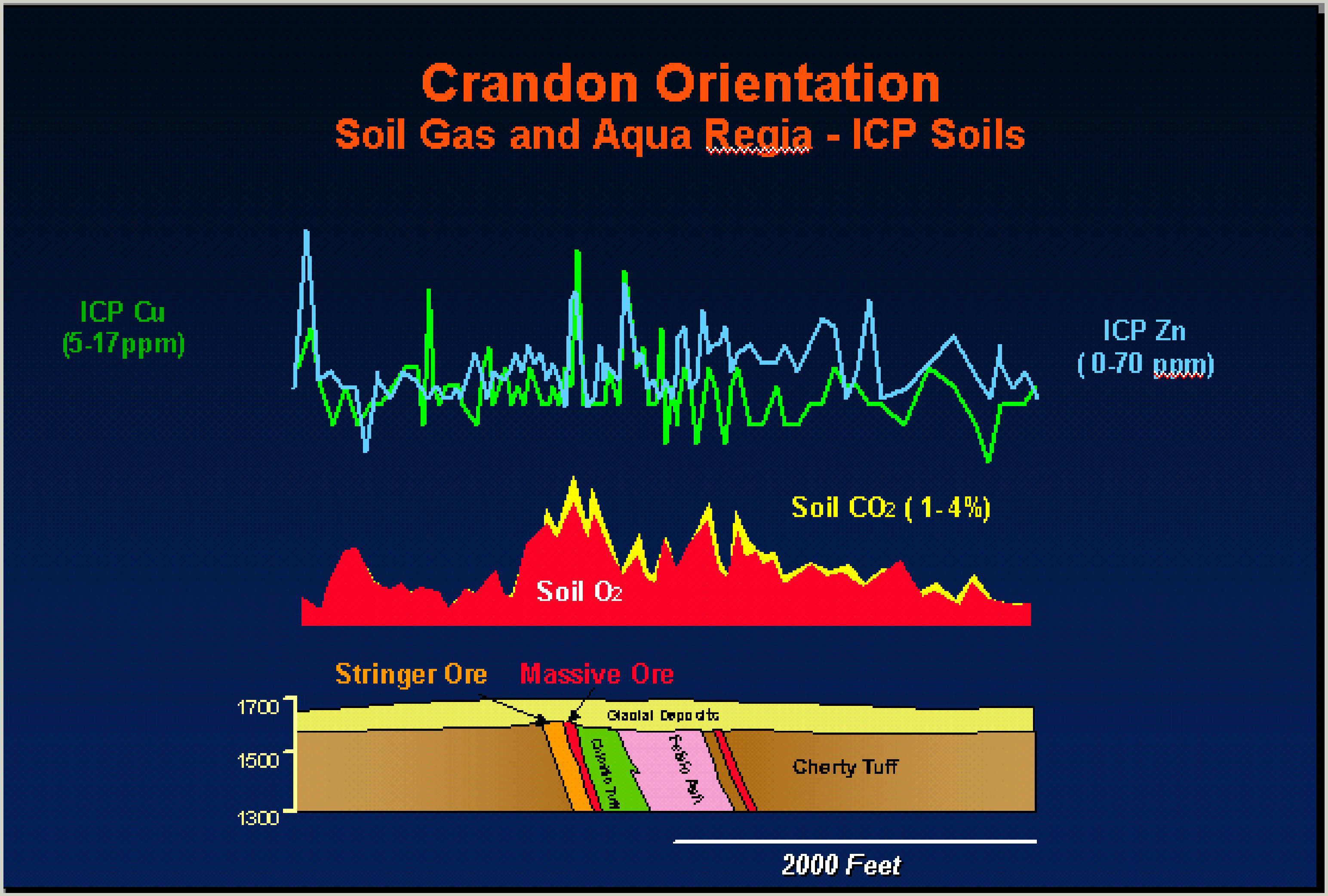




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## Crandon Orientation Results

- $CO_2$ and $O_2$ anomalies over mineralization
- Weak soil anomalies
- Gas and soil anomalies coincident
- $CO_2$ and $O_2$ discriminates conductor types
- Soil gas – inexpensive and effective

# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview

TILL GEOCHEMISTRY AT THE CLEAR LAKE SEDIMENTARY EXHALATIVE DEPOSIT,
Yukon Territory, Canada

W.K. Fletcher, J. D. Bond and A. Plouffe
Department of Earth and Ocean Sciences, University of British Columbia

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Fig. 1 Aqua regia lead and zinc

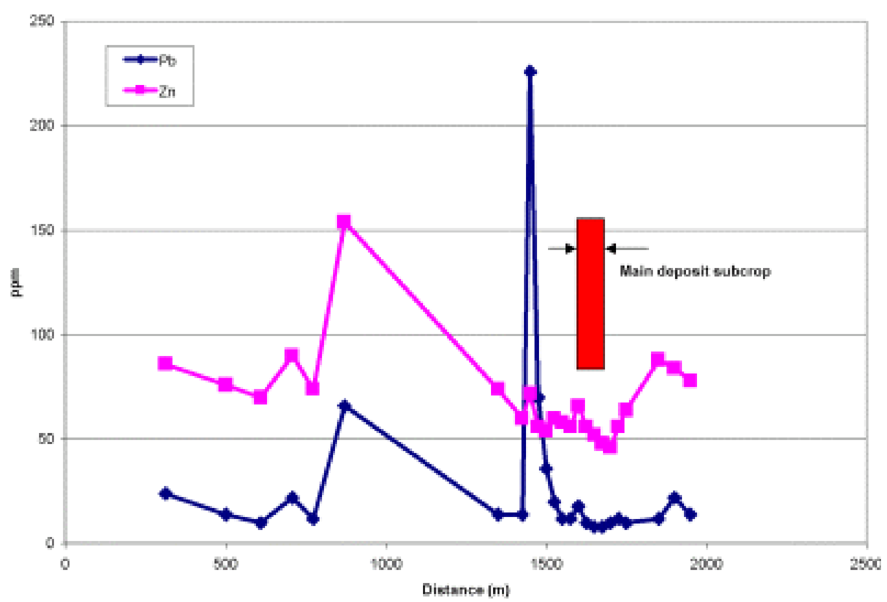
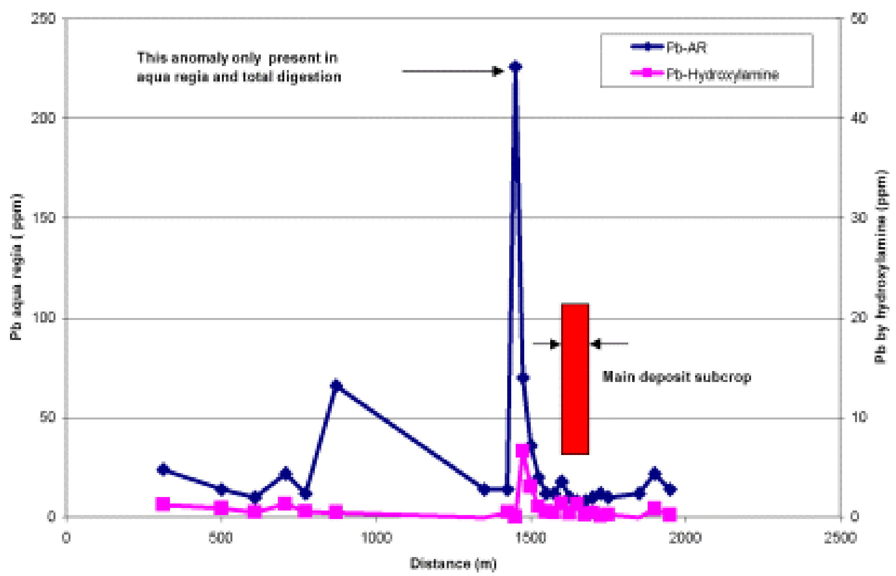



