

Geochemical Modeling

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Geological Survey of Canada
Metals In The Environment

Geochemical Modeling

- To link geochemistry and mineralogy within environmental models

The Project

- Based on a pilot study for the geochemical survey of North America project (with R. Garrett)
- Environmental applications of geoscience models (Environment Canada)

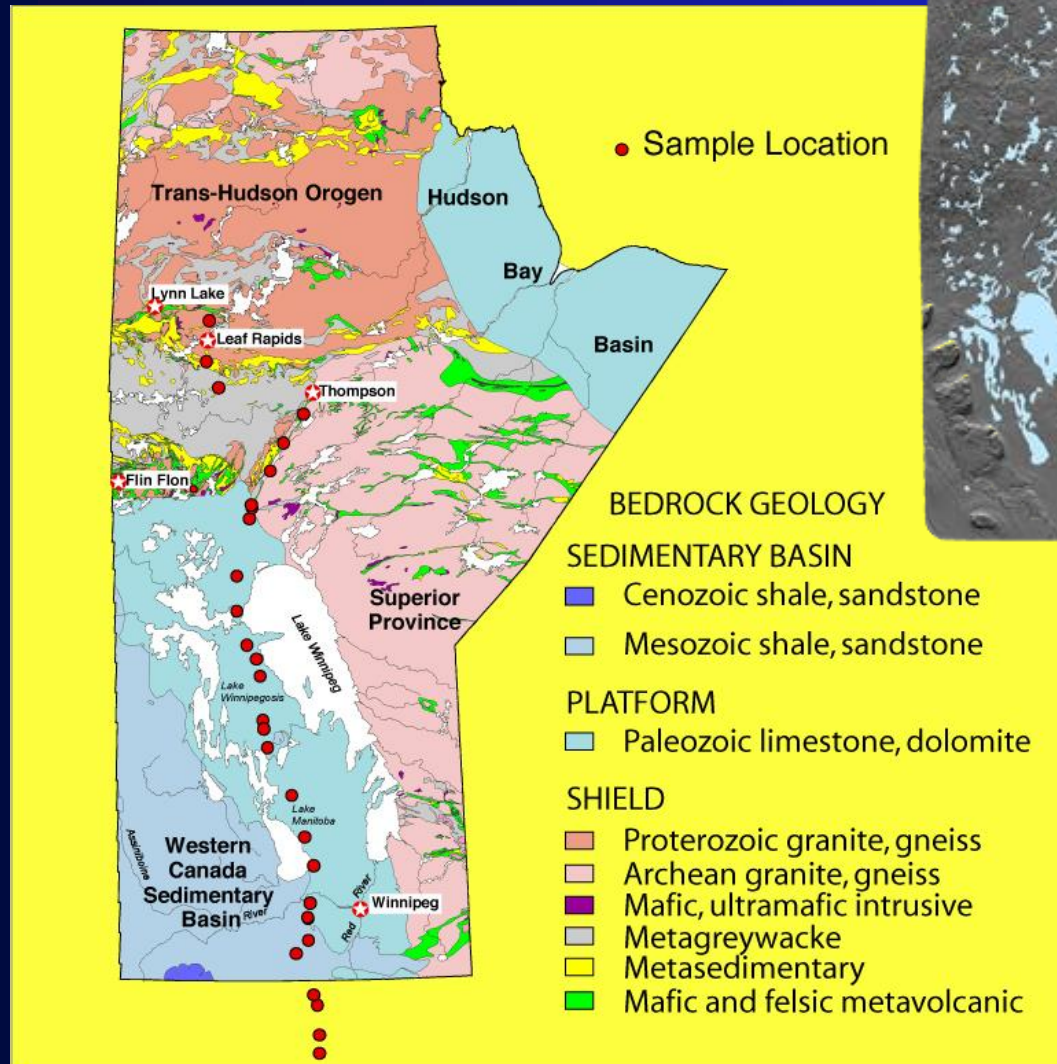
Geological Models

Geochemical and mineralogical **properties** of soil parent materials reflect:

- Provenance – bedrock origins
- Process – physical actions of wind, water, ice
- Protocol – preparation and geochemical analysis methods
- Past – sediment type, depositional environment, stratigraphic associations, geological history

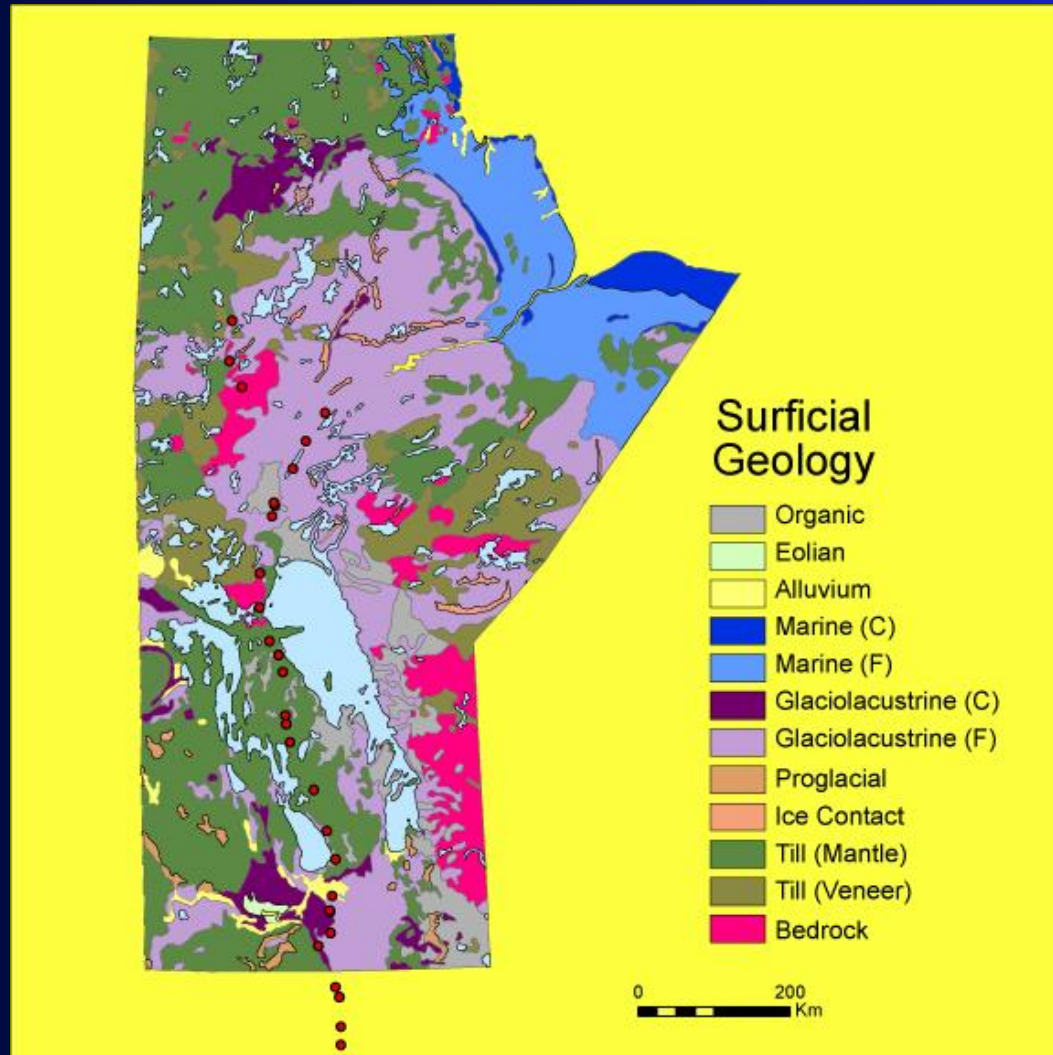
Bedrock Geology

Manitoba



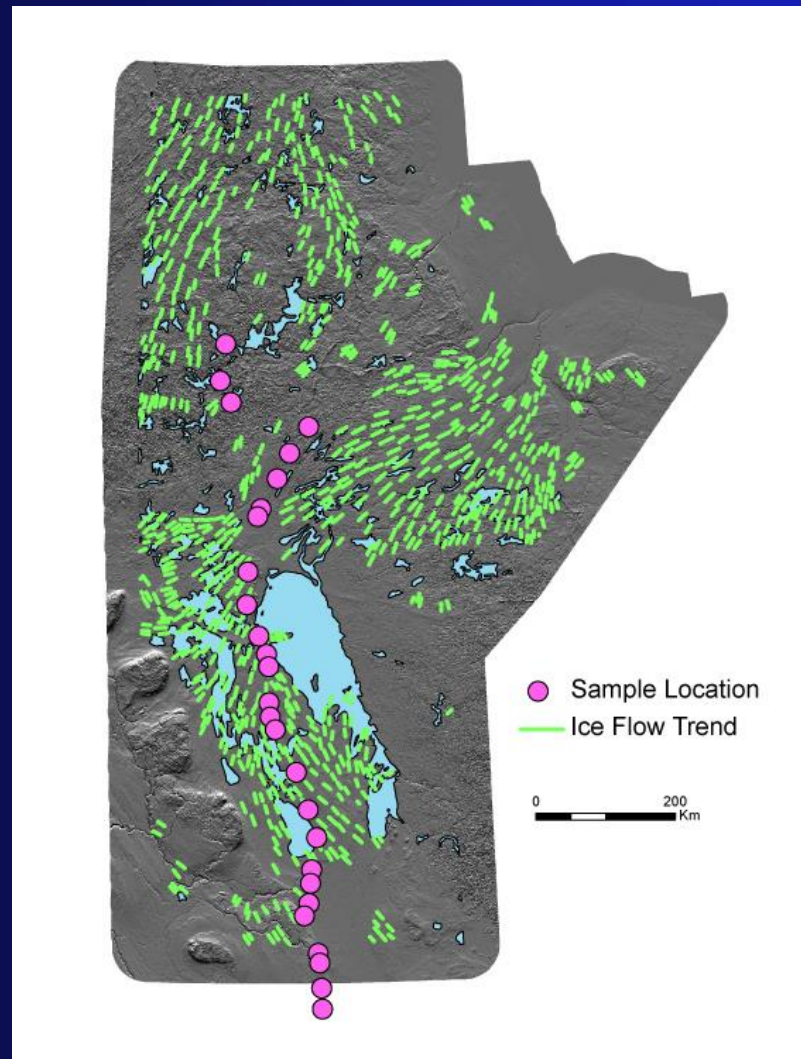
Surficial Geology

Manitoba



Ice Flow History

Manitoba



Surficial Geology – The View

Manitoba



N Glaciolacustrine



Pas Moraine



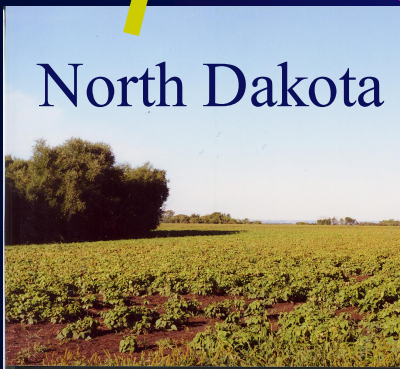
Legend:

- Proglacial
- Marine (C)
- Marine (F)
- Glaciolacustrine (C)
- Proglacial
- Ice Contact
- Till (Mantle)



Interlake Till

North Dakota



S Glaciolacustrine

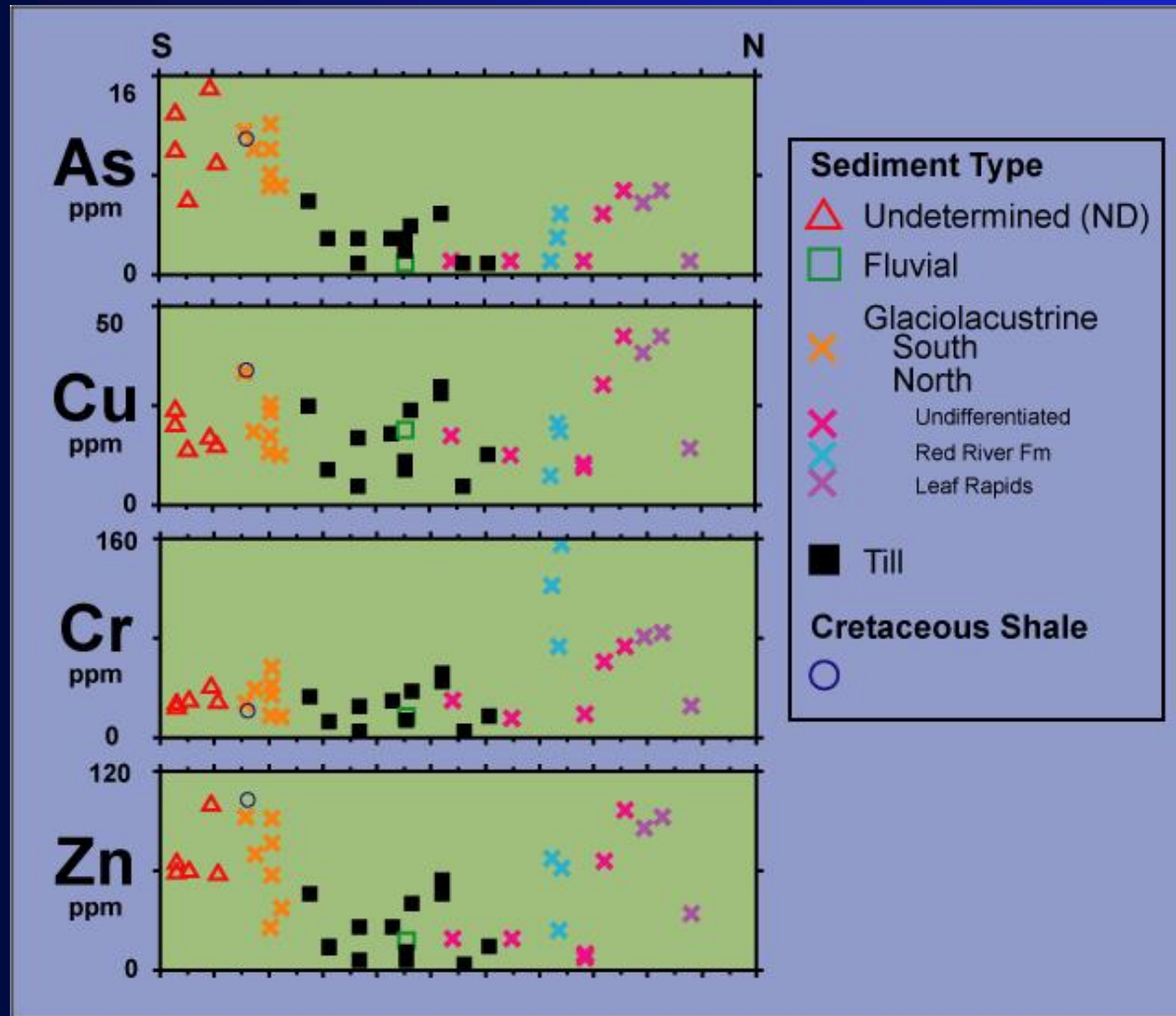


Analysis Schedule

Analysis	<0.002 mm	<0.063 mm	<2 mm
<i>Organic C</i>		●	●
<i>Inorganic C</i>		●	●
<i>LOI</i>		●	
<i>Total</i>		●	●
<i>Strong Acid</i>	●	●	
<i>Partial</i>	●	●	
<i>XRD</i>	●	●	

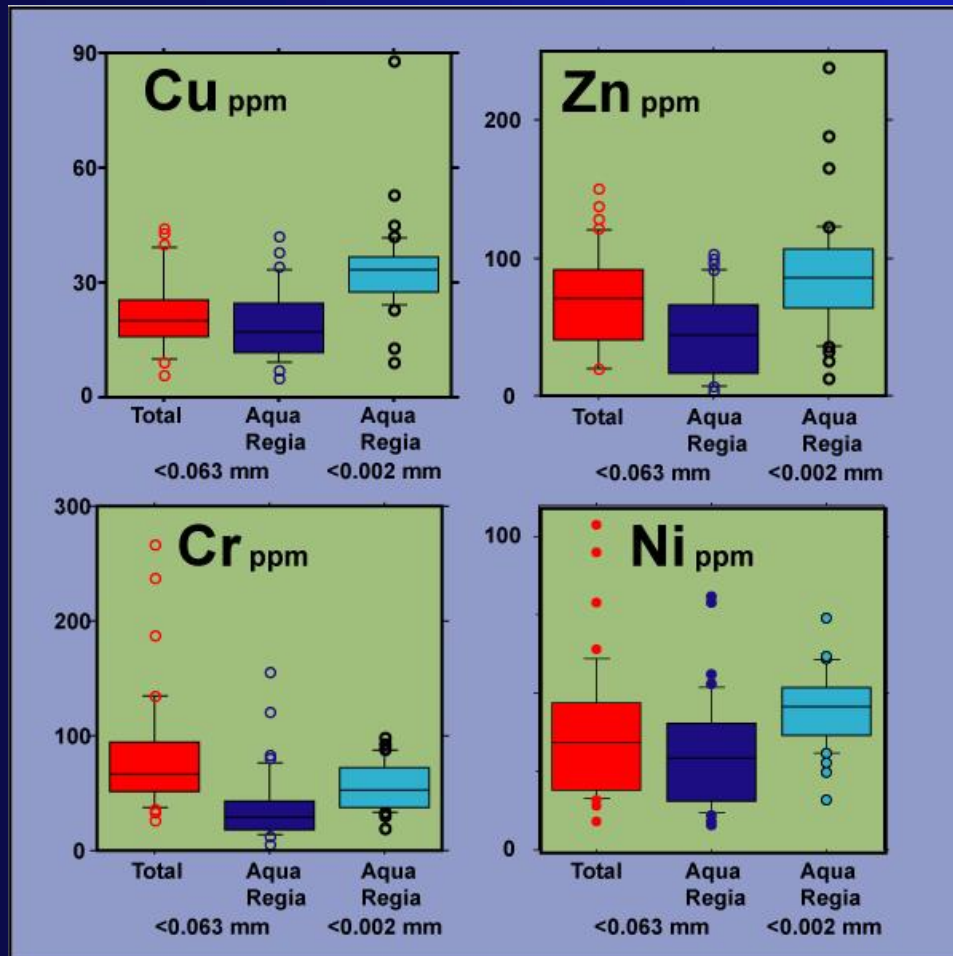
Geochemical Transect Profiles

Trace Elements (Aqua Regia, $\leq 0.063\text{mm}$)



