

Typical and exotic rock physical property distributions

Randy Enkin, GSC-Pacific

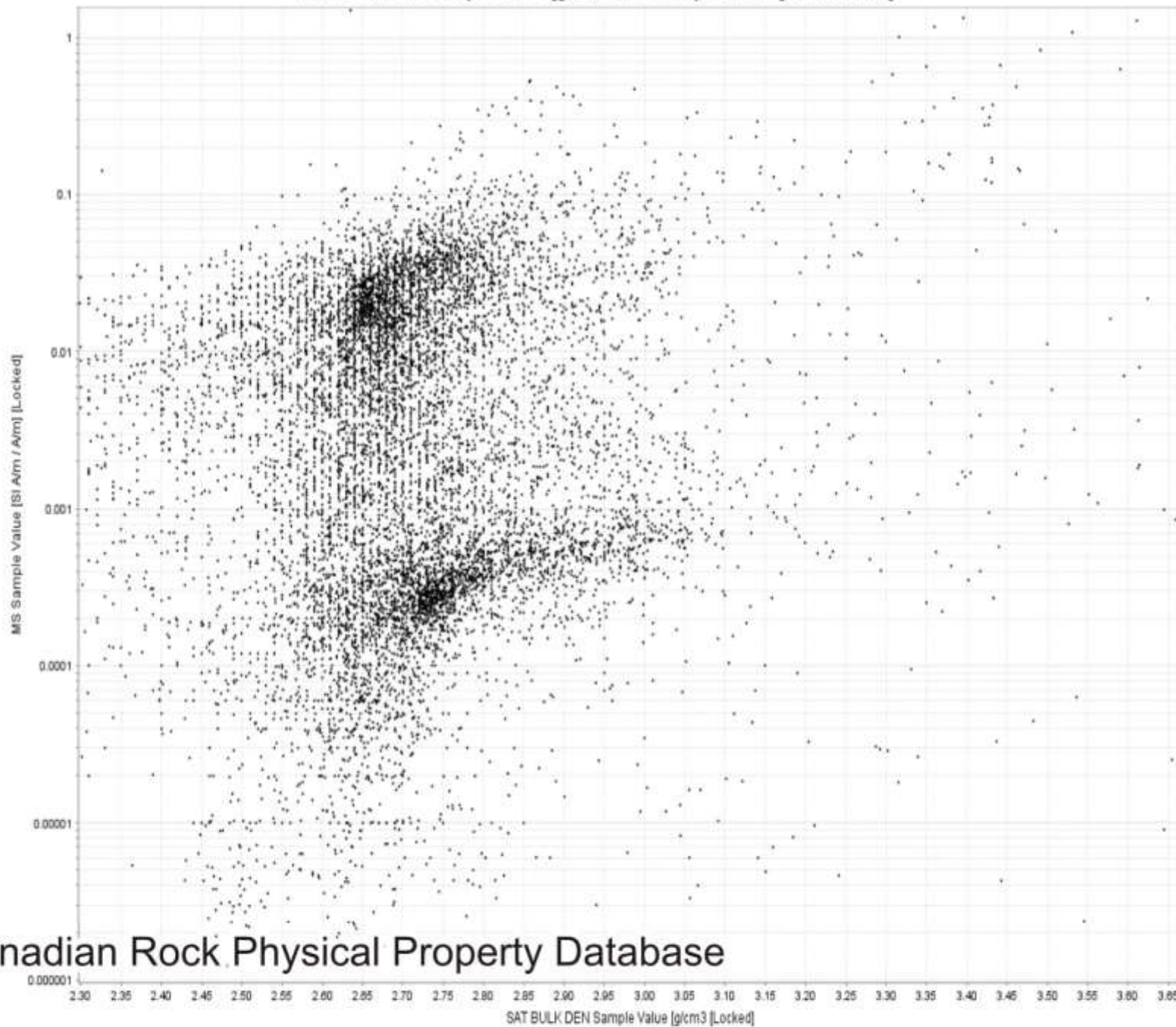
Paleomagnetism and Petrophysics Laboratory



Natural Resources Canada
Ressources naturelles Canada



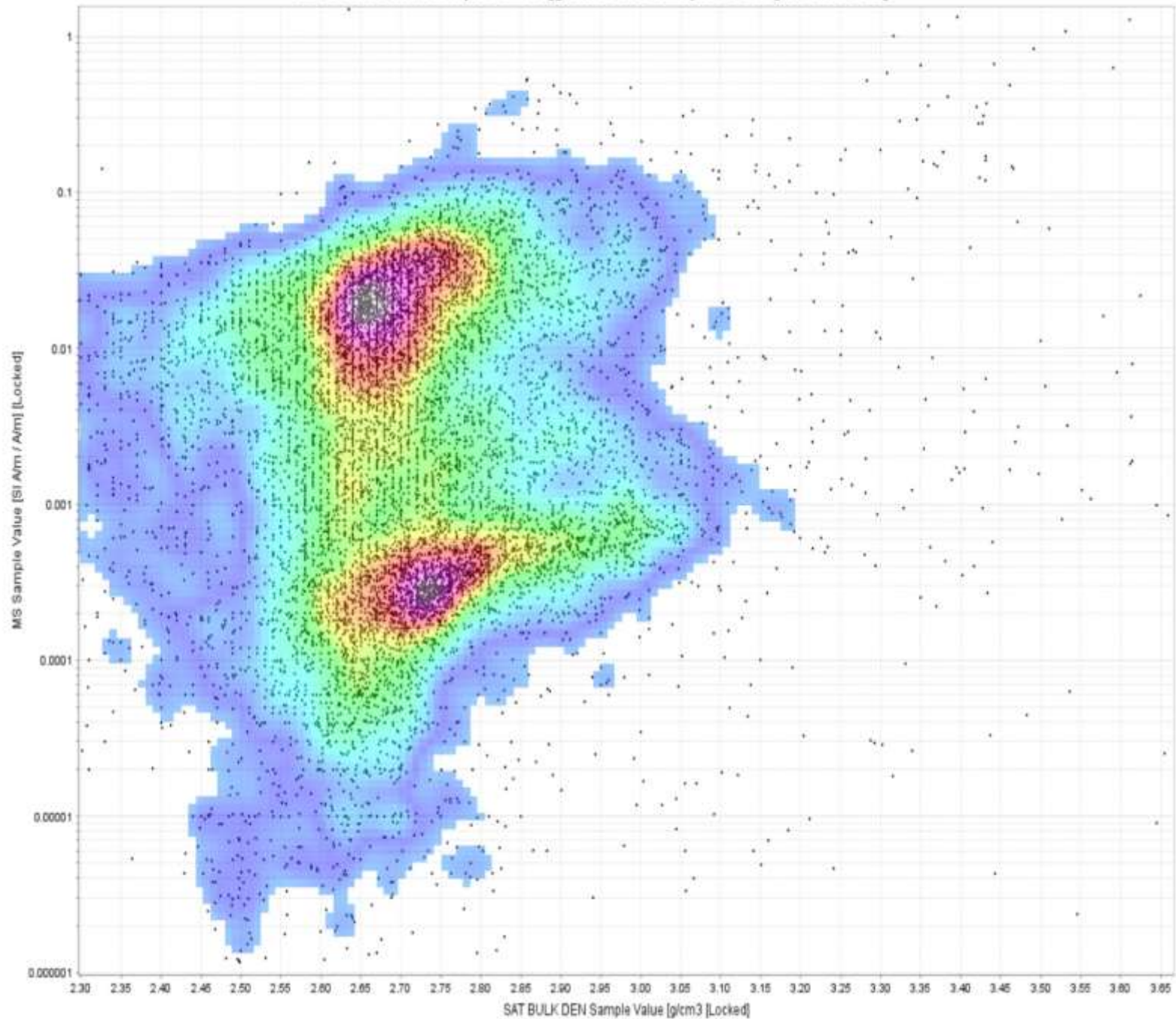
SAT BULK DEN Sample Value [g/cm3 : MS Sample Value [SI A/m / A/m]