Fig. 2. Pb by aqua regia & hydroxylamine



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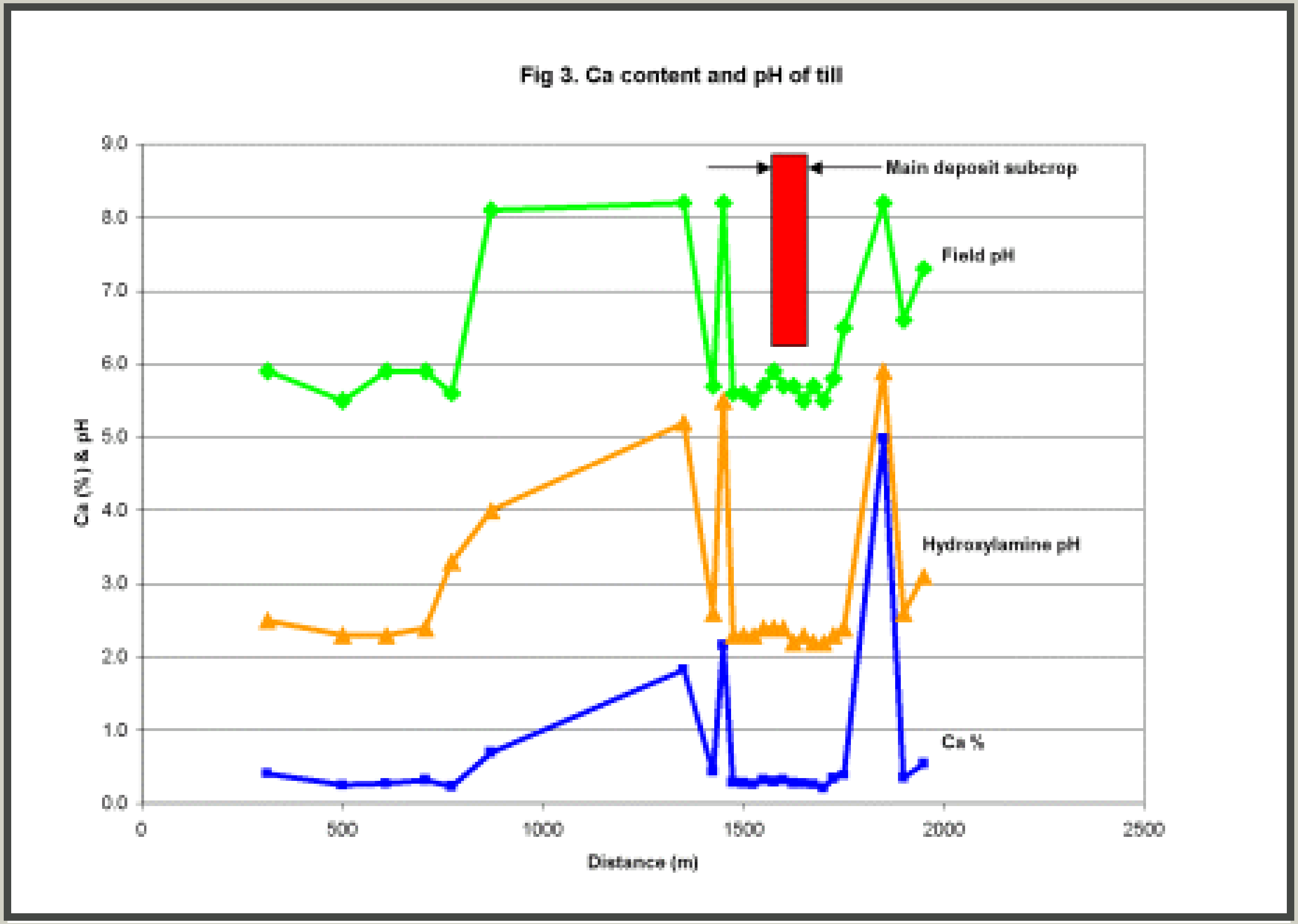




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## Application of the Mobile Metal Ion process for exploration in areas of thick overburden: a Canadian perspective.