Trace Metals

Preparation and Analytical Protocols



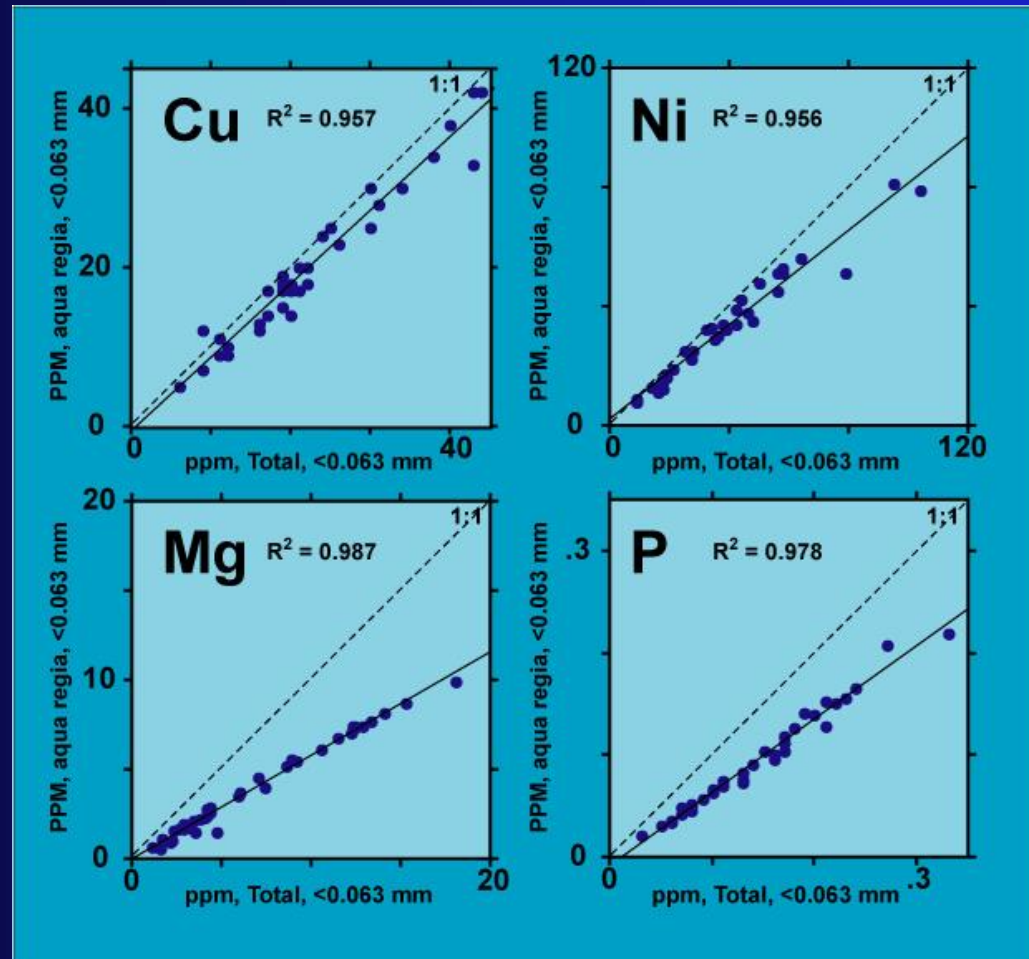
Total vs Aqua Regia Digestion

Linear Correlations

Strong	Partial	None
Ca	Al	Cd
Co	Ba	Na
Cu	Cr	Sb
Fe	K	
La	Sr	
Mg	Ti	
Mn	Zn	
Ni		
P		

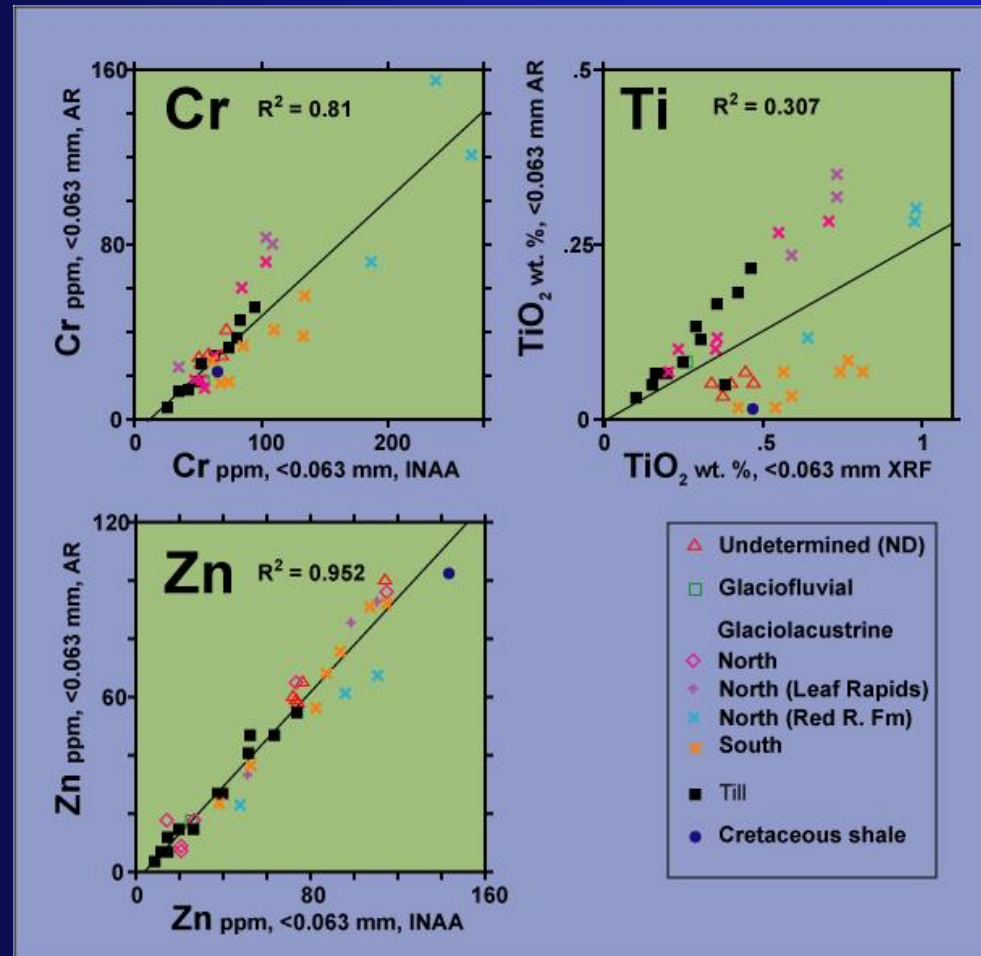
Aqua Regia Vs 'Total'

Correlation – Provenance Independent



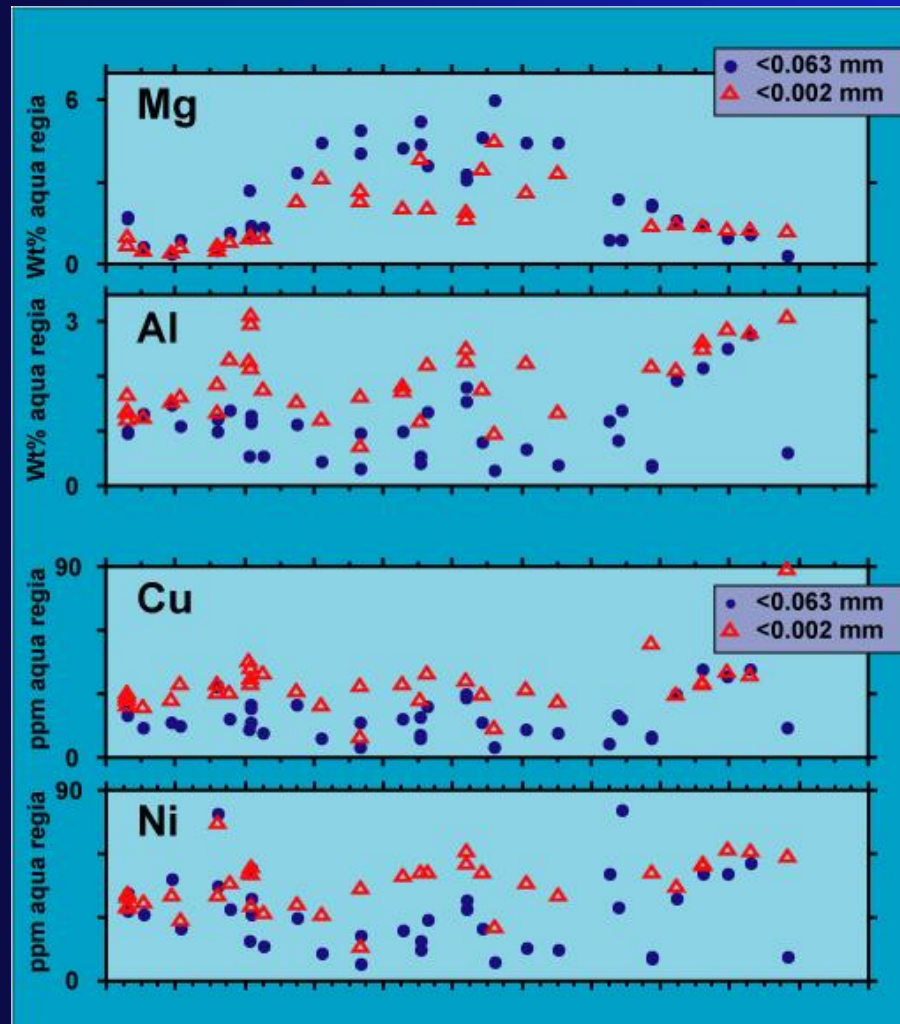
Aqua Regia Vs Total

Poor Correlation – Provenance Dependent



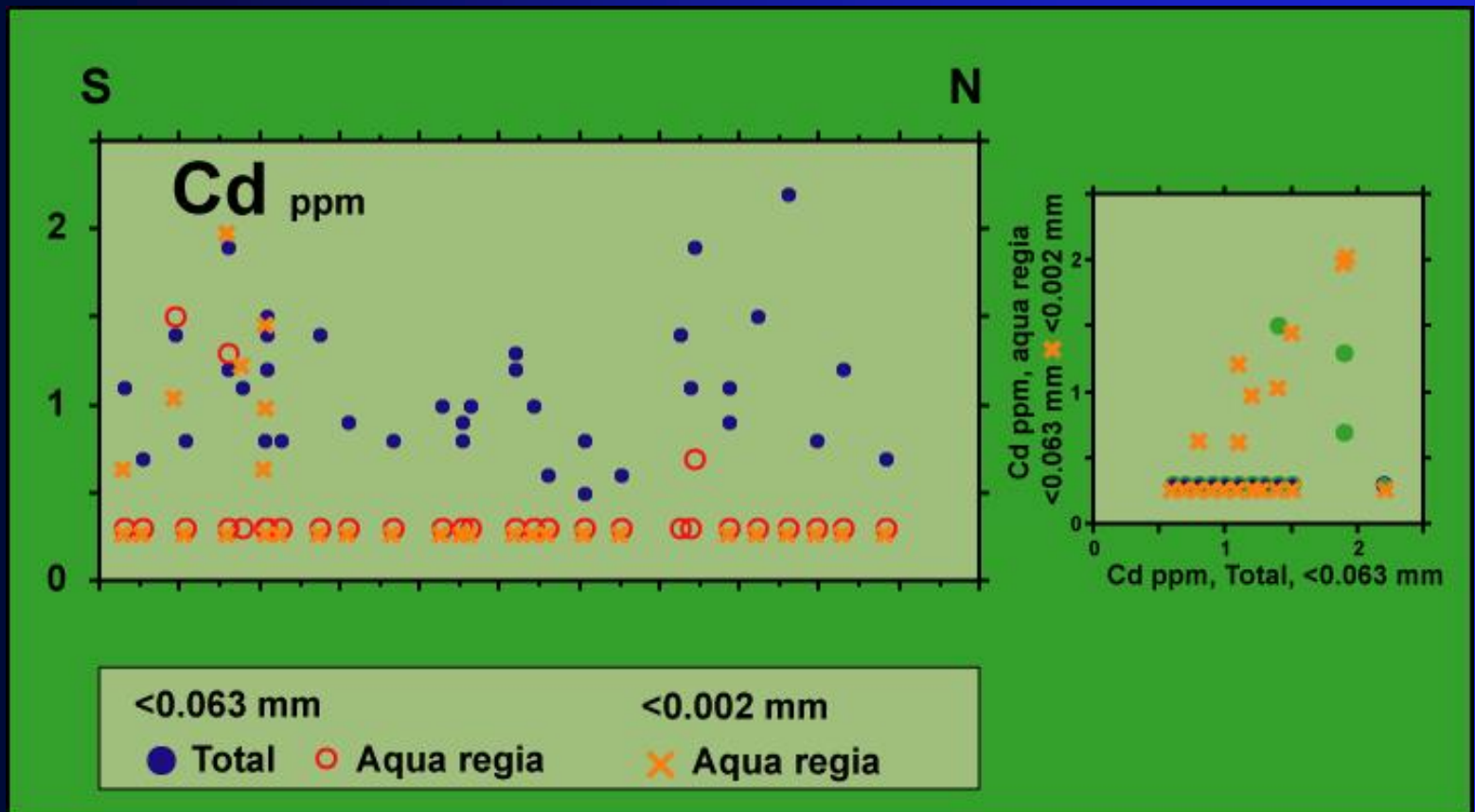
Geochemical Transect Profiles

$\leq 0.063\text{mm}$ - $\leq 0.002\text{ mm}$ Comparison



Geochemical Transect Profile

Grain Size and Mineral Residence Sites - Cd



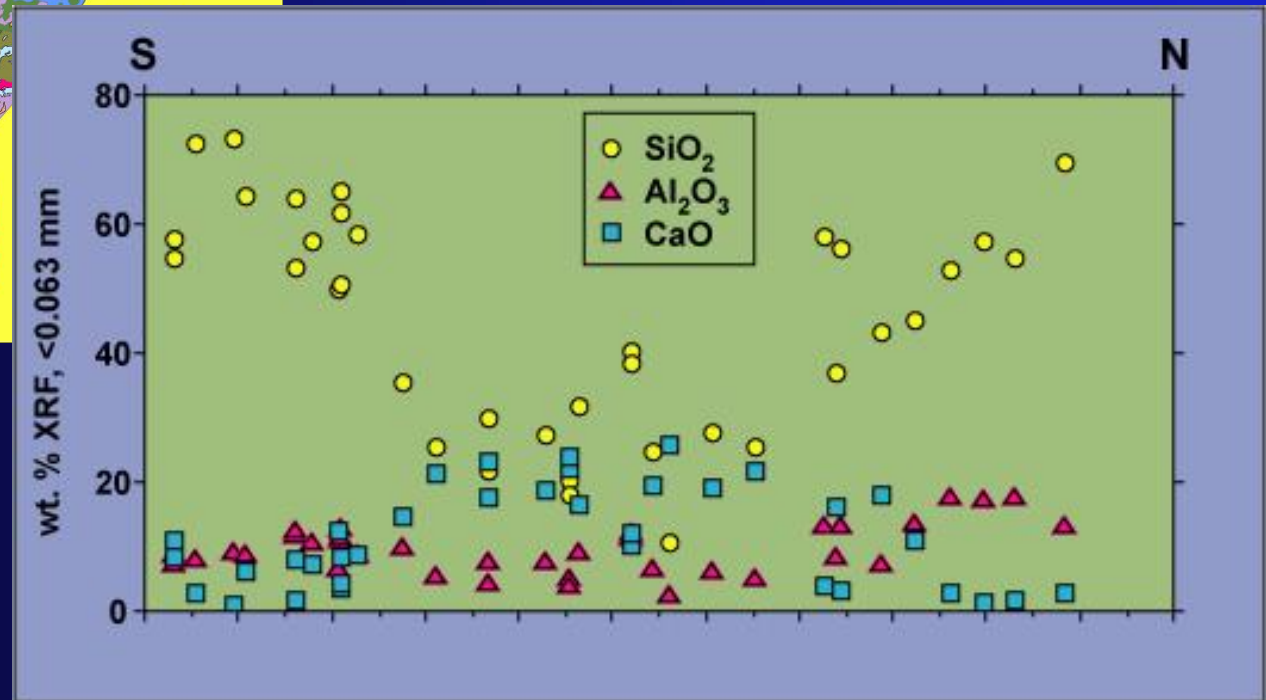
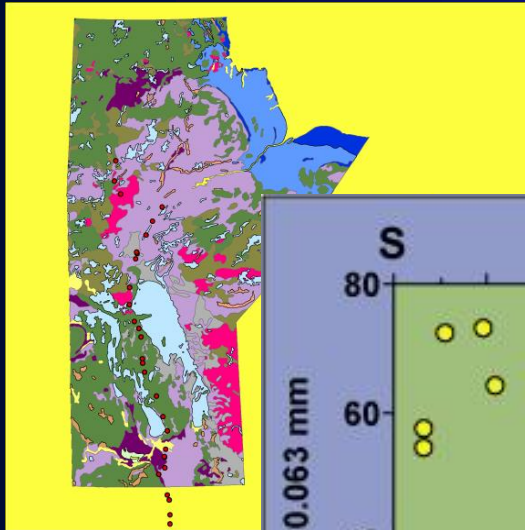
Provenance and Mineralogy

Aqua Regia decomposition

	Mesozoic	Paleozoic	Shield
Plagioclase	●		●
K-Feldspar			●
Amphibole			●
Chlorite			●
Muscovite	●		●
Mixed Layer			●
Smectite	●	●	
Kaolin	●	●	
Opal	●		
Calcite		●	
Dolomite		●	