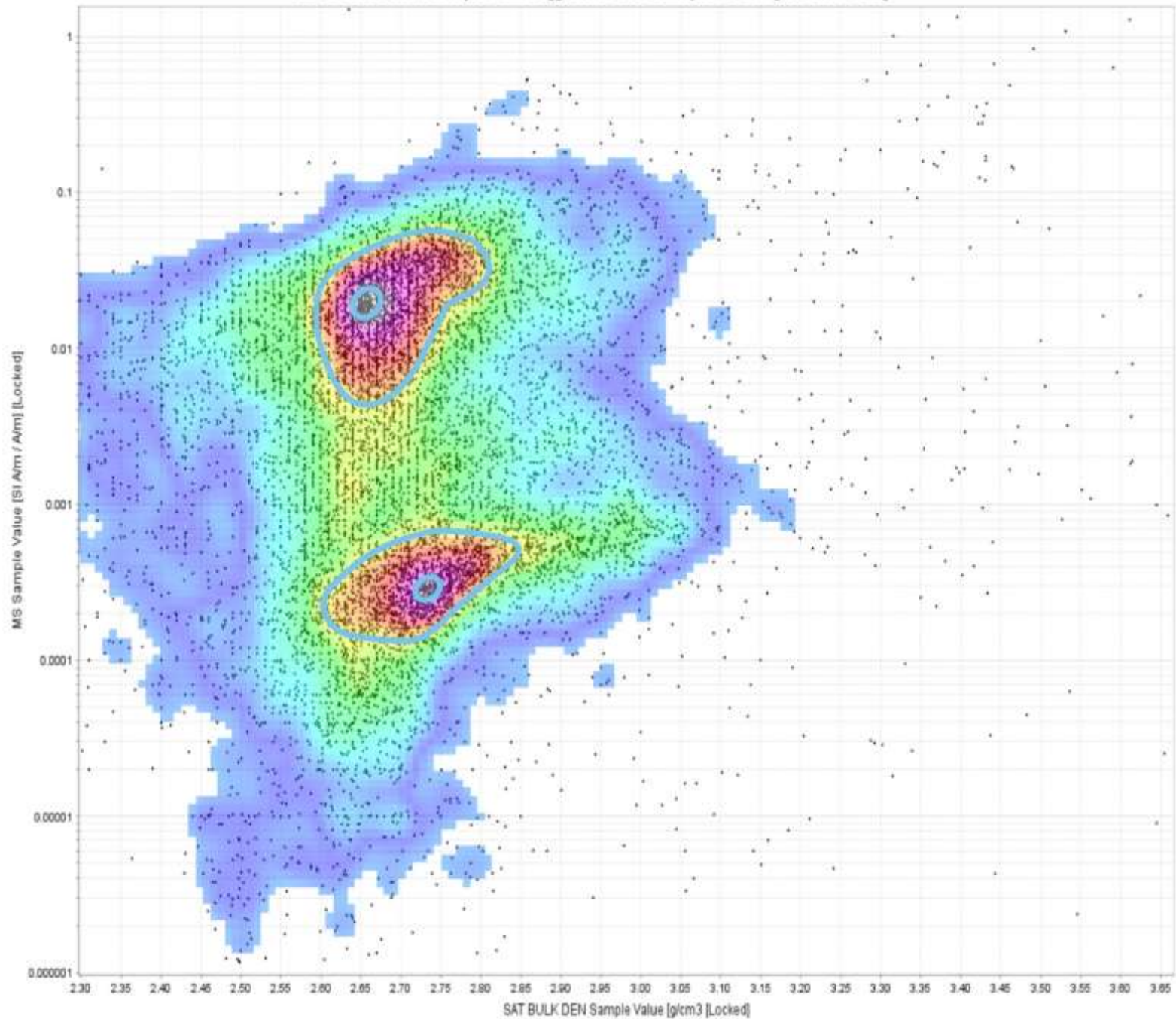
Canadian Rock Physical Property Database

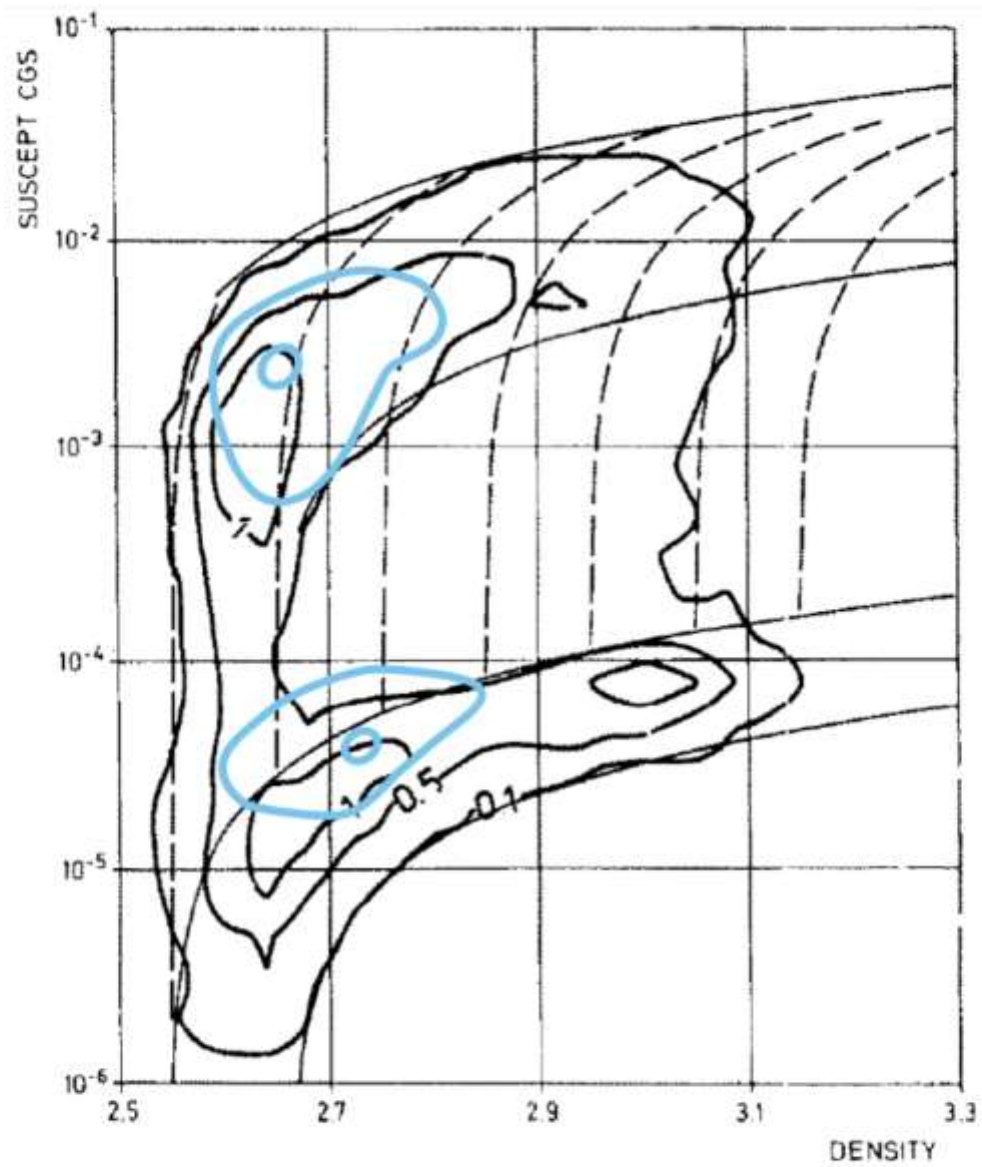
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SAT BULK DEN Sample Value [g/cm3] [Locked]