Hugh de Souza[1] , Alan W. Mann[2], Cris Dragusanu[1]

[1]SGS Minerals Services, 1885 Leslie Street, Toronto

[2]Geochemistry Research Centre, Perth, Australia

WHEN YOU NEED TO BE SURE

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## The MMI Process

- Weak non-specific extraction that targets mobile metals ions related to mineralization.
- Controls re-adsorption for consistent measurement of low level abundances typical in glaciated terrains
- Sampling at constant depth of 15-20 cm depth or at peat/ sediment interface is critical in identifying anomalous zones

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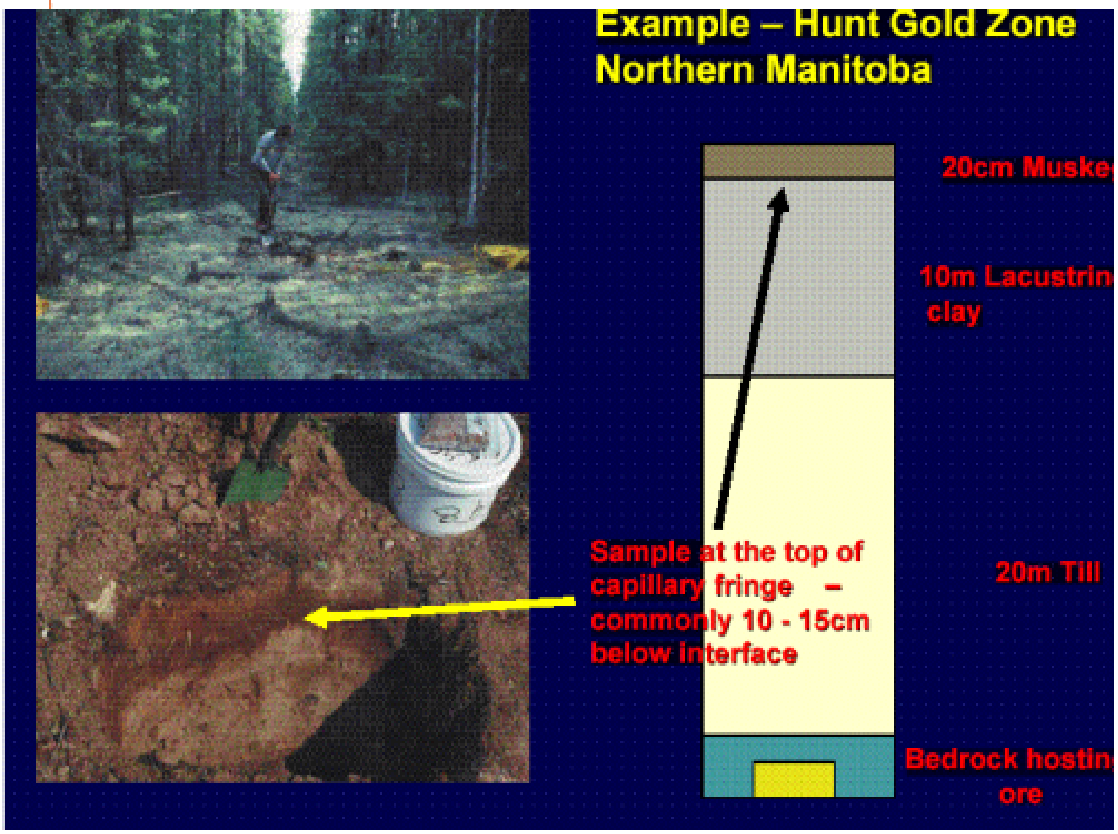


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# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview

## On-Site Selective Leach Geochemistry

Dr Robert Ellis, GEDEX, Mississauga, Canada

Step 1 : Orientation sampling

Step 2 : Analysis by Site-Portable ICP-MS

Step 3 : Data review

Step 4 : Follow-up sampling & further methods

2 – 3 days per cycle

- Deliver samples to on-site lab for overnight turnaround
- Use data to define further sampling while crew is in place
- Multiple, user defined methods with ICP-MS finish
- Make fast, accurate, detailed studies

GEDEX

# Modern Geochemical Techniques For Exploration In Glaciated Terrains: An Overview

21st IGES, Dublin, Ireland - Aug. 28th to Sept. 3rd, 2003

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