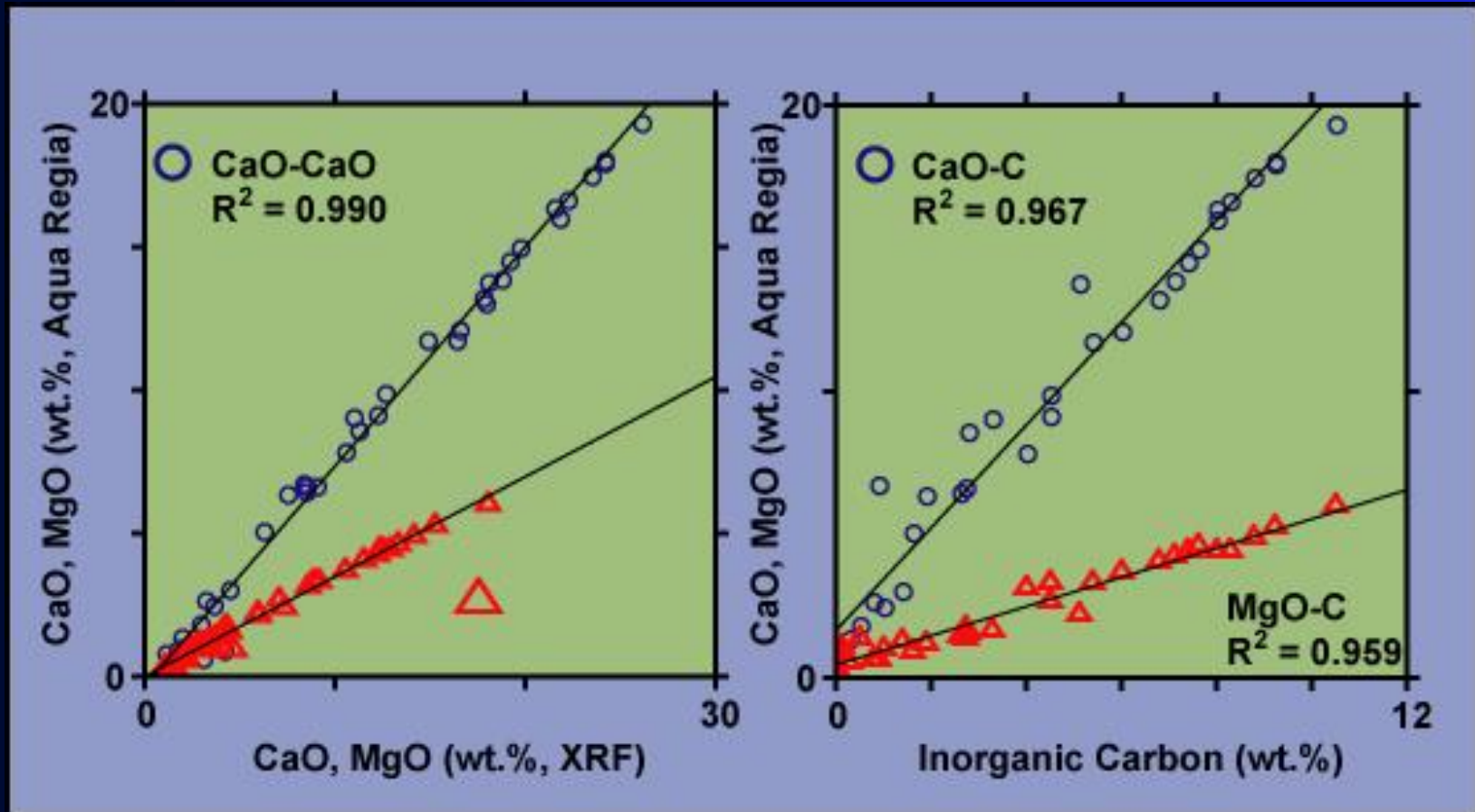
Geochemical Transect Profiles

SiO_2 , Al_2O_3 , CaO wt%



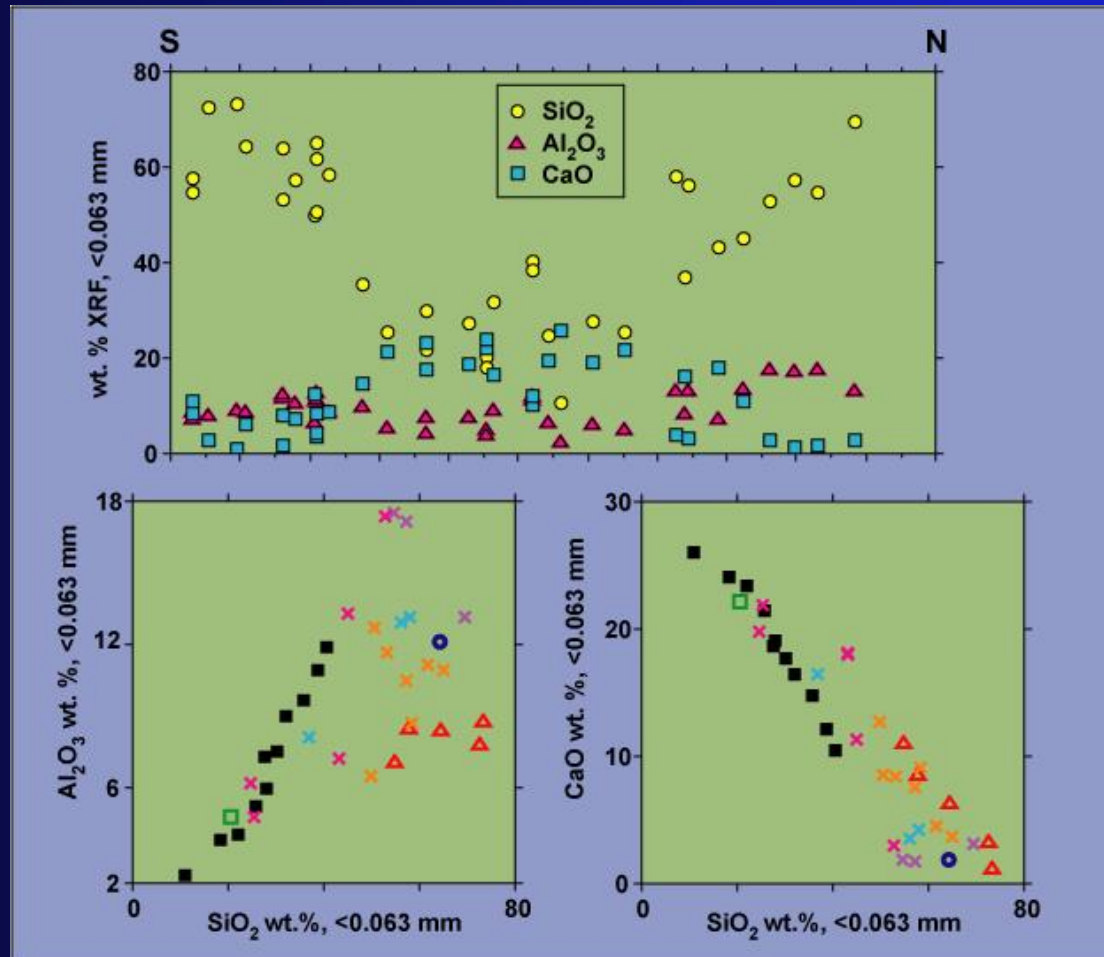
Geochemistry-Mineralogy

Carbonate Minerals



Geochemical Transect Profiles

SiO_2 , Al_2O_3 , CaO wt%



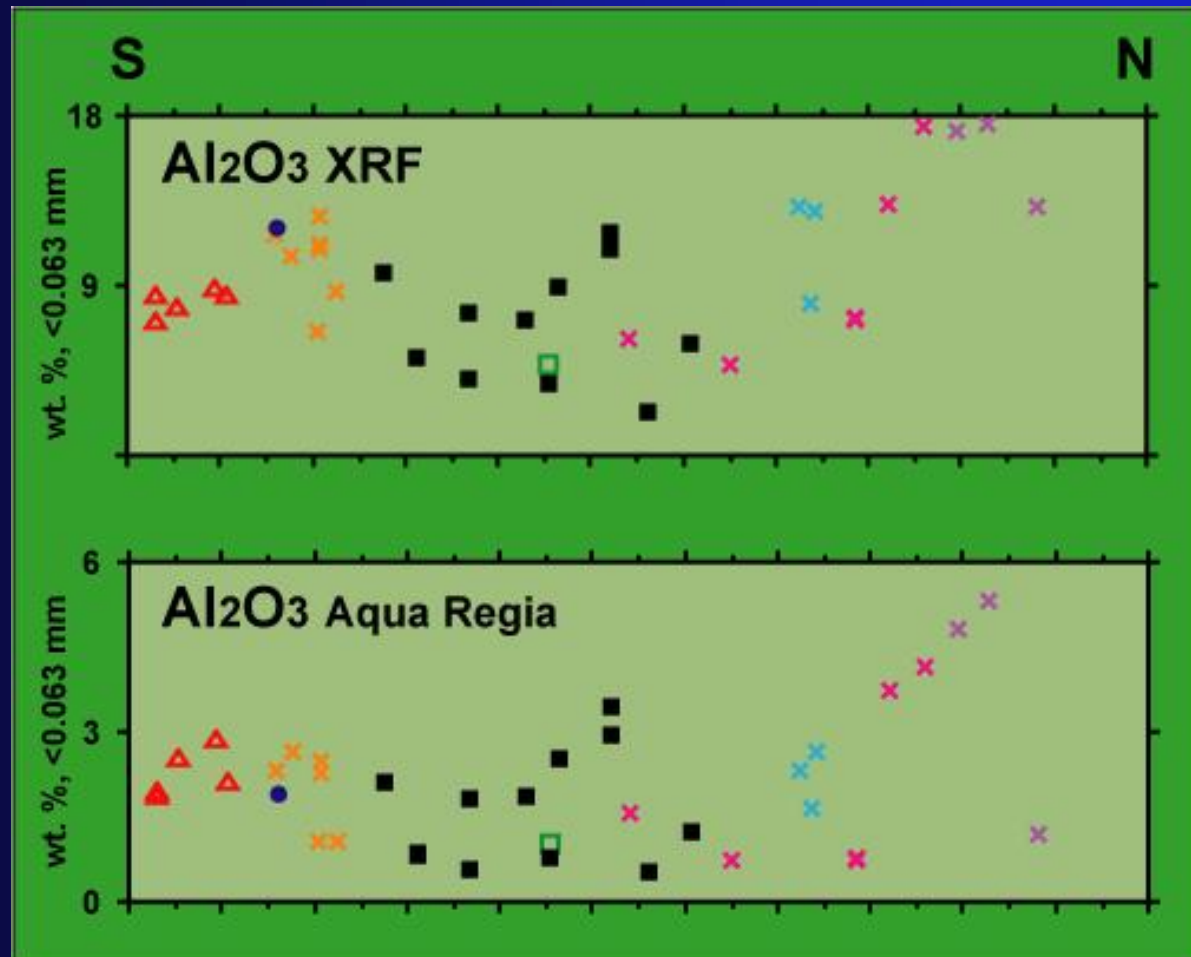
Provenance and Mineralogy

Aqua Regia decomposition

	Mesozoic	Paleozoic	Shield
Plagioclase	●		●
K-Feldspar			●
Amphibole			●
Chlorite			●
Muscovite			●
Mixed Layer	●		●
Smectite	●	●	
Kaolin	●	●	
Opal	●		
Calcite		●	
Dolomite		●	