SAT BULK DEN Sample Value [g/cm3 : MS Sample Value [SI A/m / A/m]

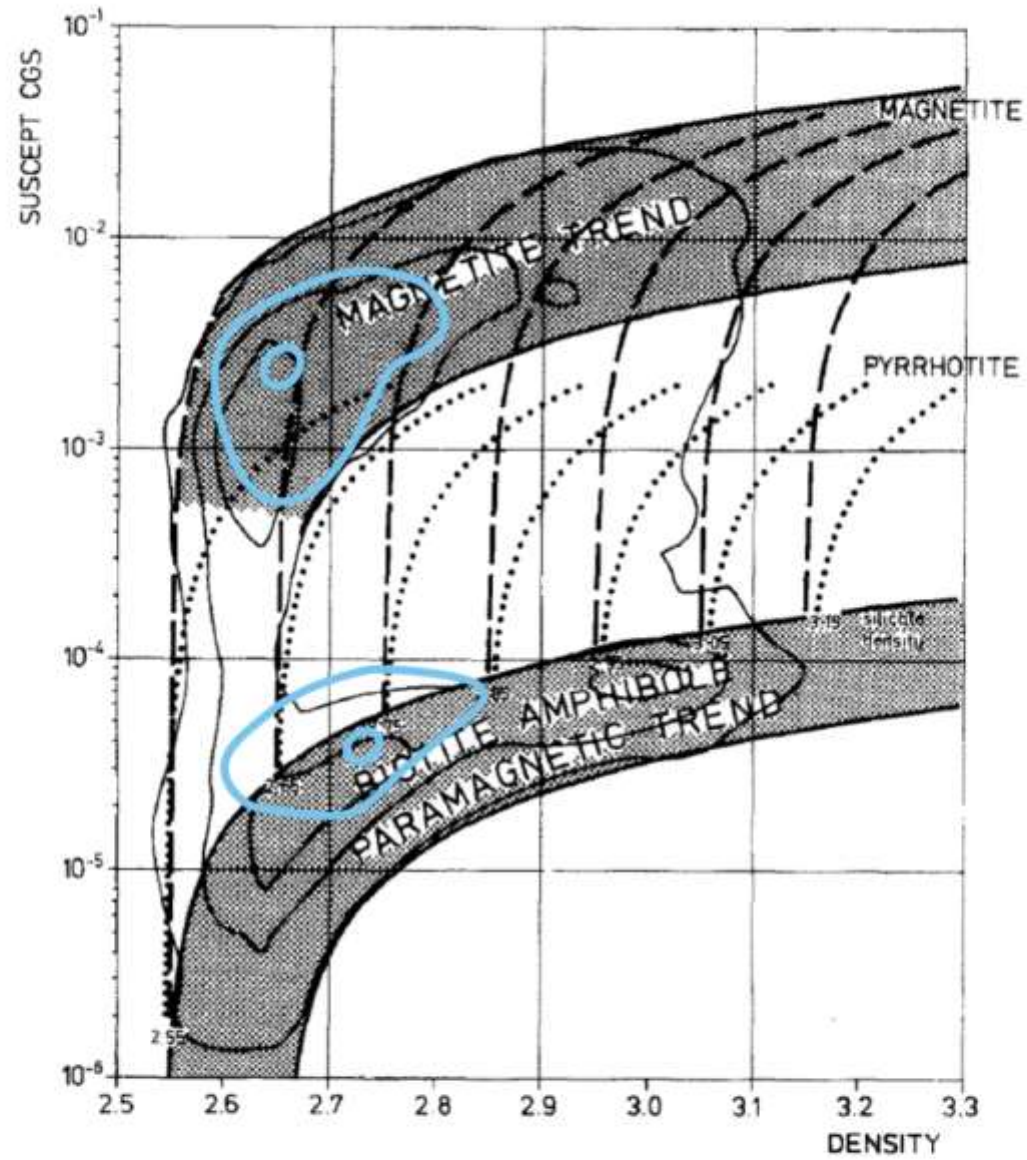


SAT BULK DEN Sample Value [g/cm3 : MS Sample Value [SI A/m / A/m]