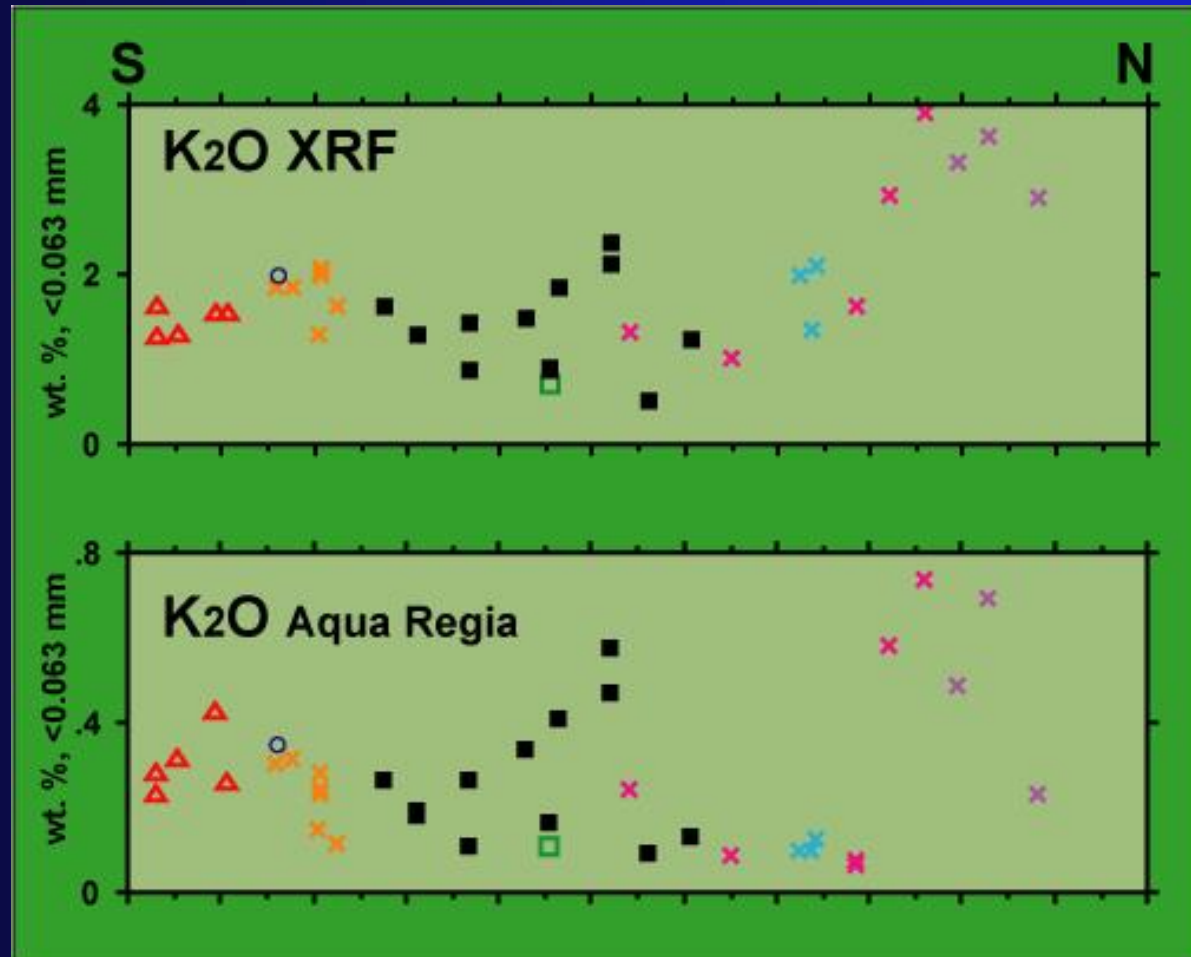
Geochemical Transect Profile

Al_2O_3 – Aqua Regia, XRF



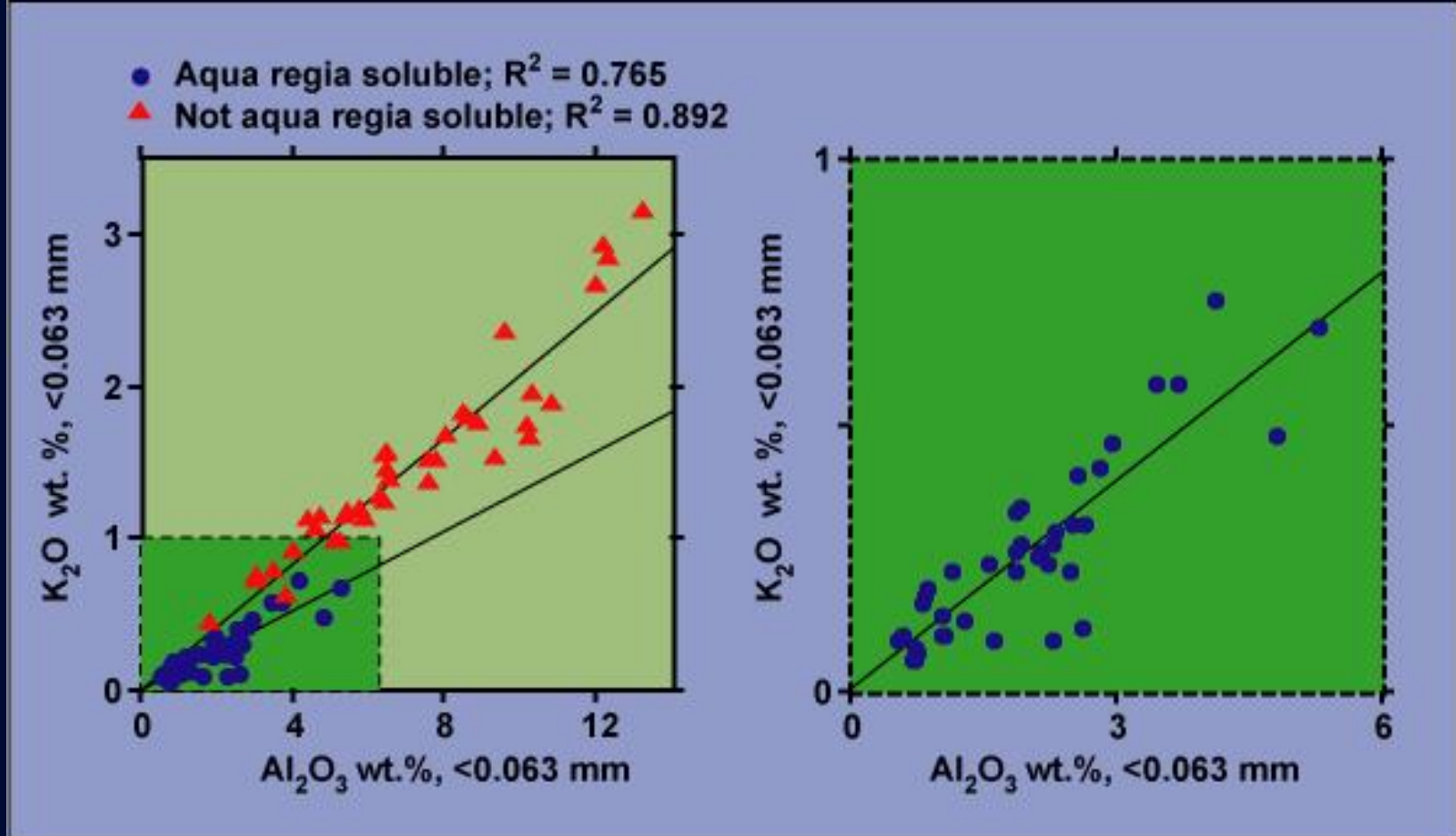
Geochemical Transect Profile

K_2O – Aqua Regia, XRF



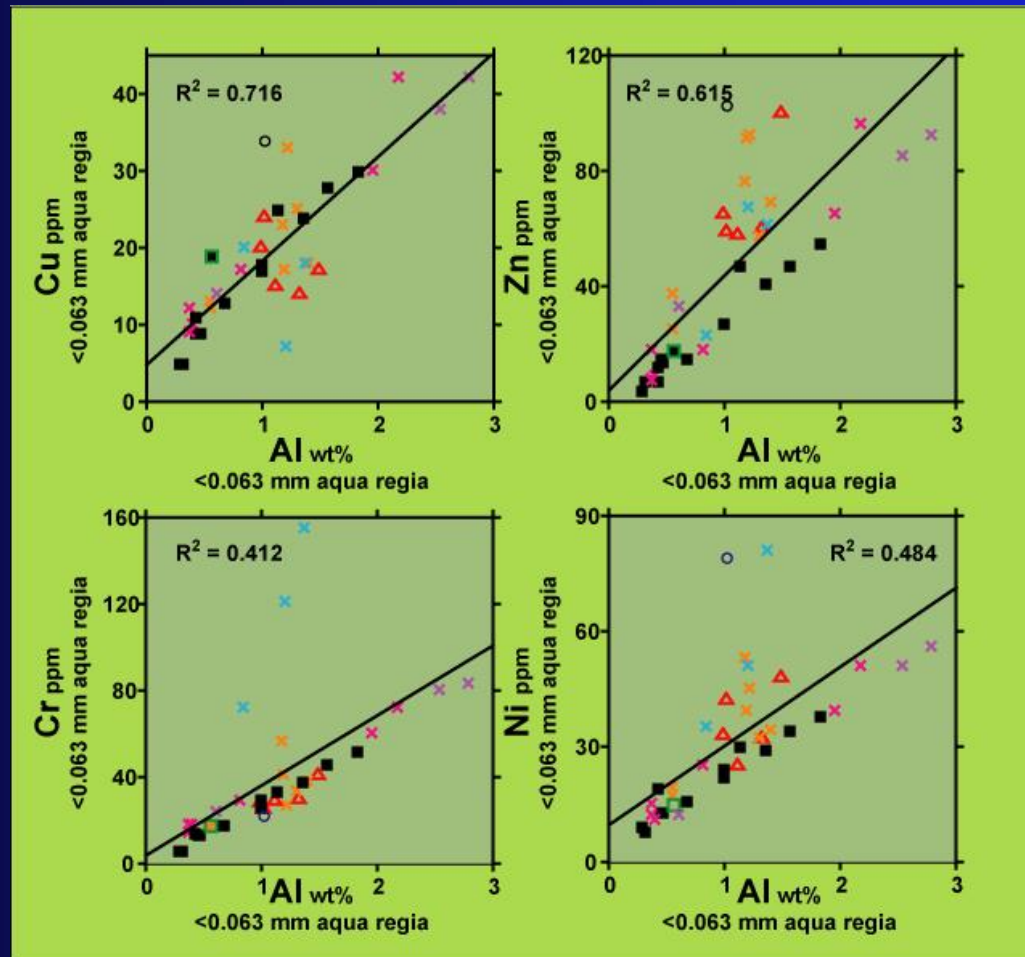
Geochemistry-Mineralogy

K-Al Minerals



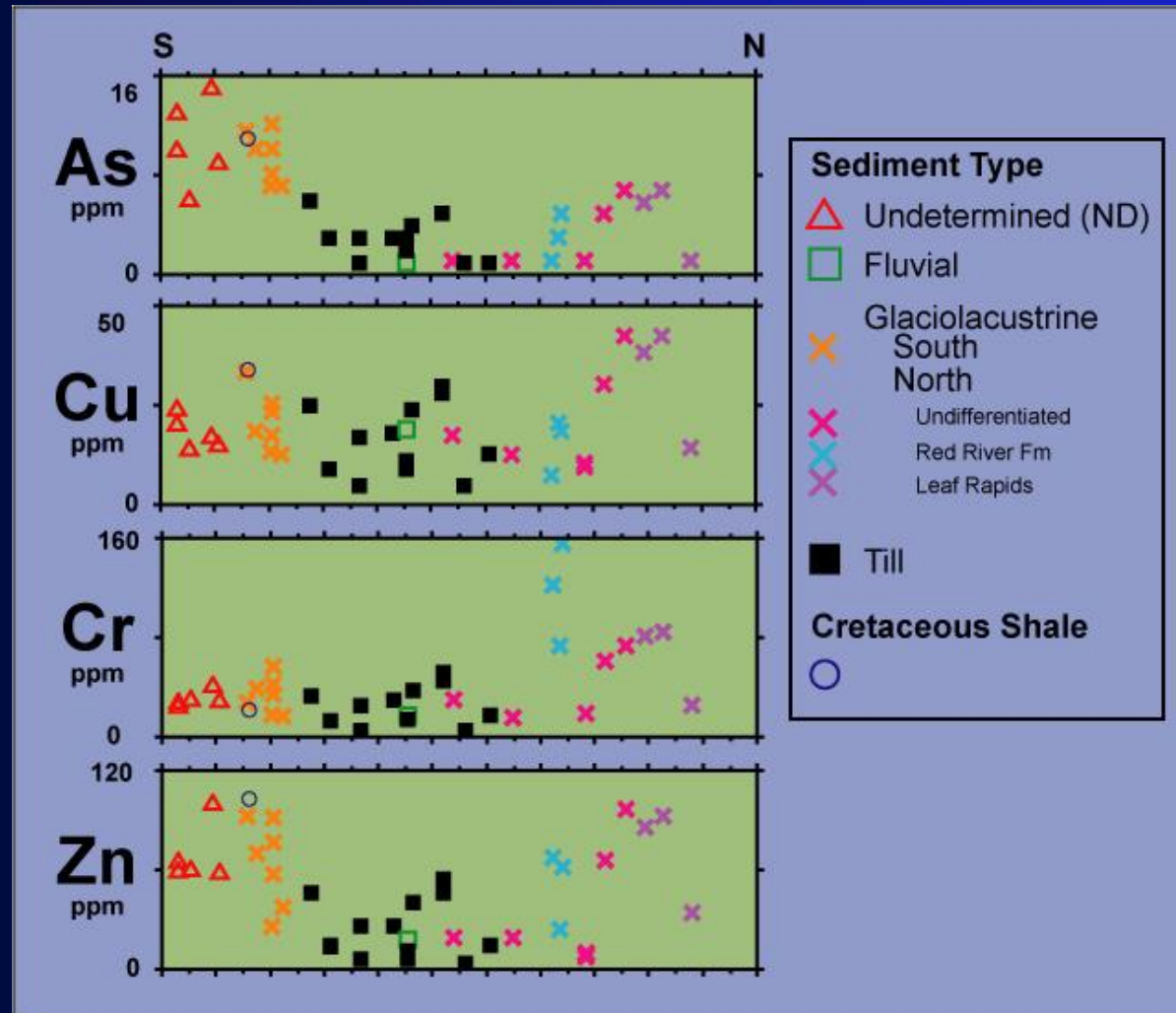
Trace Metal Associations

Cu, Zn, Cr, Ni – Al (Aqua Regia)



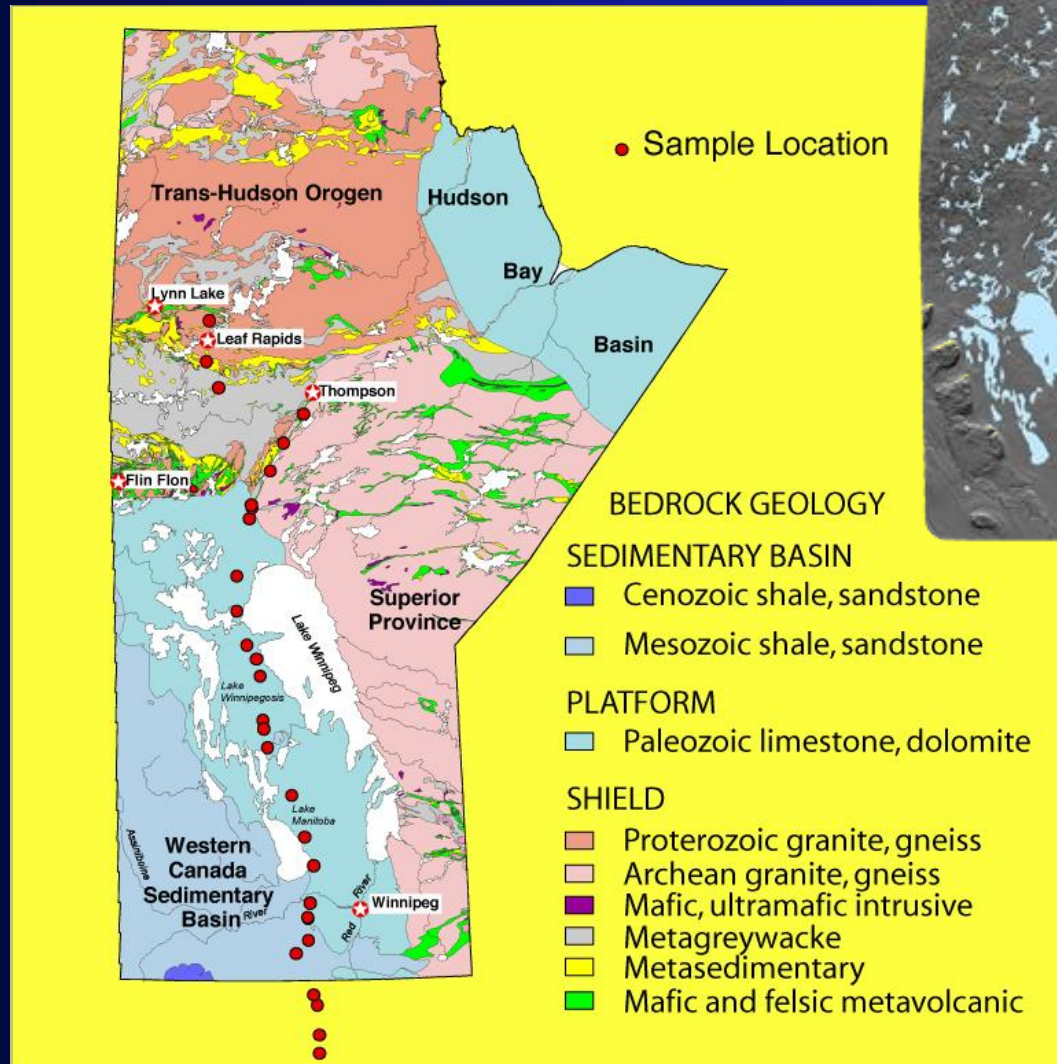
Geochemical Transect Profiles

Trace Elements (Aqua Regia, $\leq 0.063\text{mm}$)



Bedrock Geology

Manitoba



Geological Models

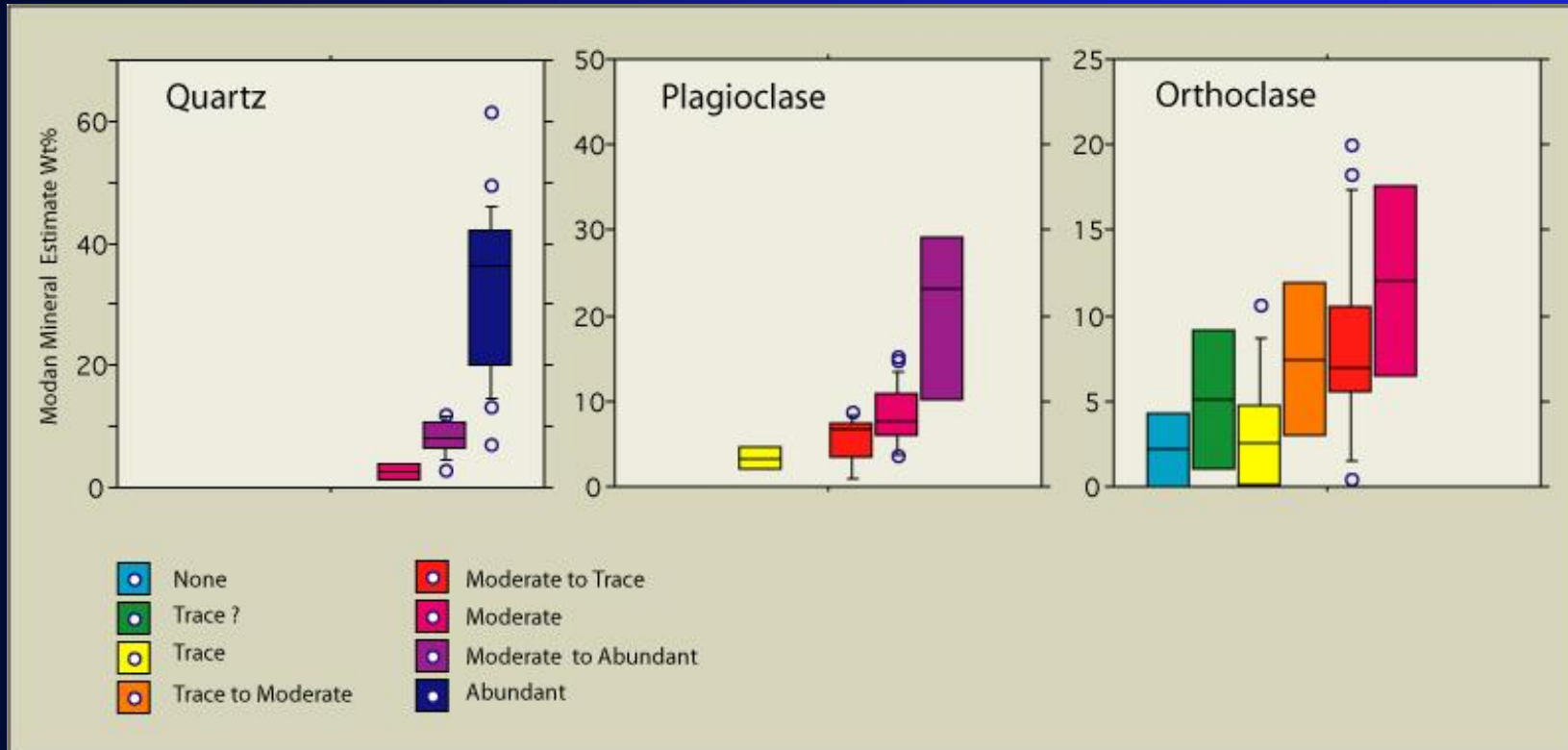
Provenance, Process, Protocol, Past



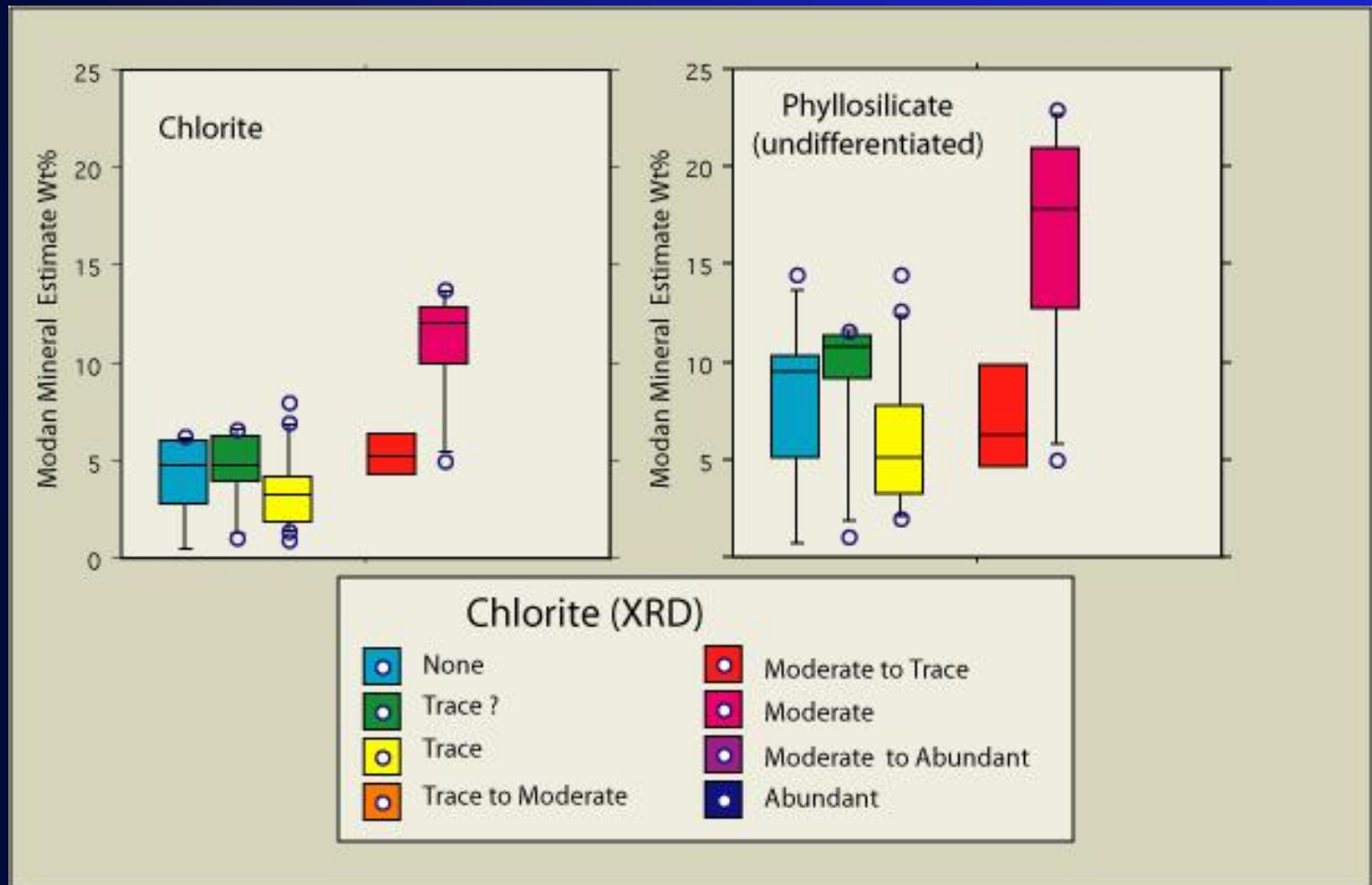
Mineral Modeling

- **Modan** - computer modeling of overburden mineralogy

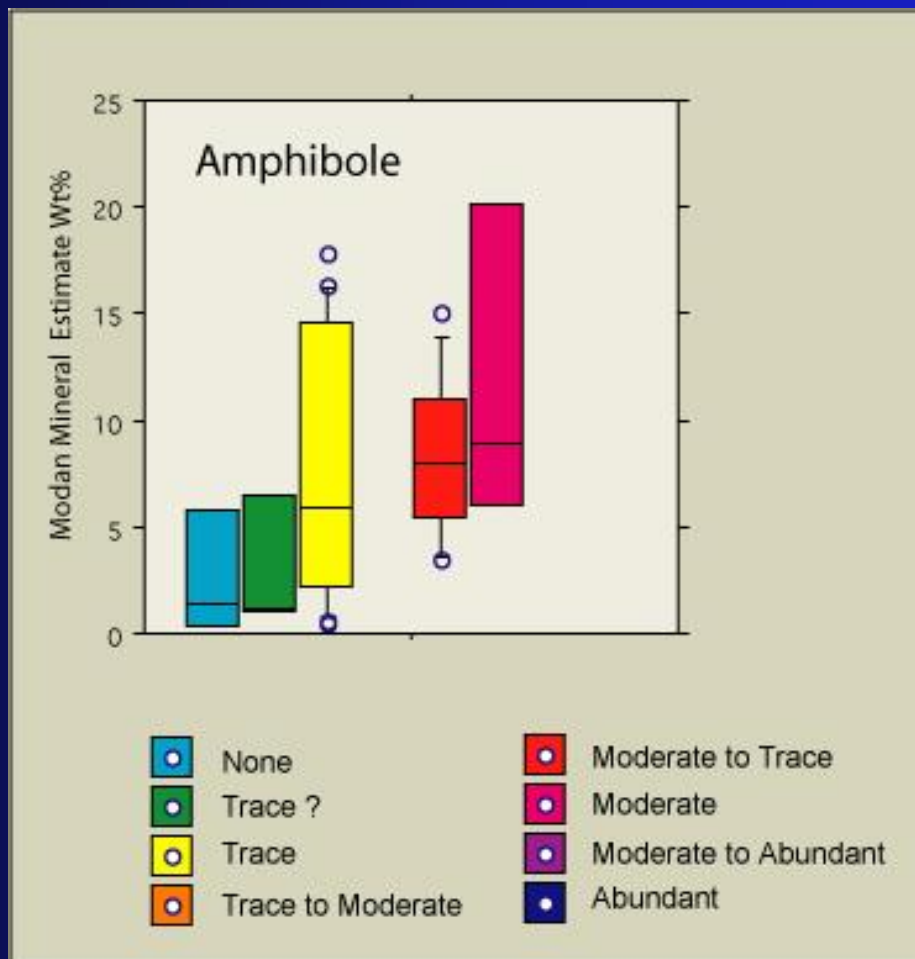
Modan - XRD Mineralogy



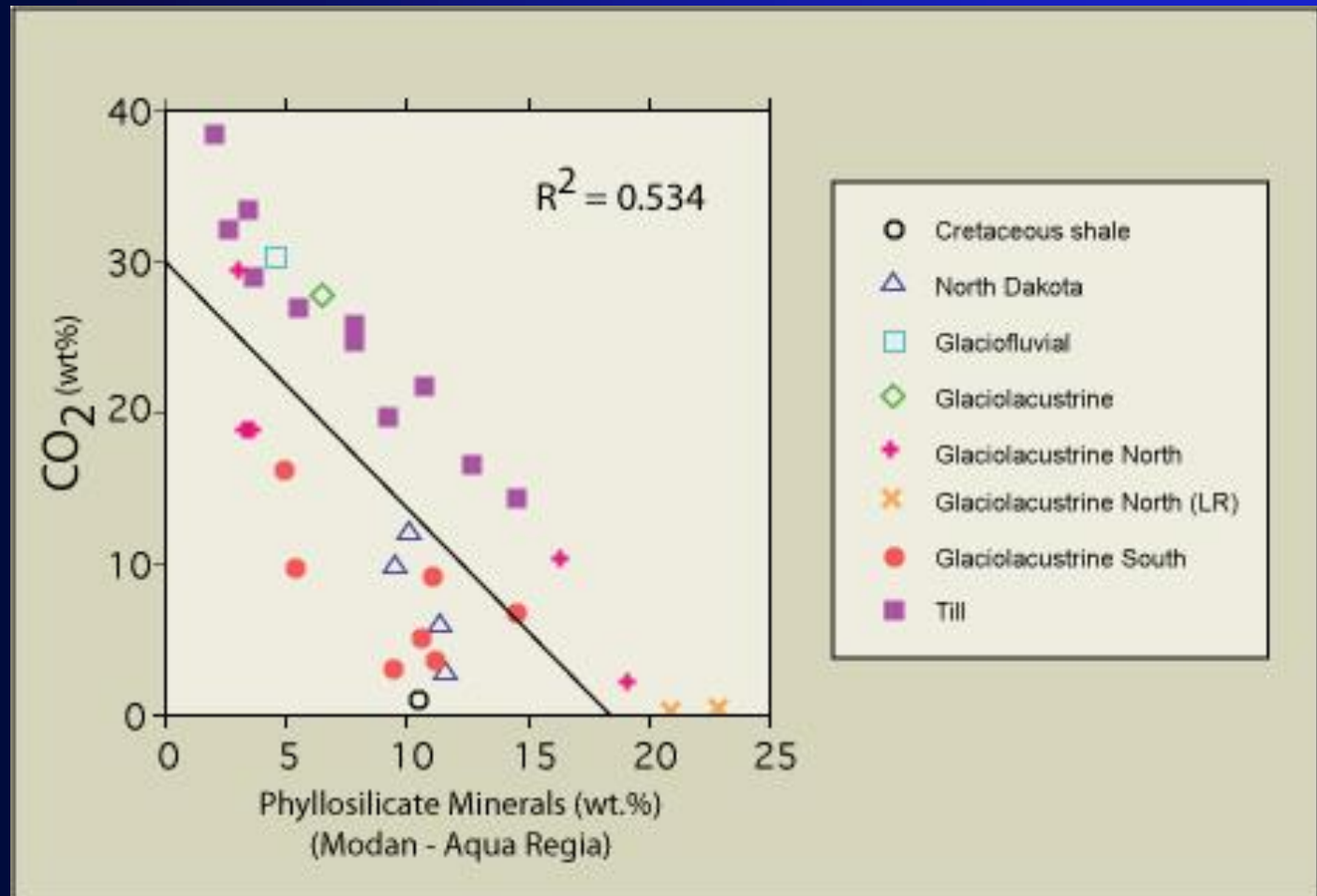
Modan Phyllosilicate - XRD Chlorite



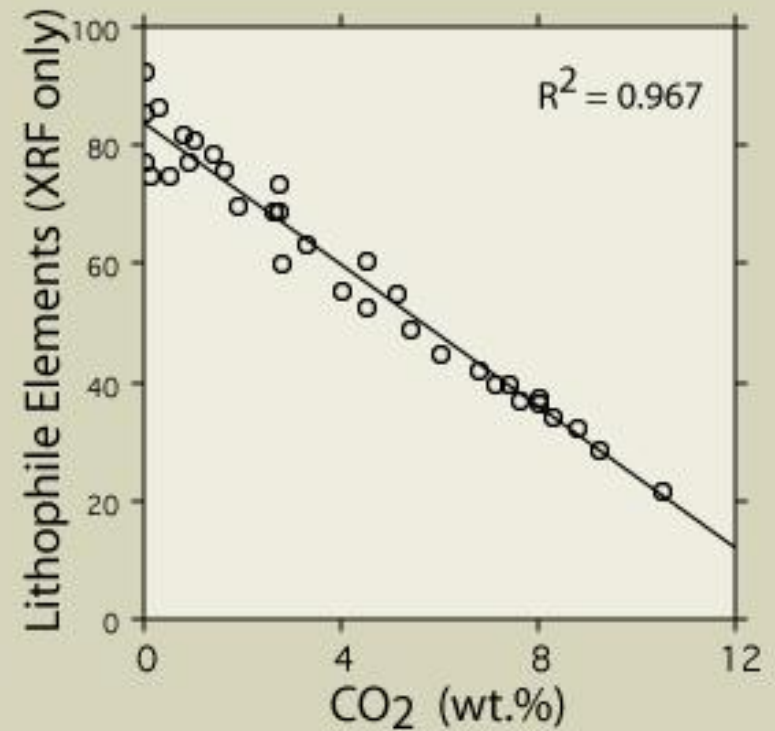
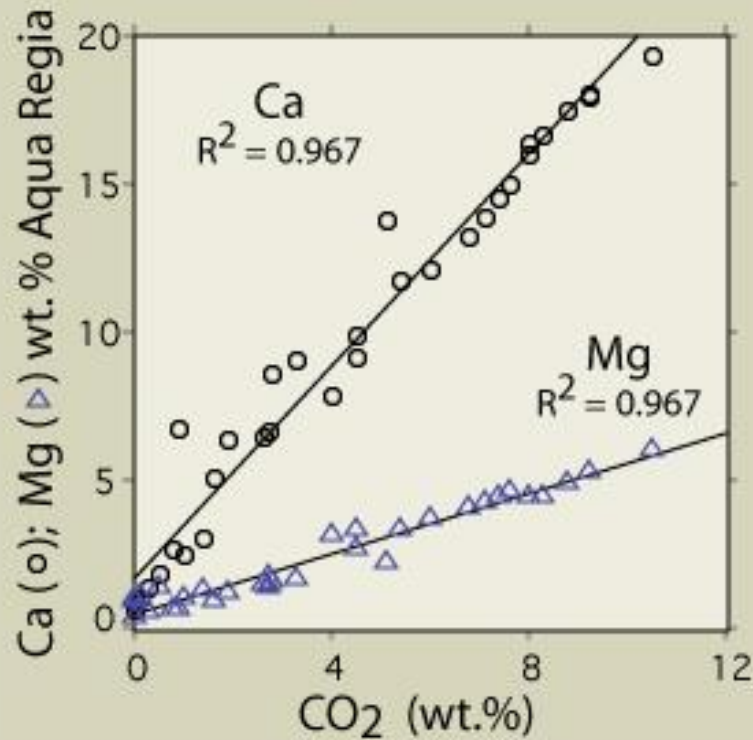
Modan - XRD Amphibole



Geochemical Modeling

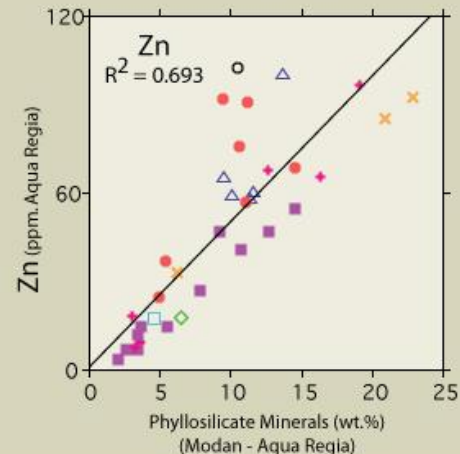
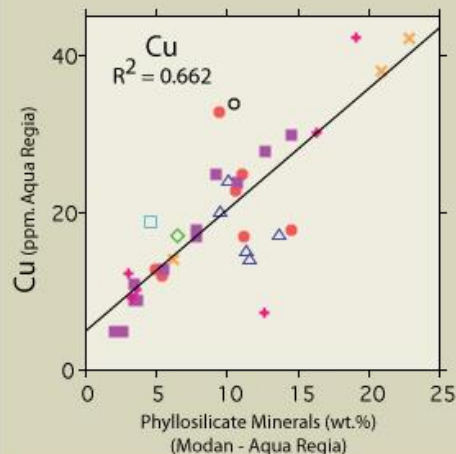
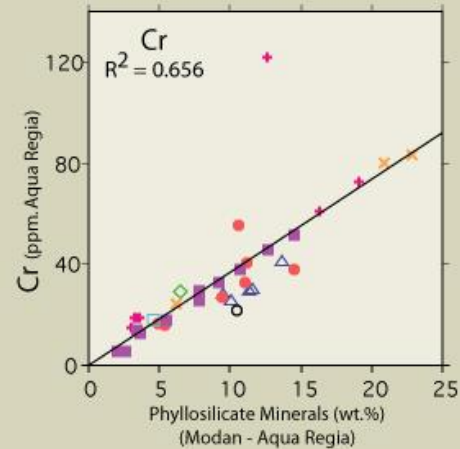
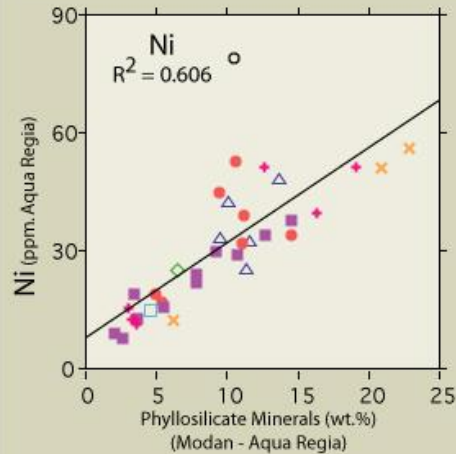


Overburden Model



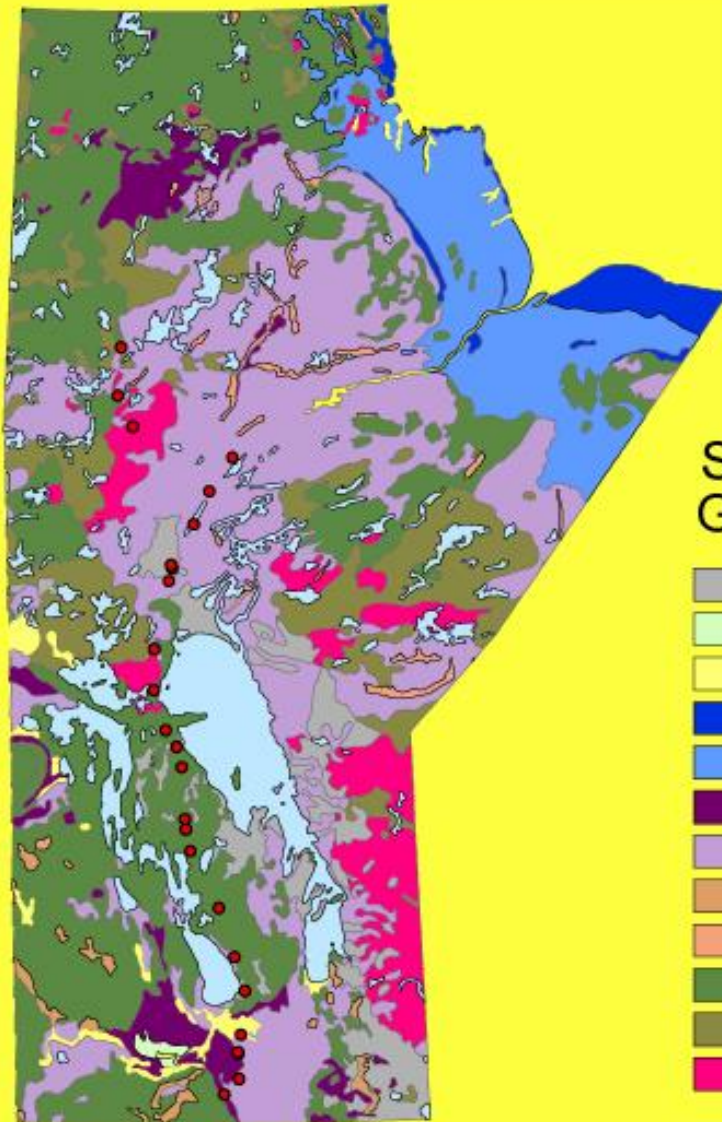
Modan Phyllosilicates-Trace Metals

- Cretaceous shale
- △ North Dakota
- Glacioluvial
- ◇ Glaciolacustrine
- ✦ Glaciolacustrine North
- ✕ Glaciolacustrine North (LR)
- Glaciolacustrine South
- Till



Geoscience and Environmental Geochemistry

- Natural Background Variation
- Source Apportionment
- Geochemical Flux

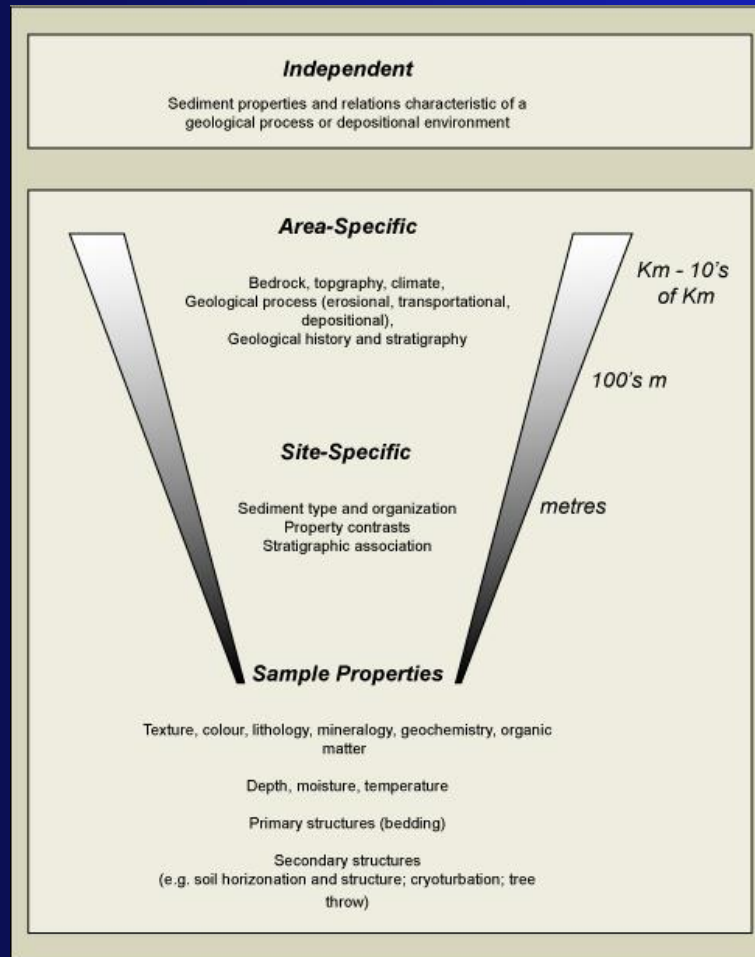


Surficial Geology

-  Organic
-  Eolian
-  Alluvium
-  Marine (C)
-  Marine (F)
-  Glaciolacustrine (C)
-  Glaciolacustrine (F)
-  Proglacial
-  Ice Contact
-  Till (Mantle)
-  Till (Veneer)
-  Bedrock