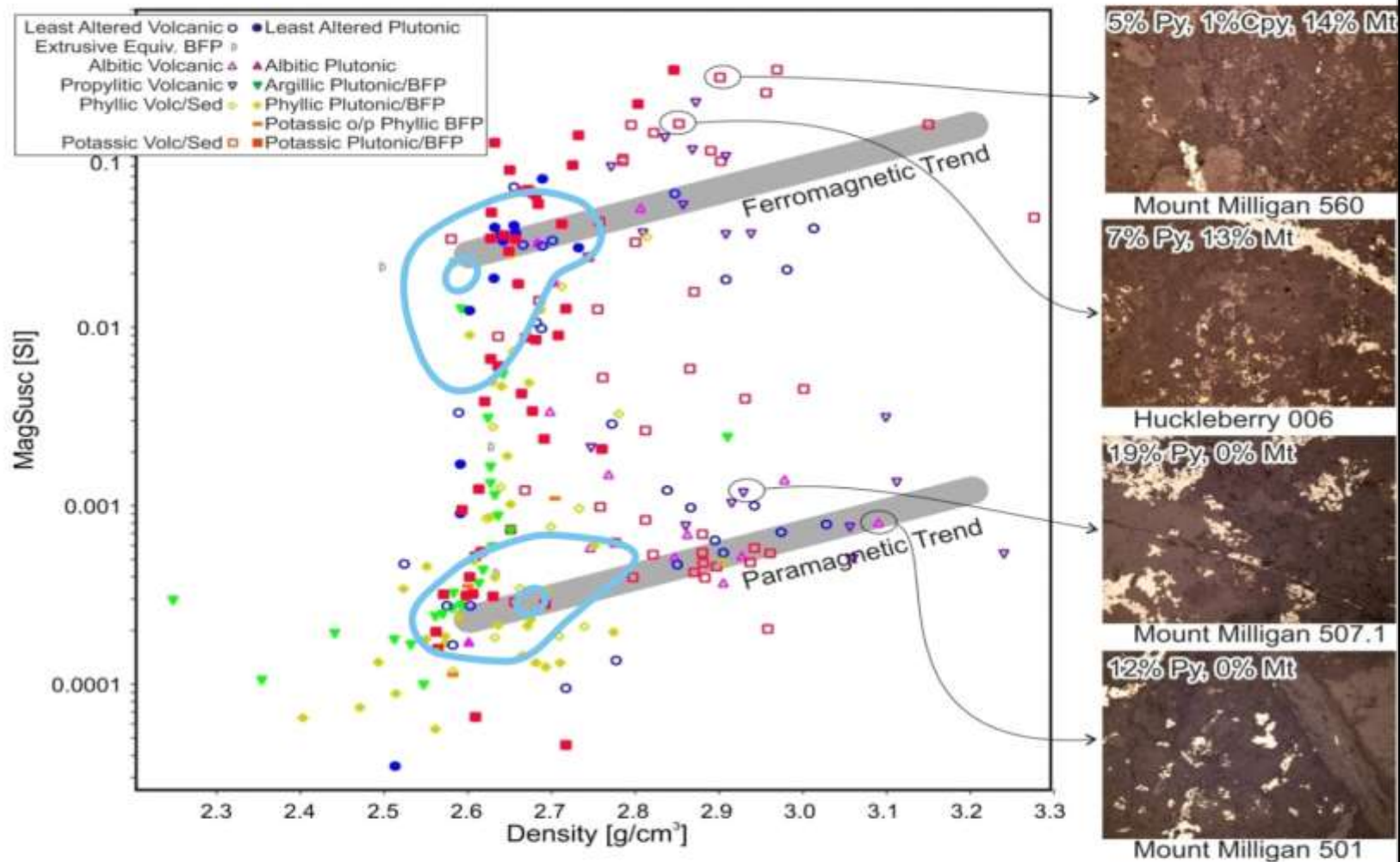




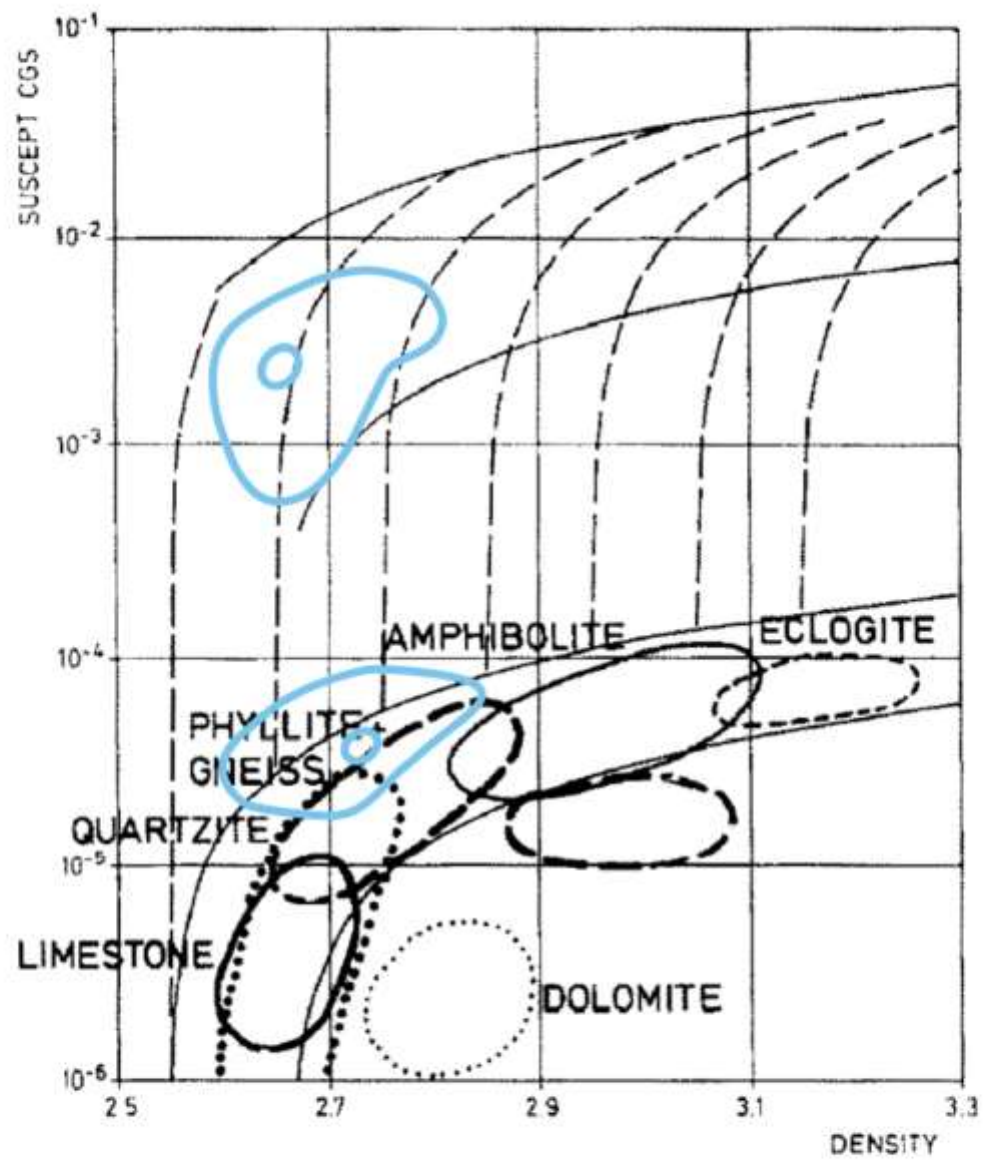
Henkel, 1991 Scandinavia, Precambrian



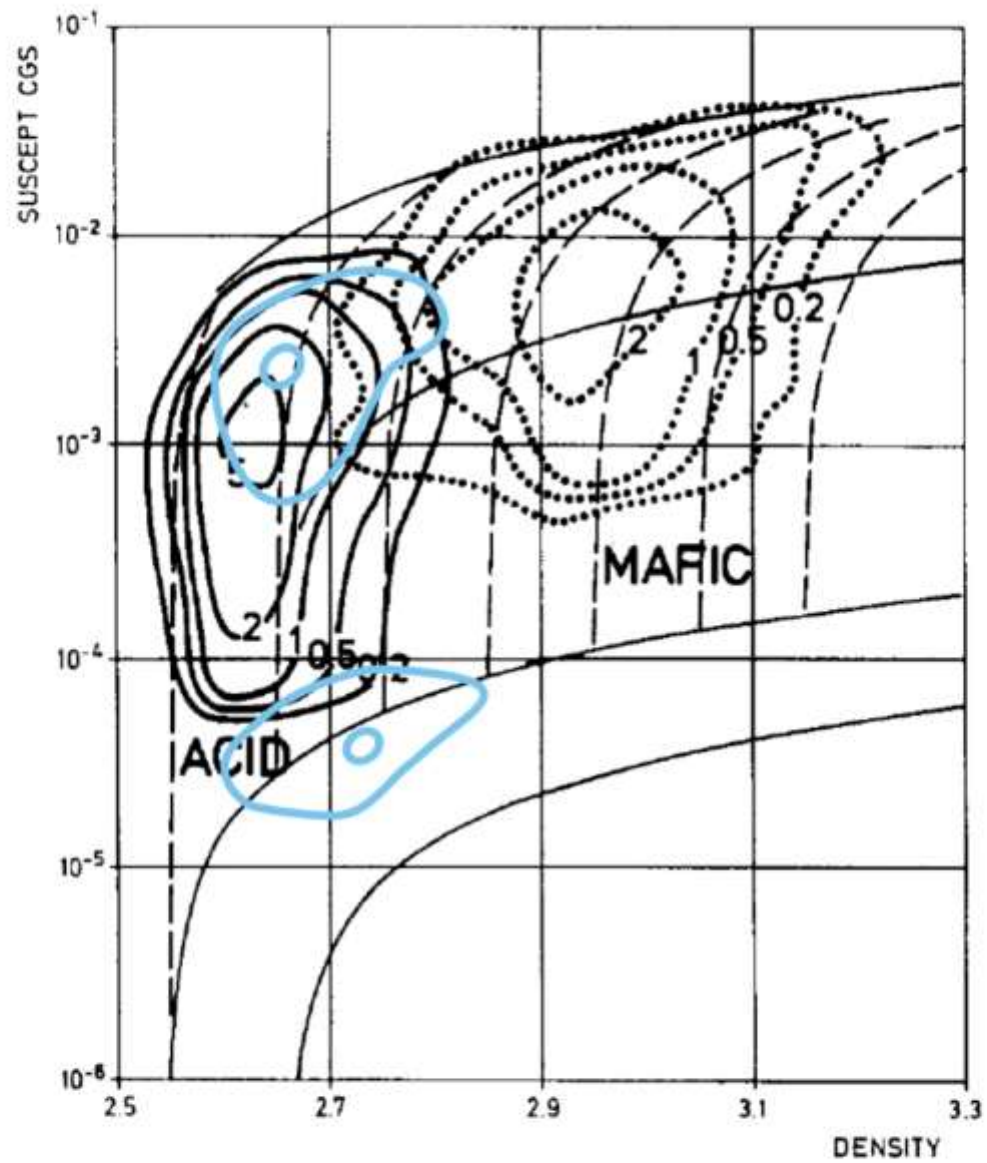