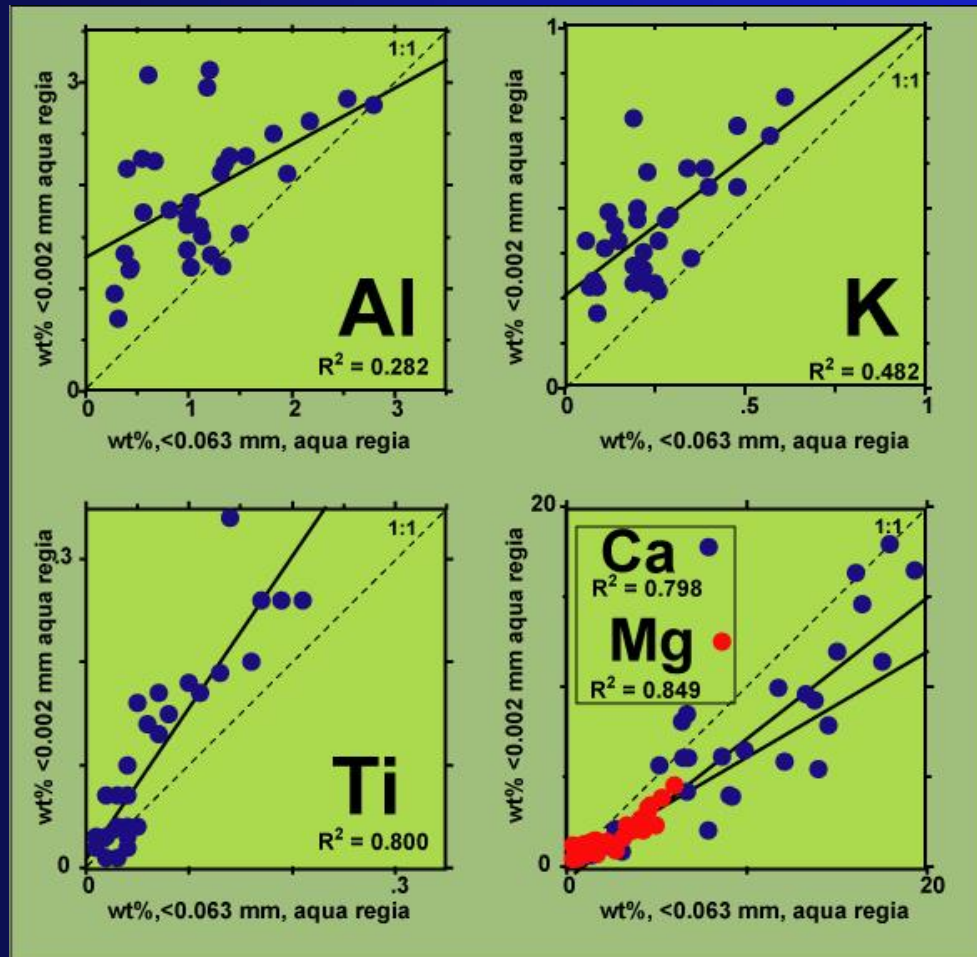
0 200
Km

Scale Values



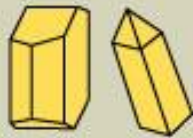
Mineral Partitioning

≤0.002 mm Vs ≤0.063 mm Al, K, Ti, Ca, Mg



Mineral Partitoning

MINERALS Resistance to Crushing & Abrasion



Feldspar Quartz



Mafic



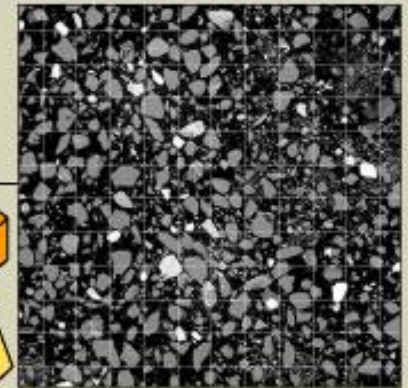
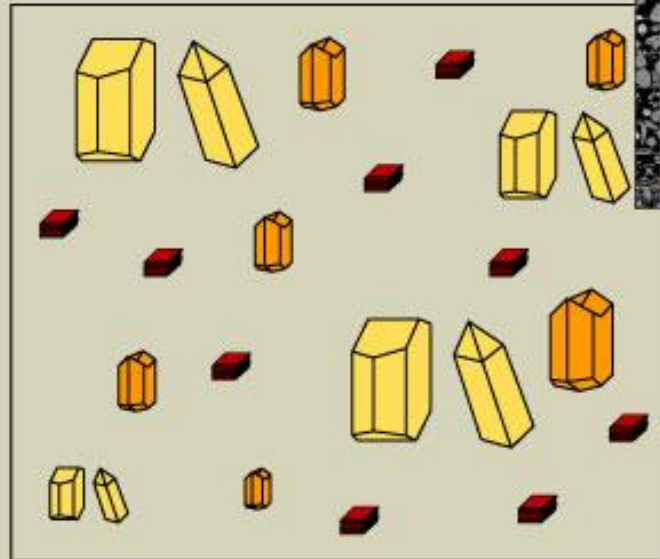
Phyllosilicate

High



Low

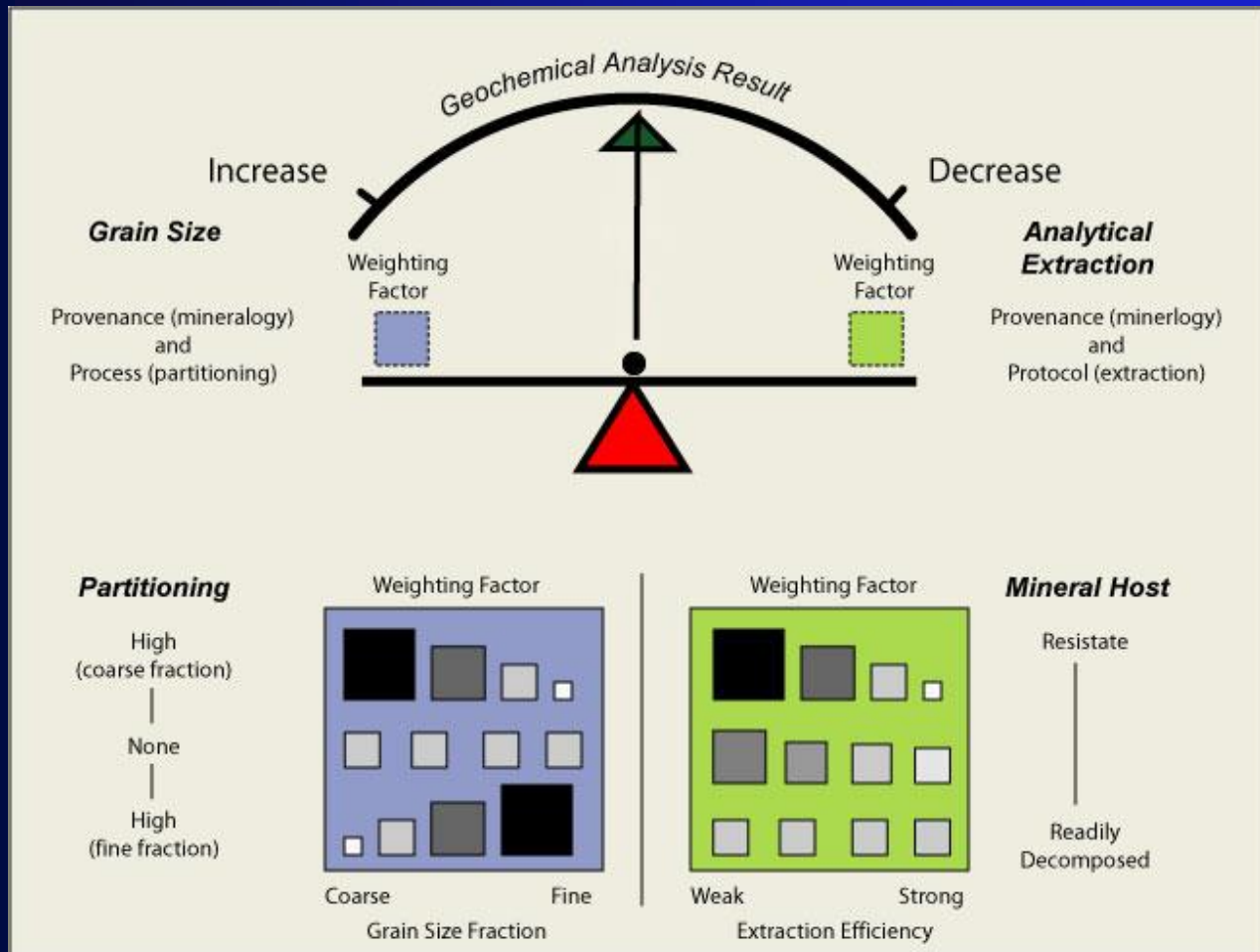
Grain Size Distribution in Glacial sediments

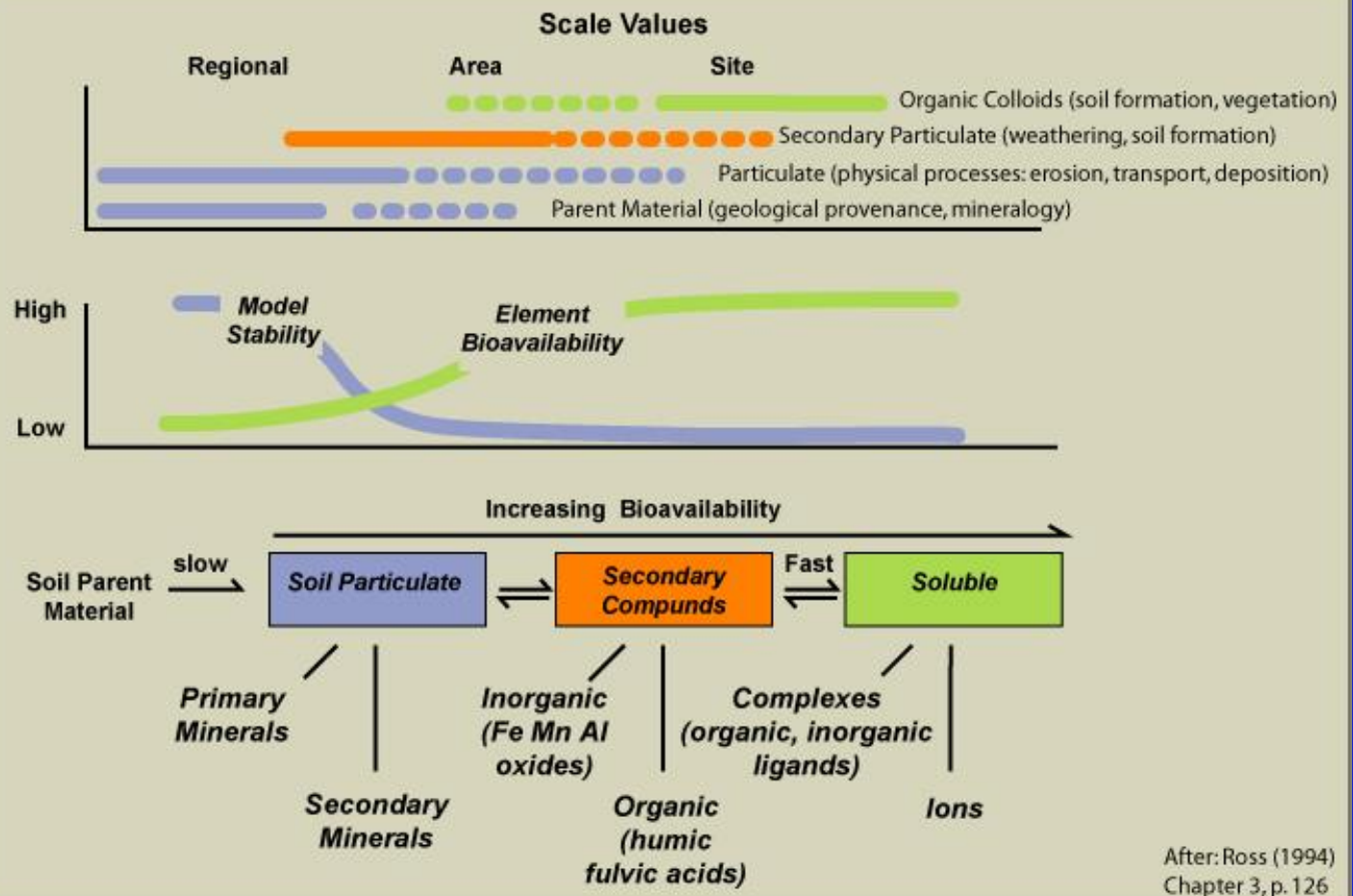


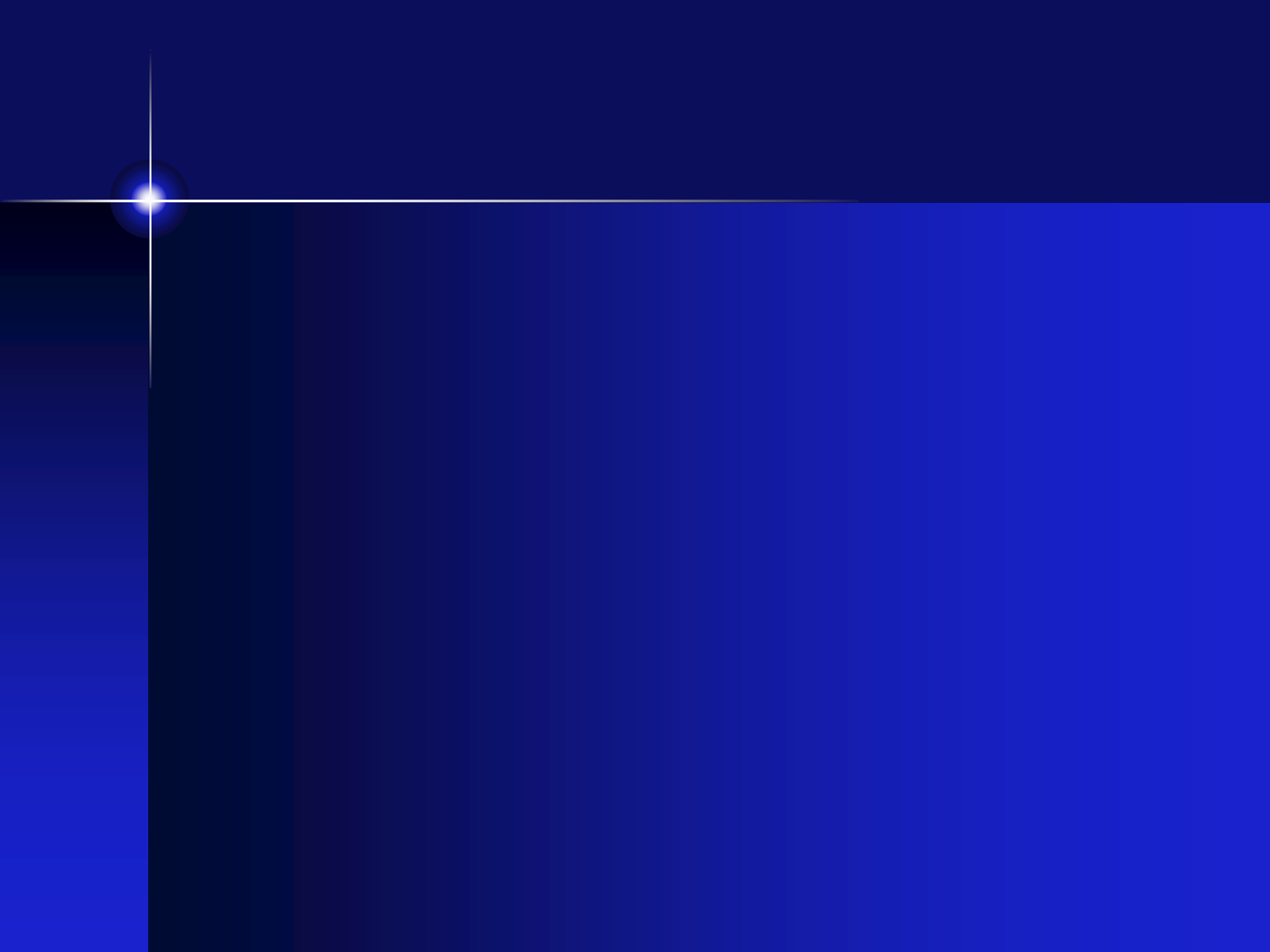
500µm

Mineral Grains

Analysis Results







Glaciolacustrine



North Dakota



Glaciolacustrine

Nearshore Facies



MB Town



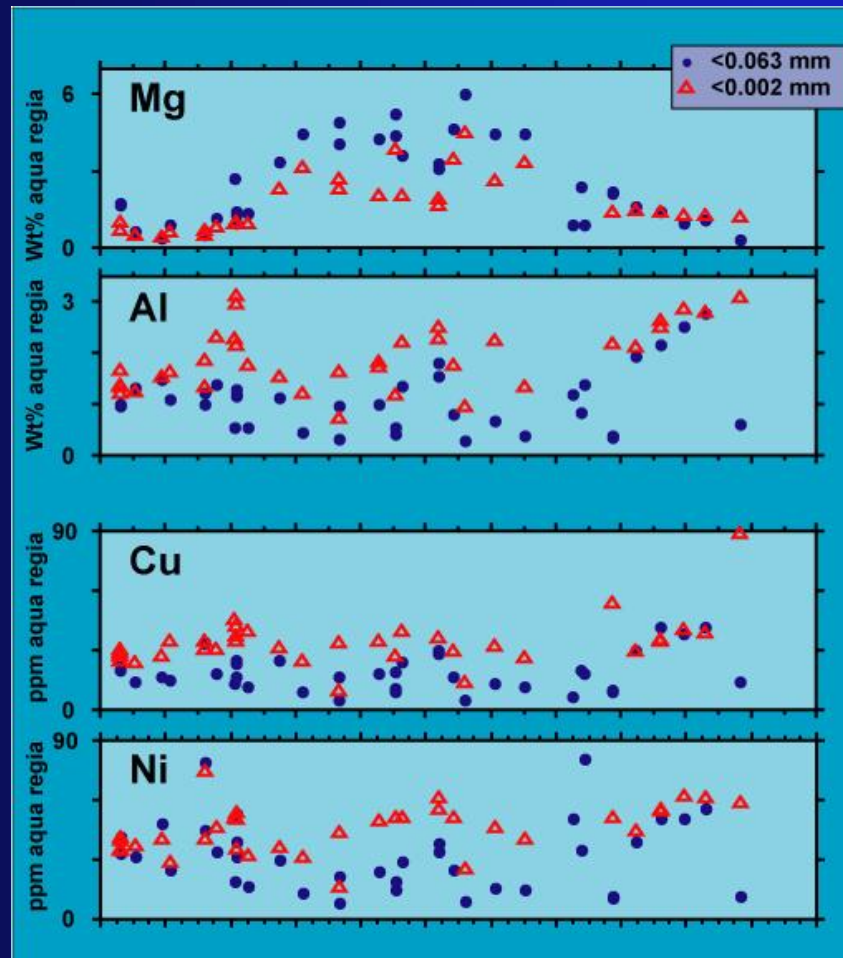
North Dakota

First Site - Northern Transect

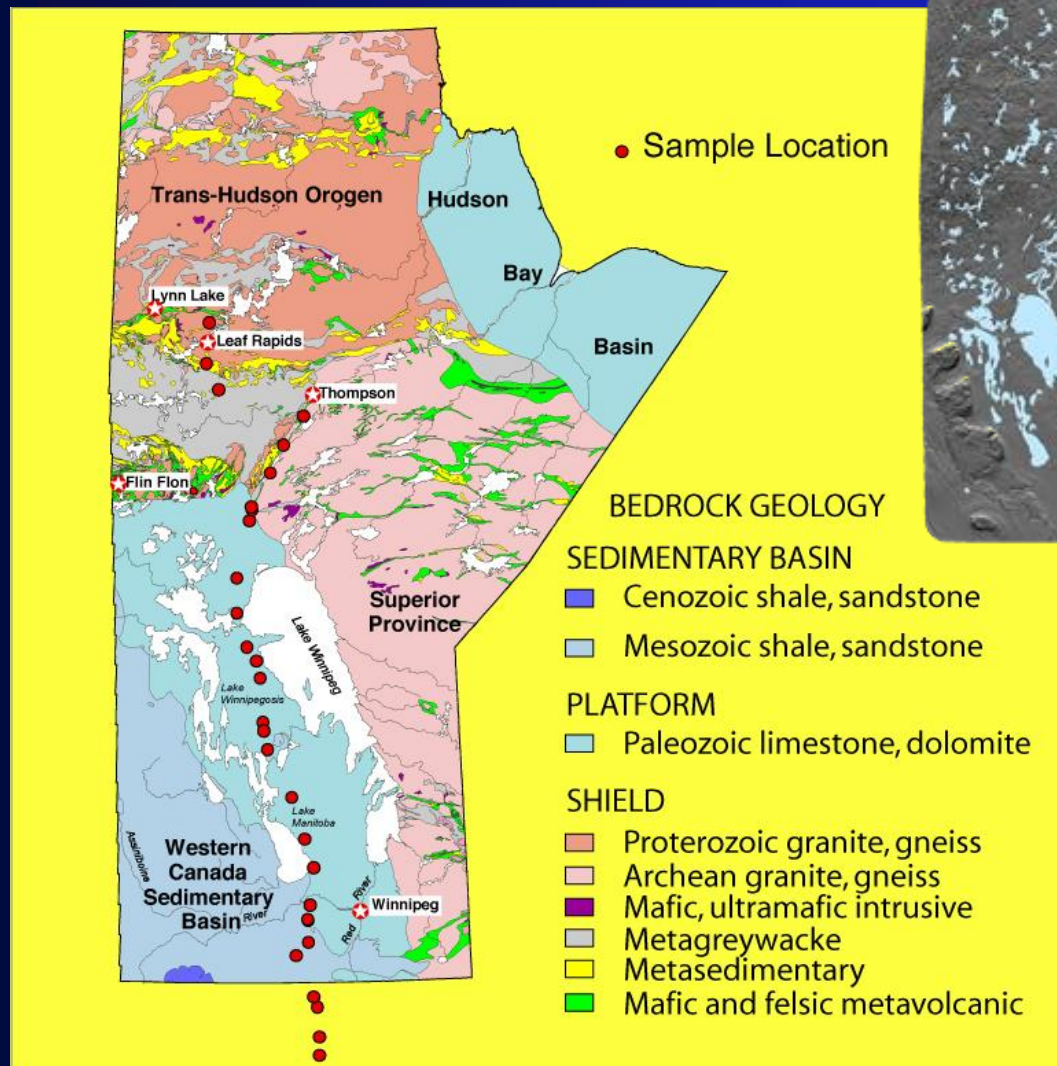


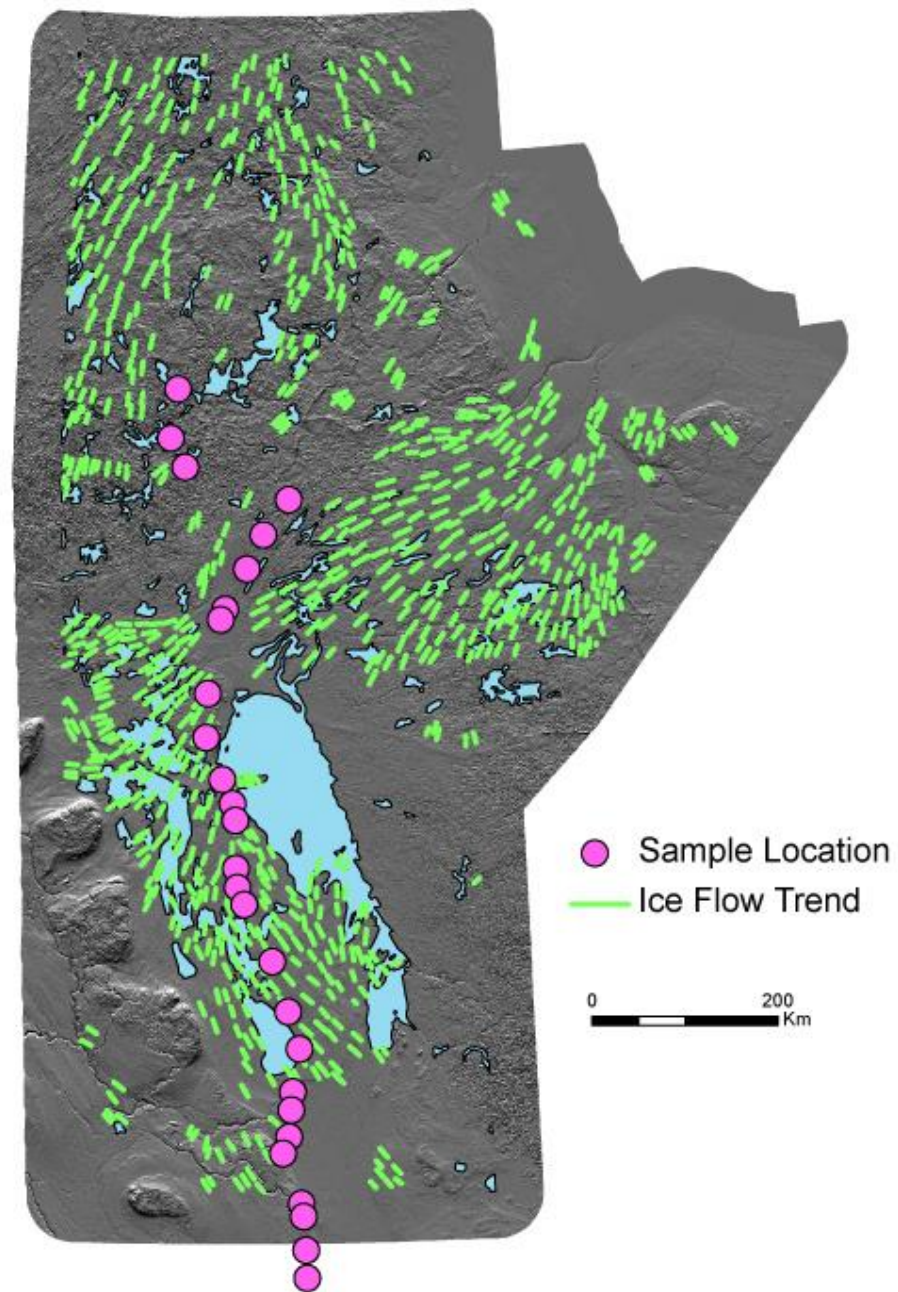
Geochemical Transect Profiles

$\leq 0.063\text{mm}$ - $\leq 0.002\text{ mm}$ Comparison



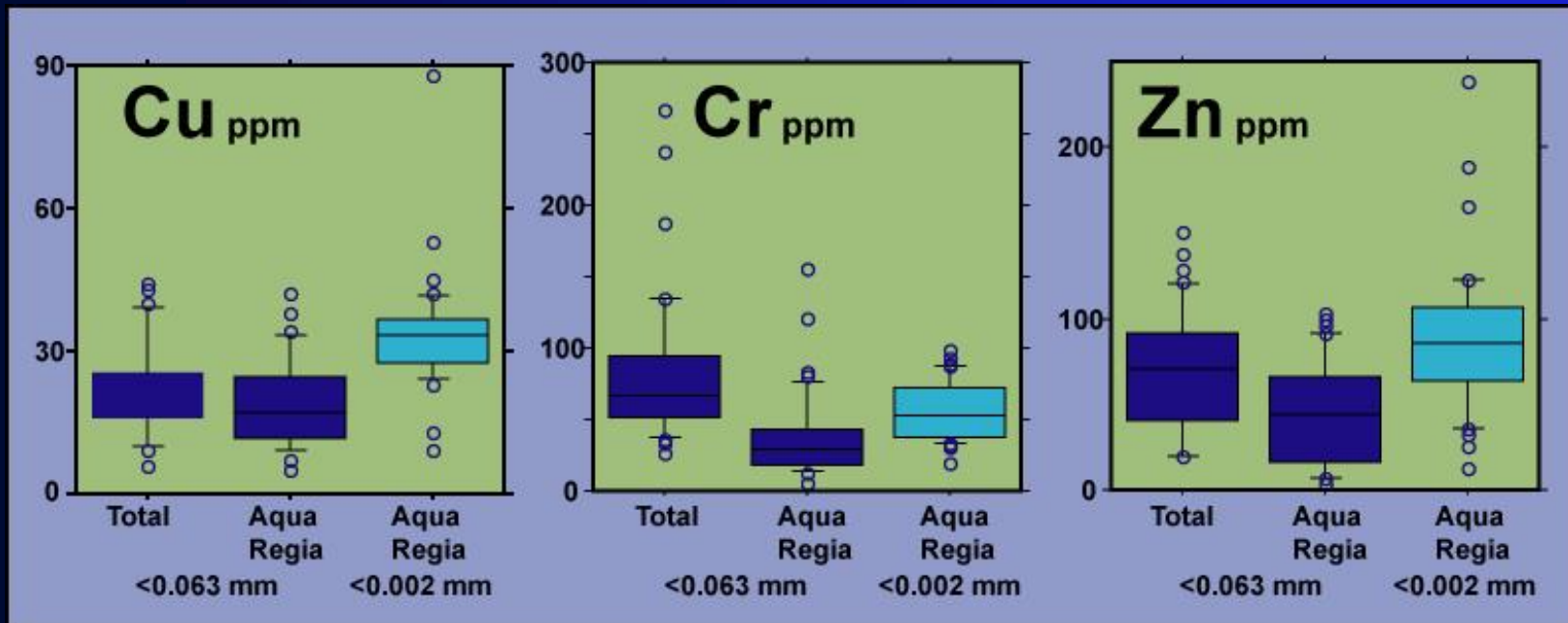
Manitoba Geology





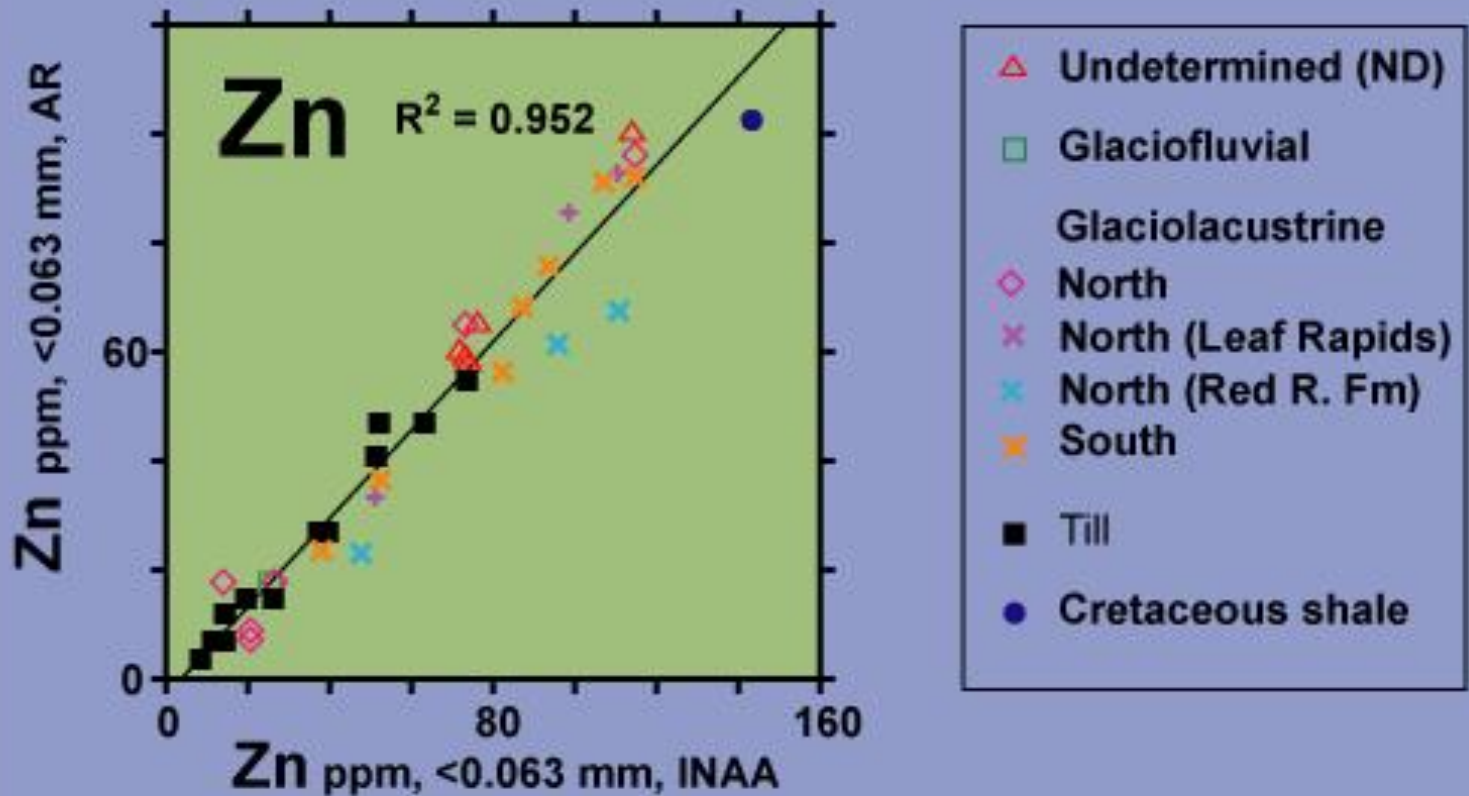
Trace Metals