Henkel, 1991



Mitchinson, Enkin and Hart, 2013 BC Porphyry Deposits



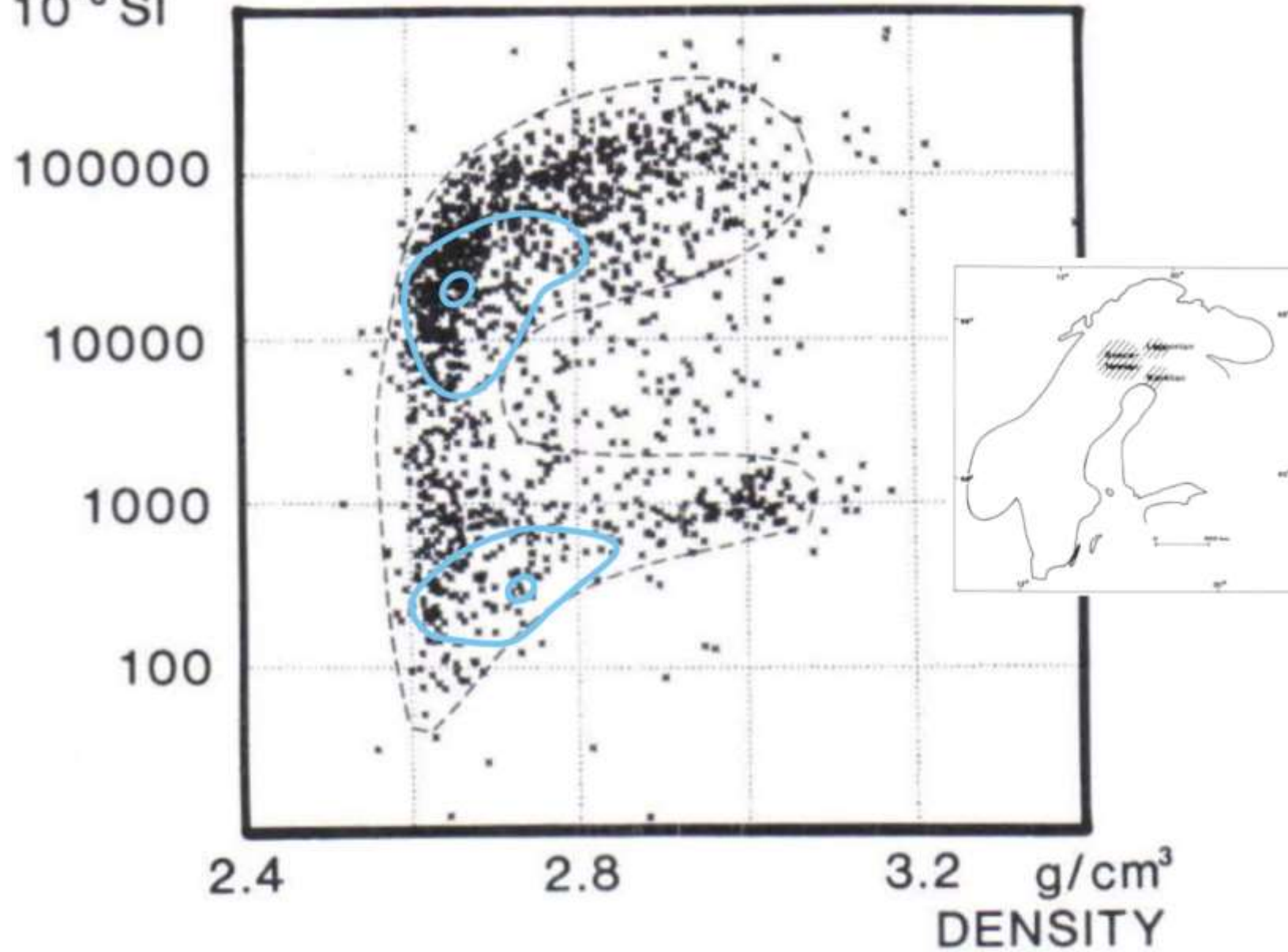
Henkel, 1991 Scandinavia, Caledonian Paramagnetic



Henkel, 1994 Scandinavia, Plutonic

SUSCEPTIBILITY

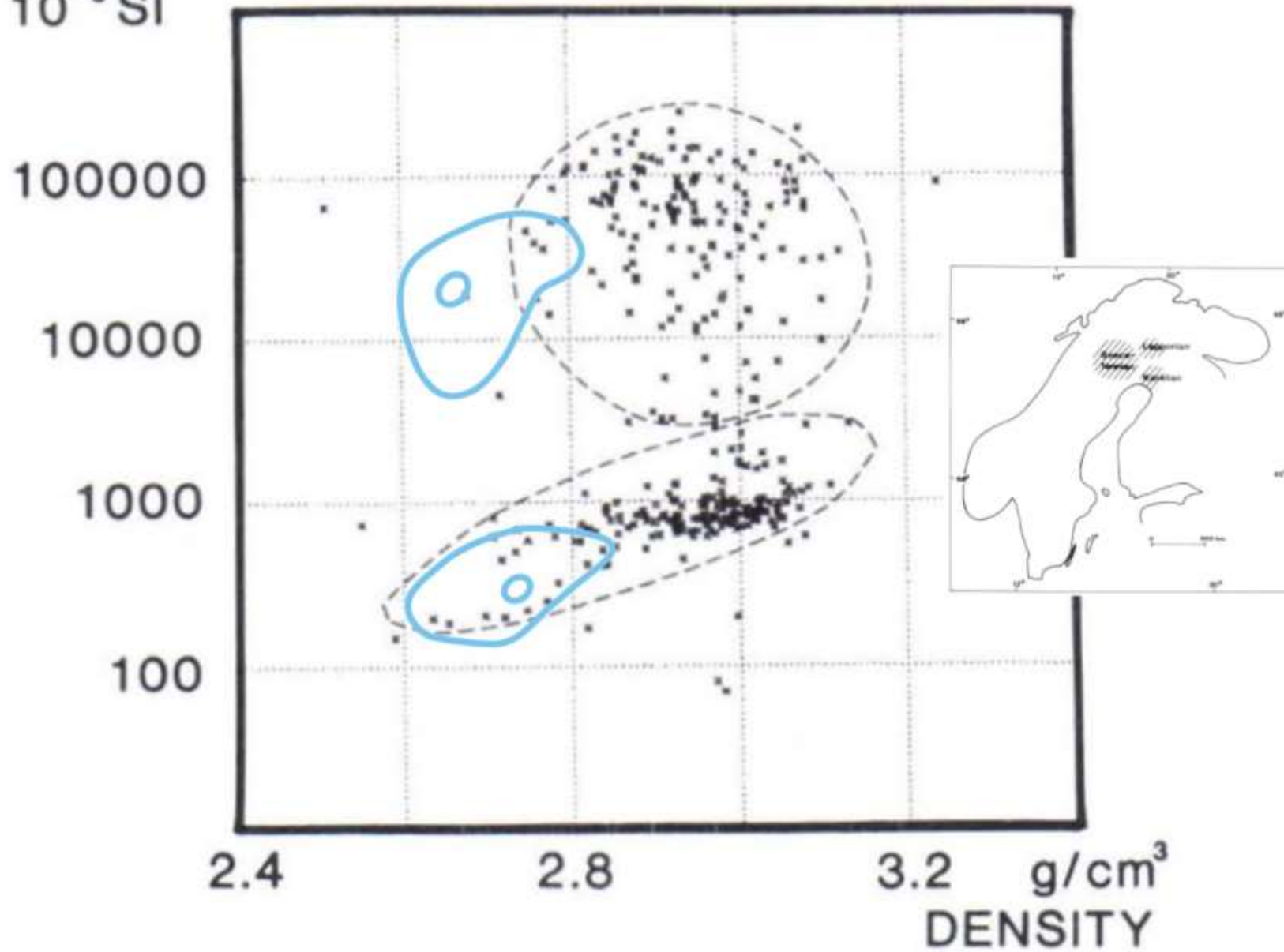
10^{-6} SI



Aero, 1990 Svecofennia

SUSCEPTIBILITY

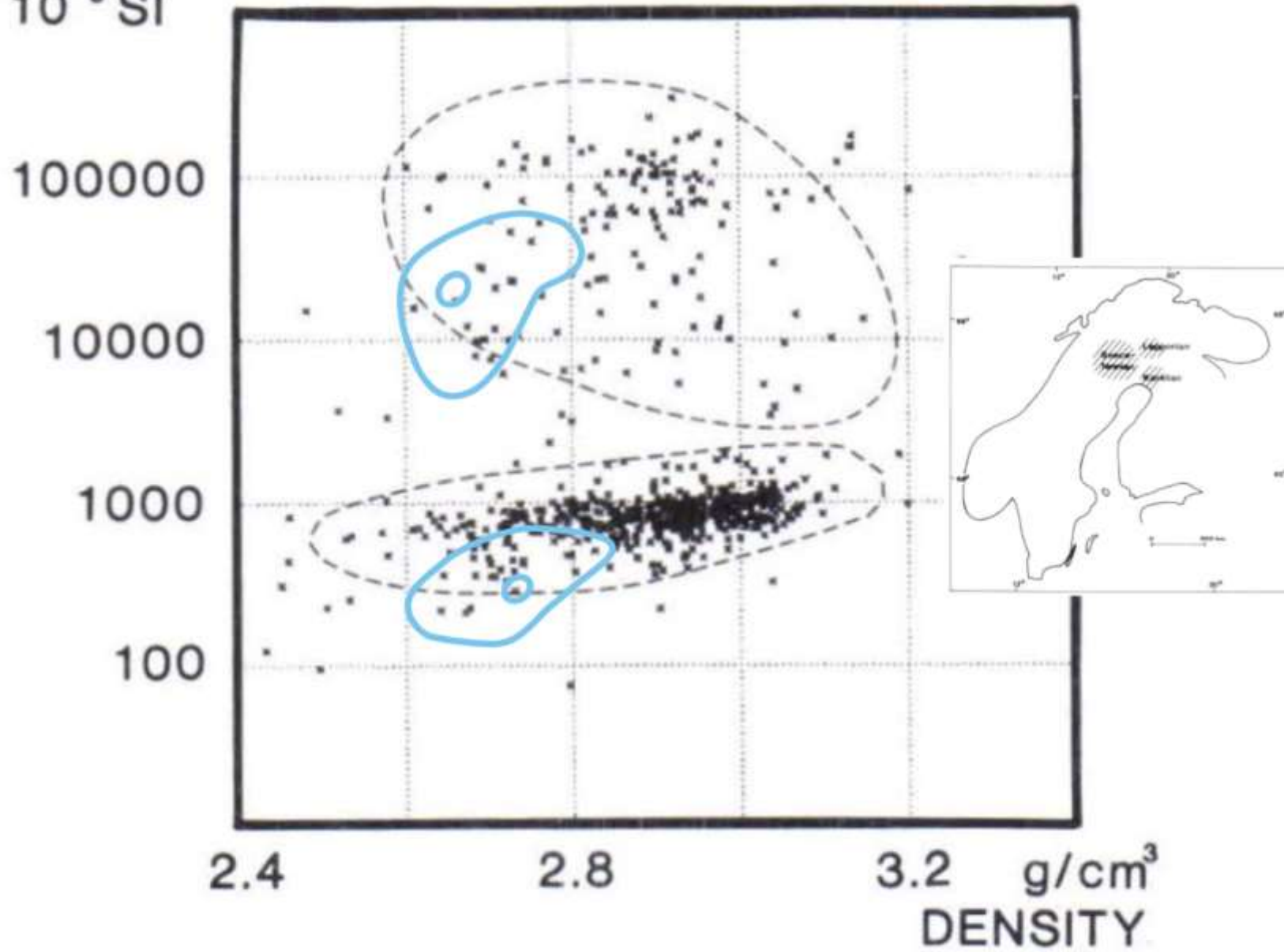