Box and Whisker Plots

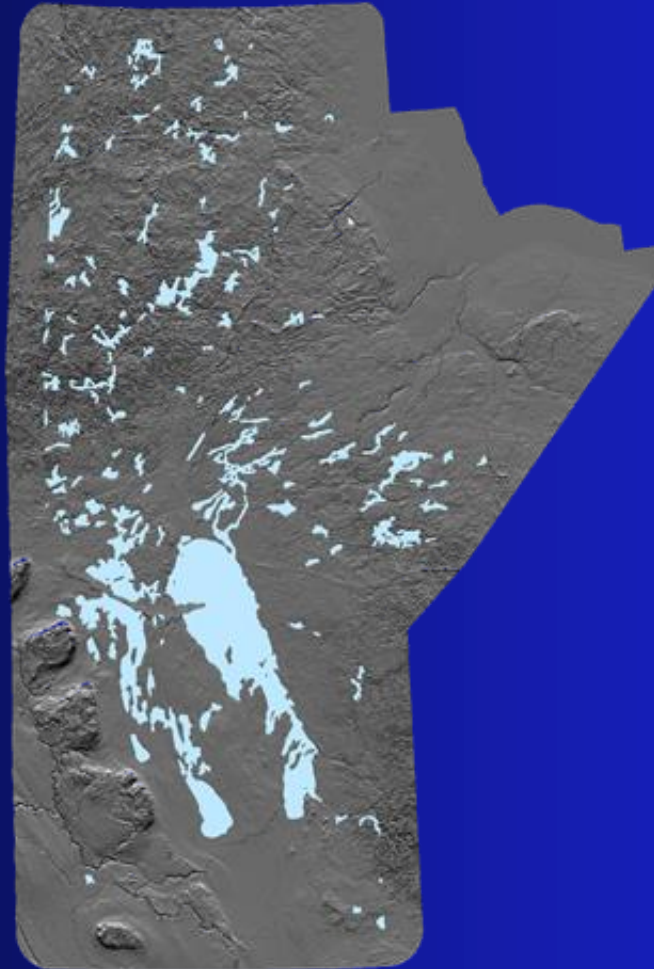


Aqua Regia Vs Total

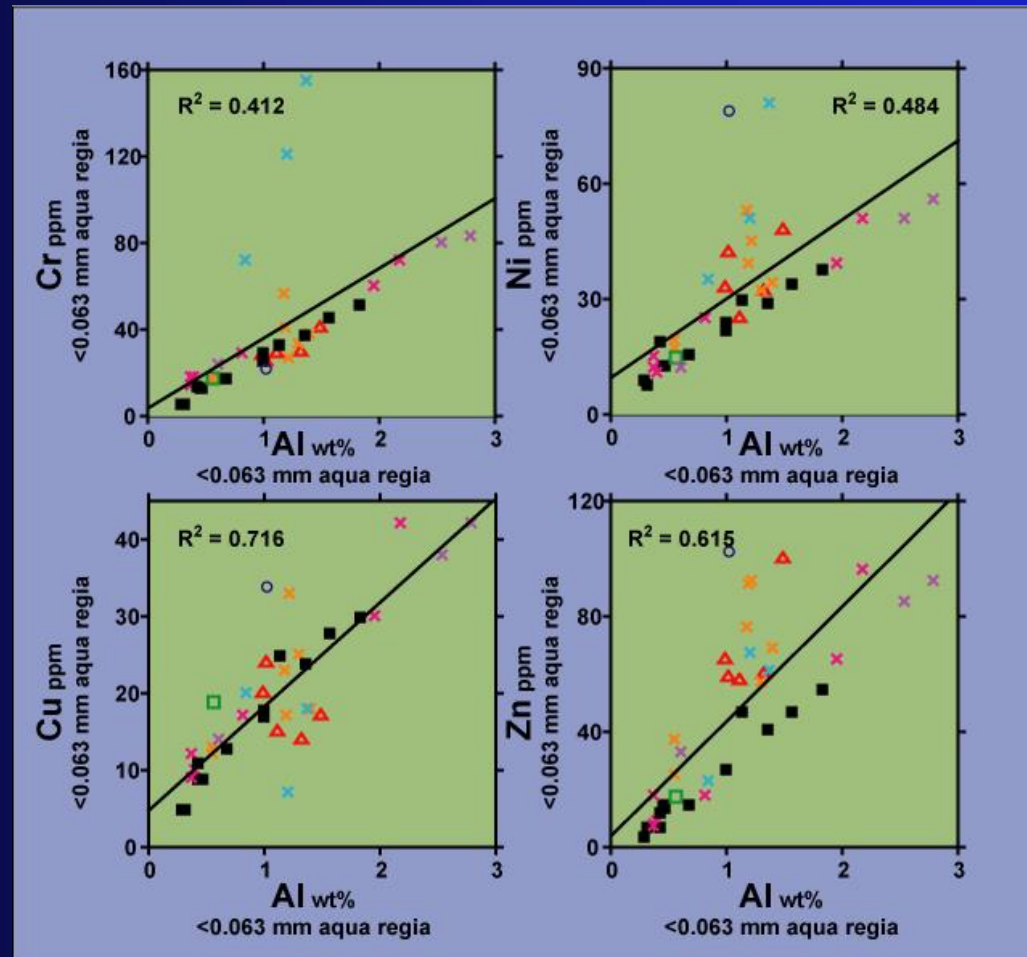
Correlation – Provenance-Dependent



Manitoba Elevation Model

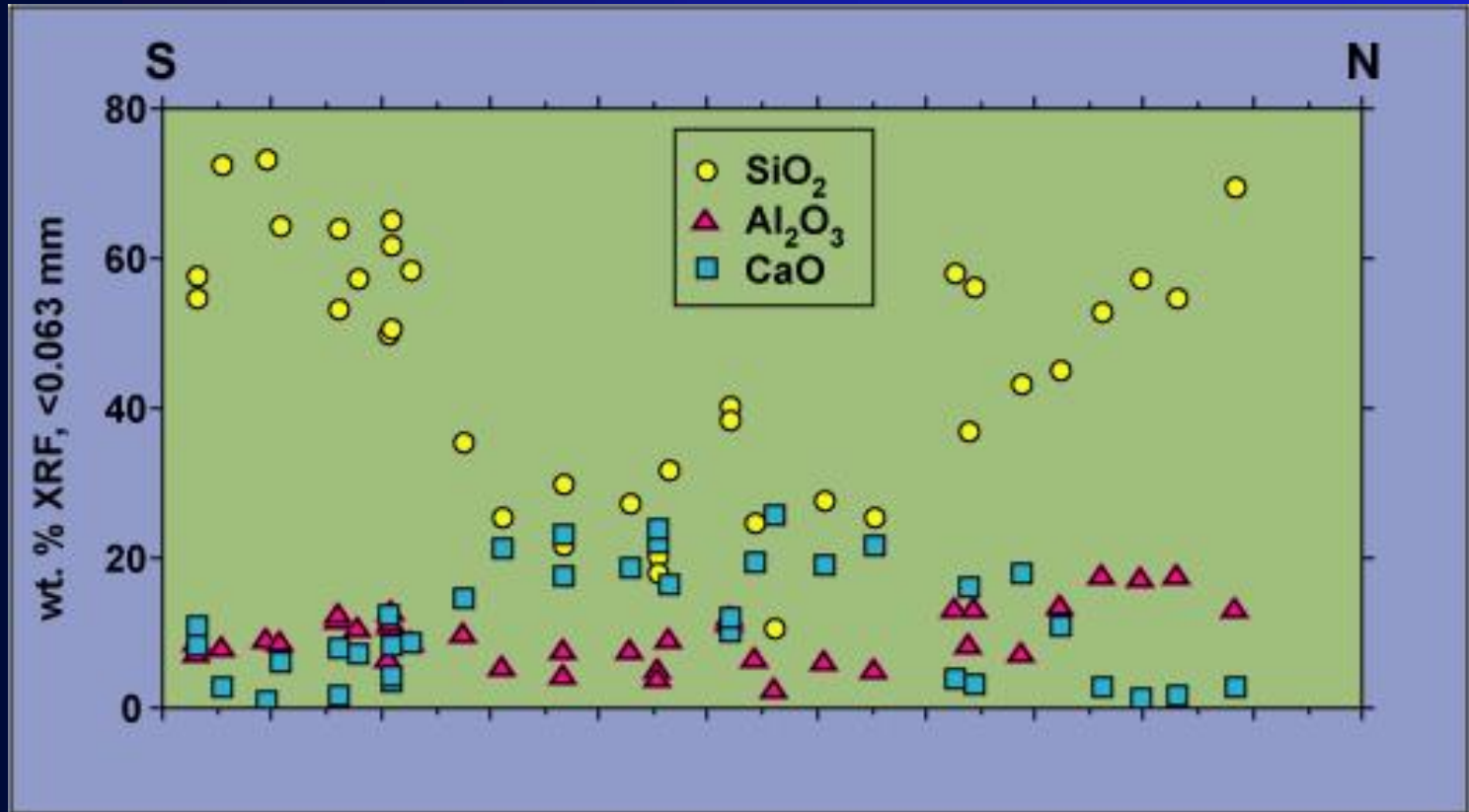


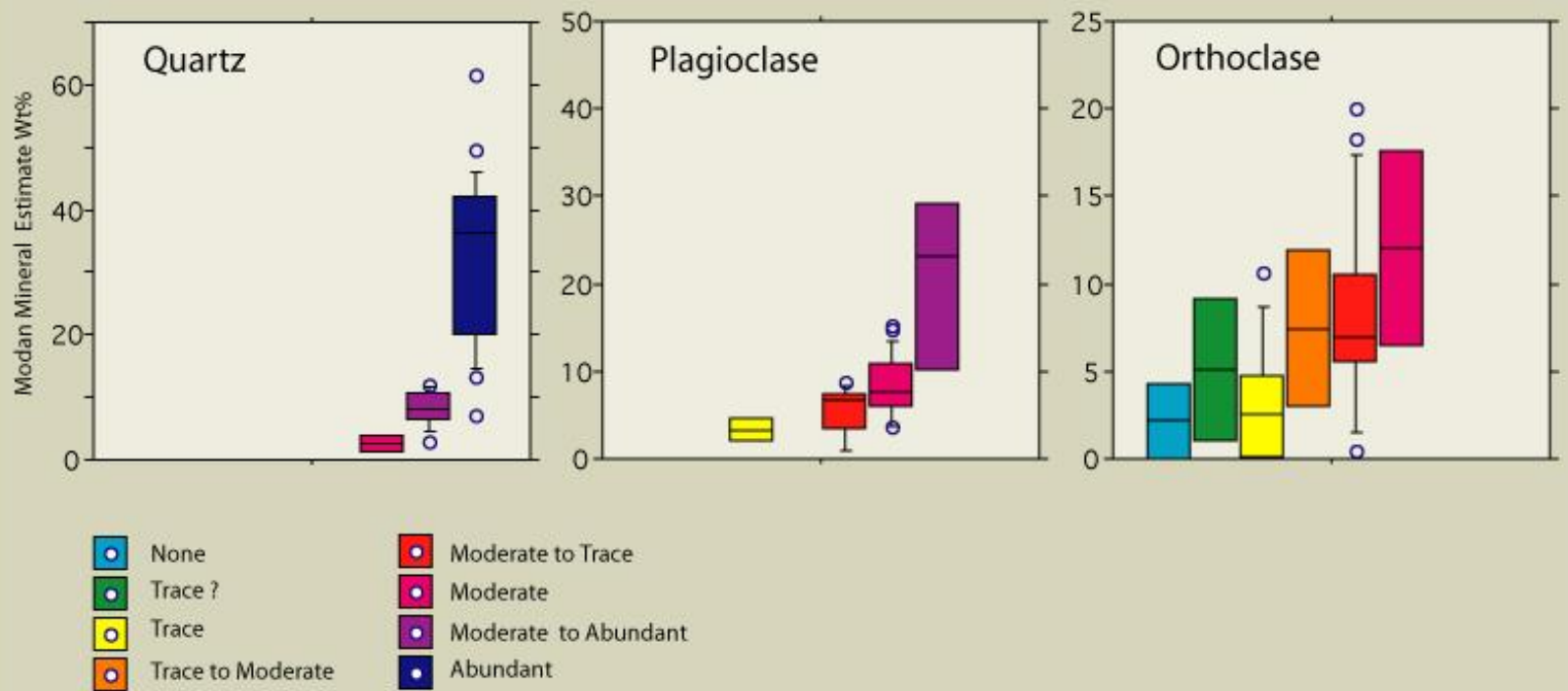
Trace Metals - Al



Geochemical Transect Profiles

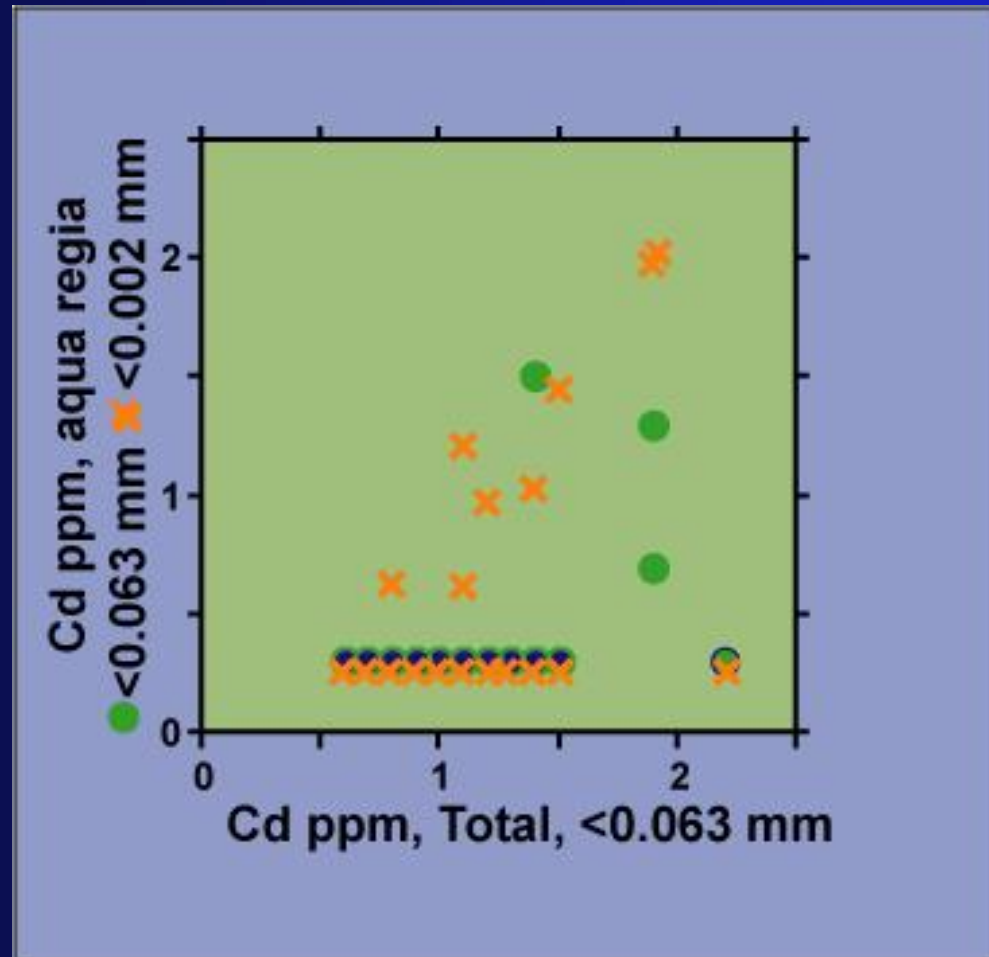
SiO_2 , Al_2O_3 , CaO wt%





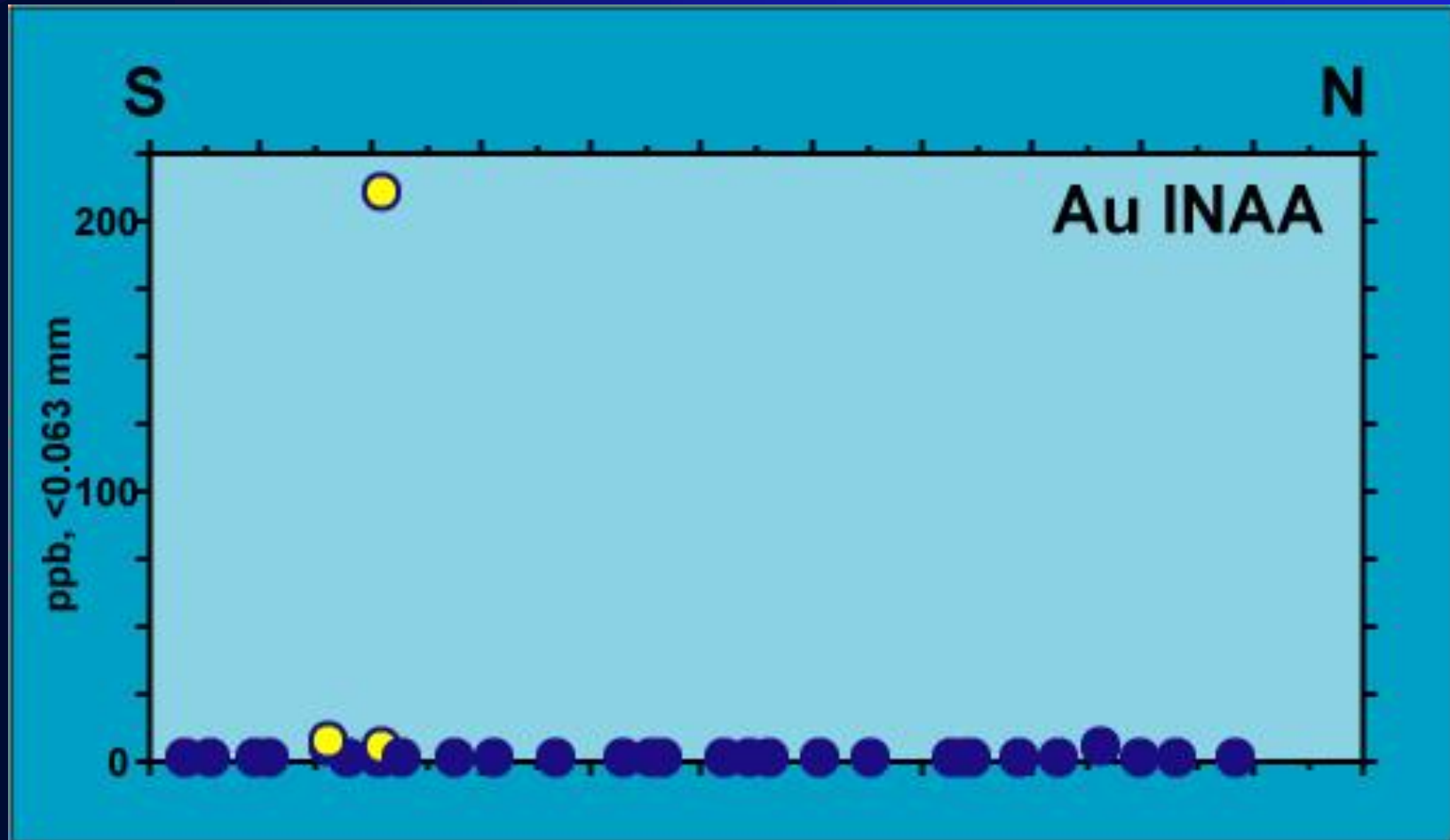
Aqua Regia Vs Total

No Correlation – Analytical Uncertainty



Geochemical Transect Profile

Mineral Resources - Au



Grain Size Comparison

≤0.002 mm Vs ≤0.063 mm