10^{-6} SI



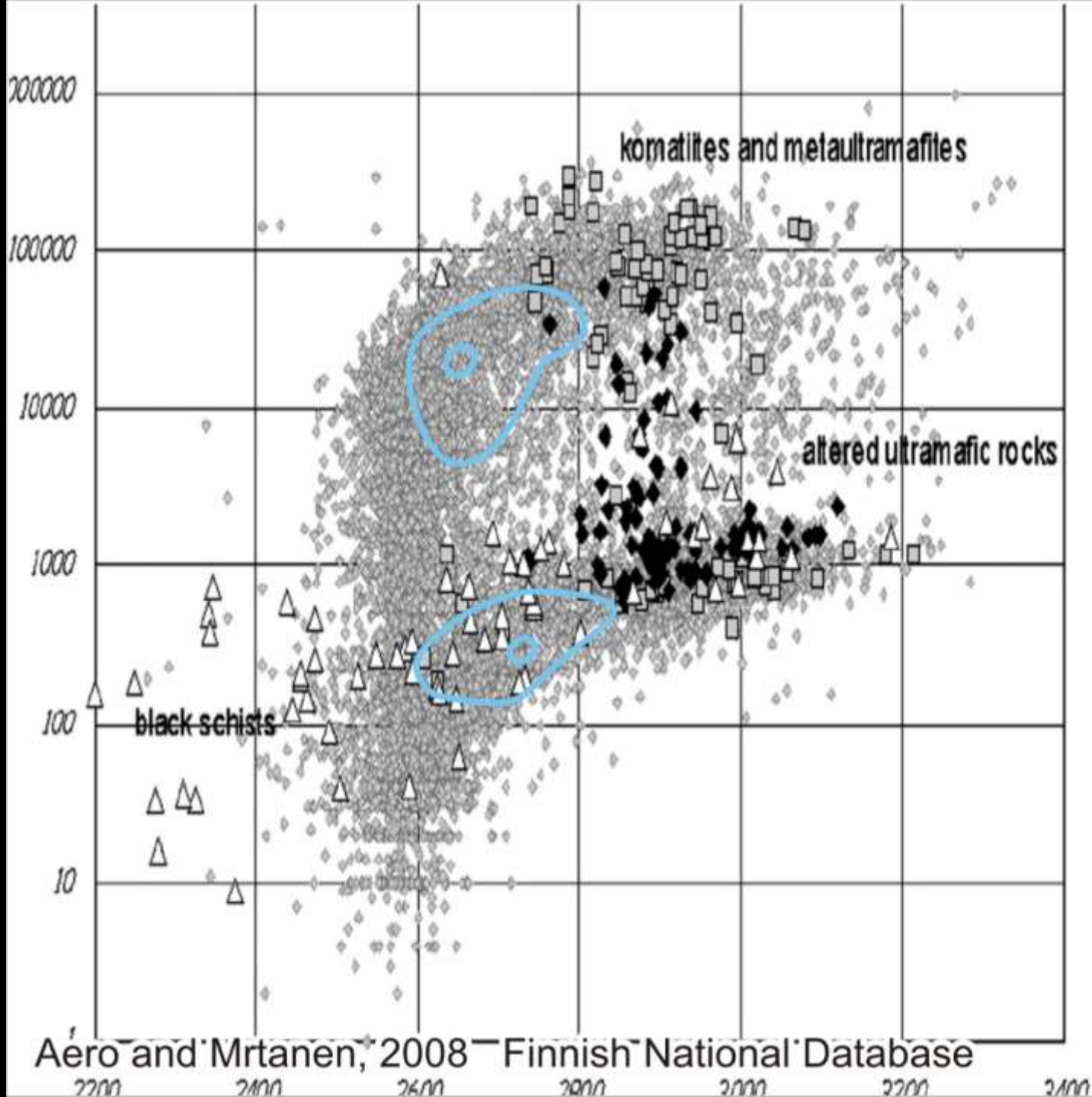
Aero, 1990 Karelia

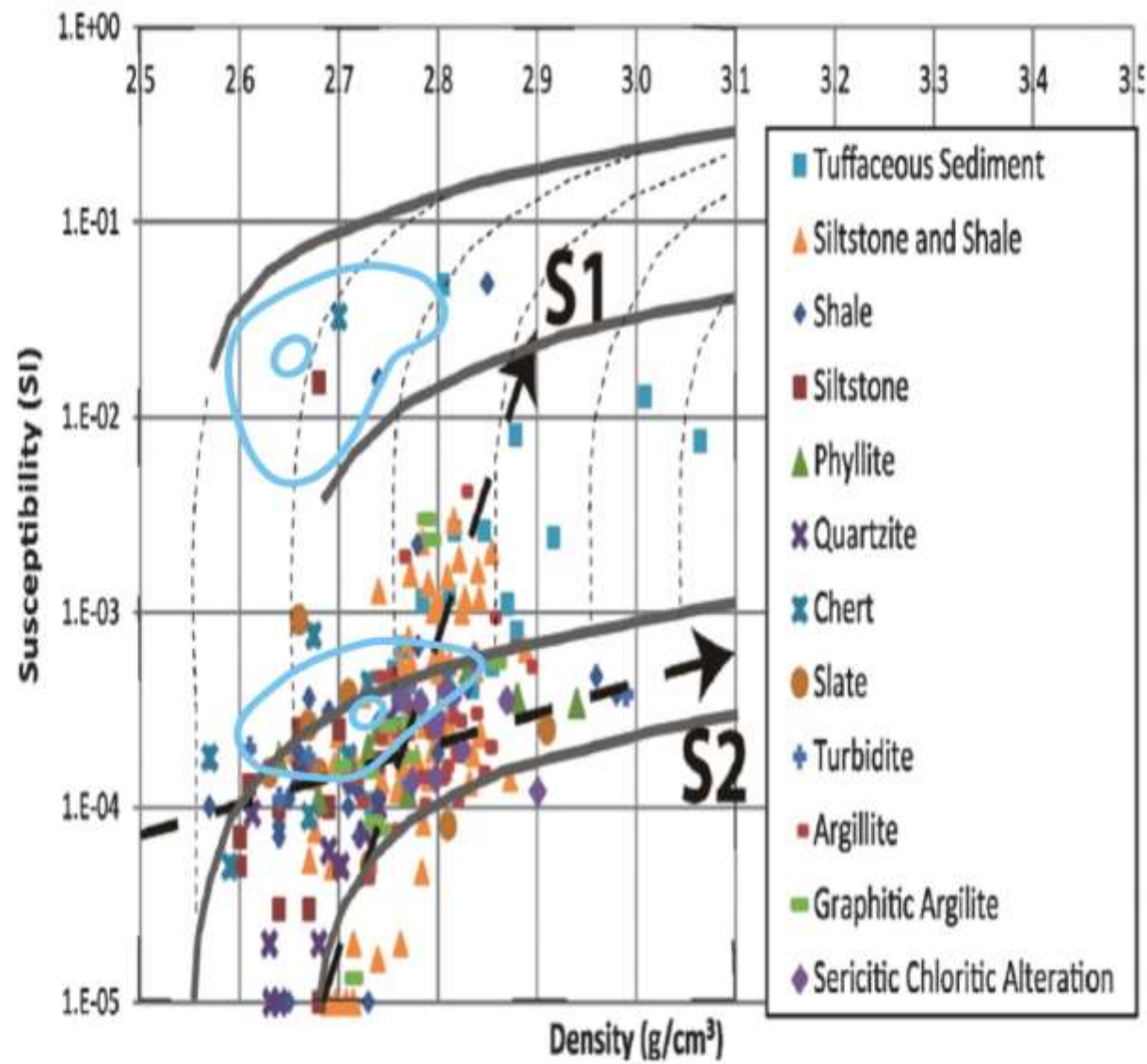
SUSCEPTIBILITY

10^{-6} SI



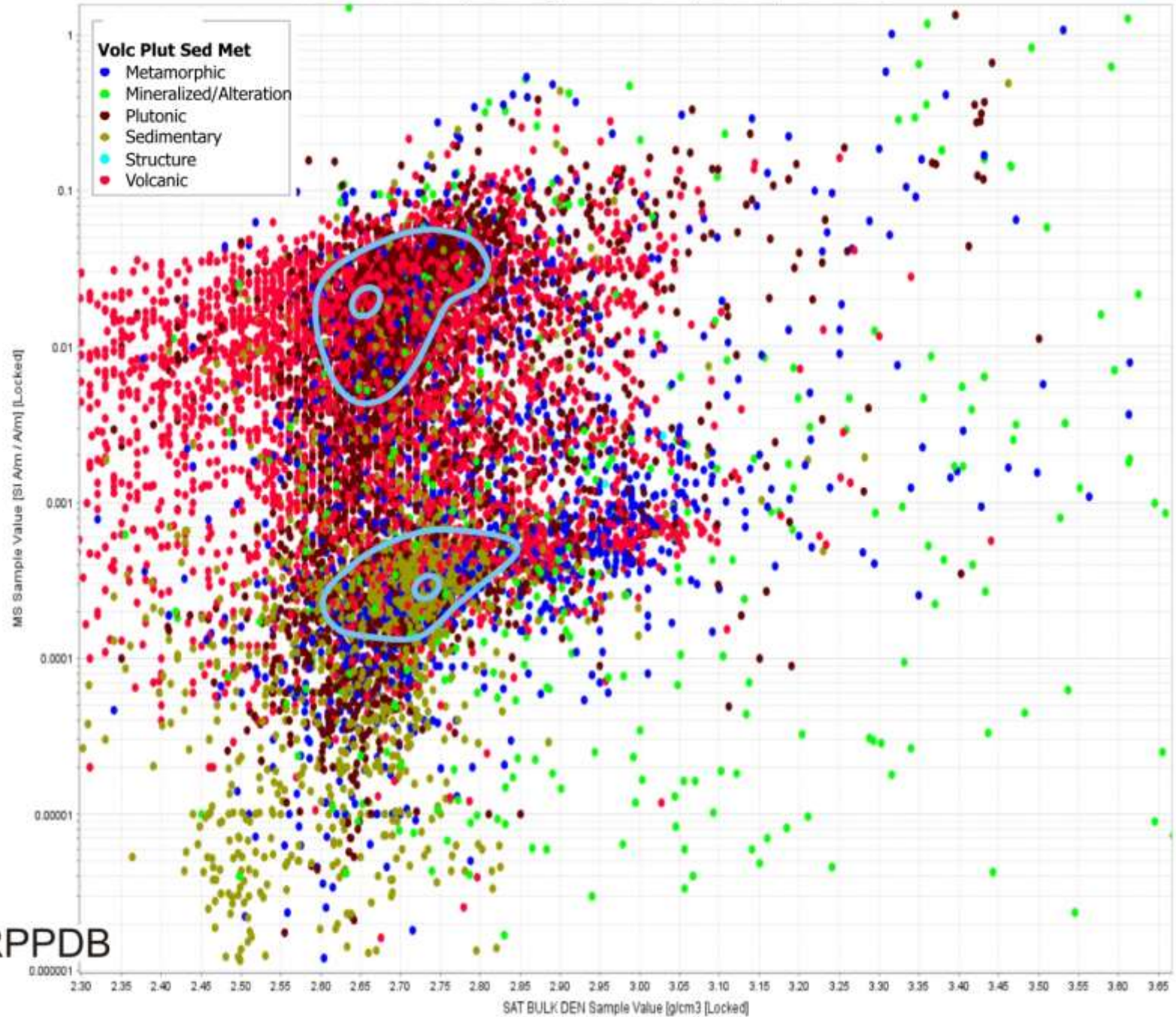
Aero, 1990 Lapponia





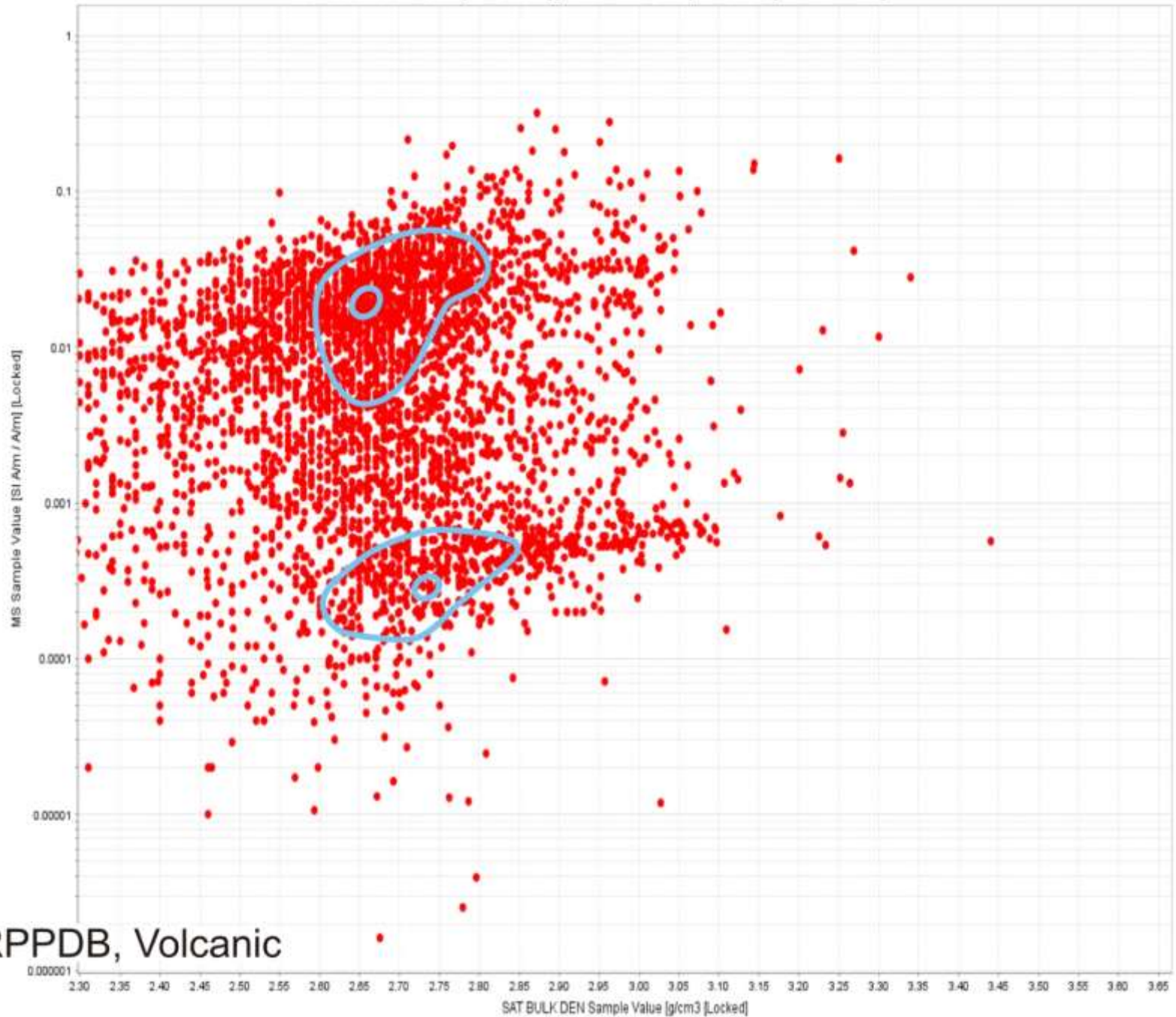
Tschirhart and Morris, 2014, Bathurst Nova Scotia, Canada

SAT BULK DEN Sample Value [g/cm³ : MS Sample Value [SI A/m / A/m]



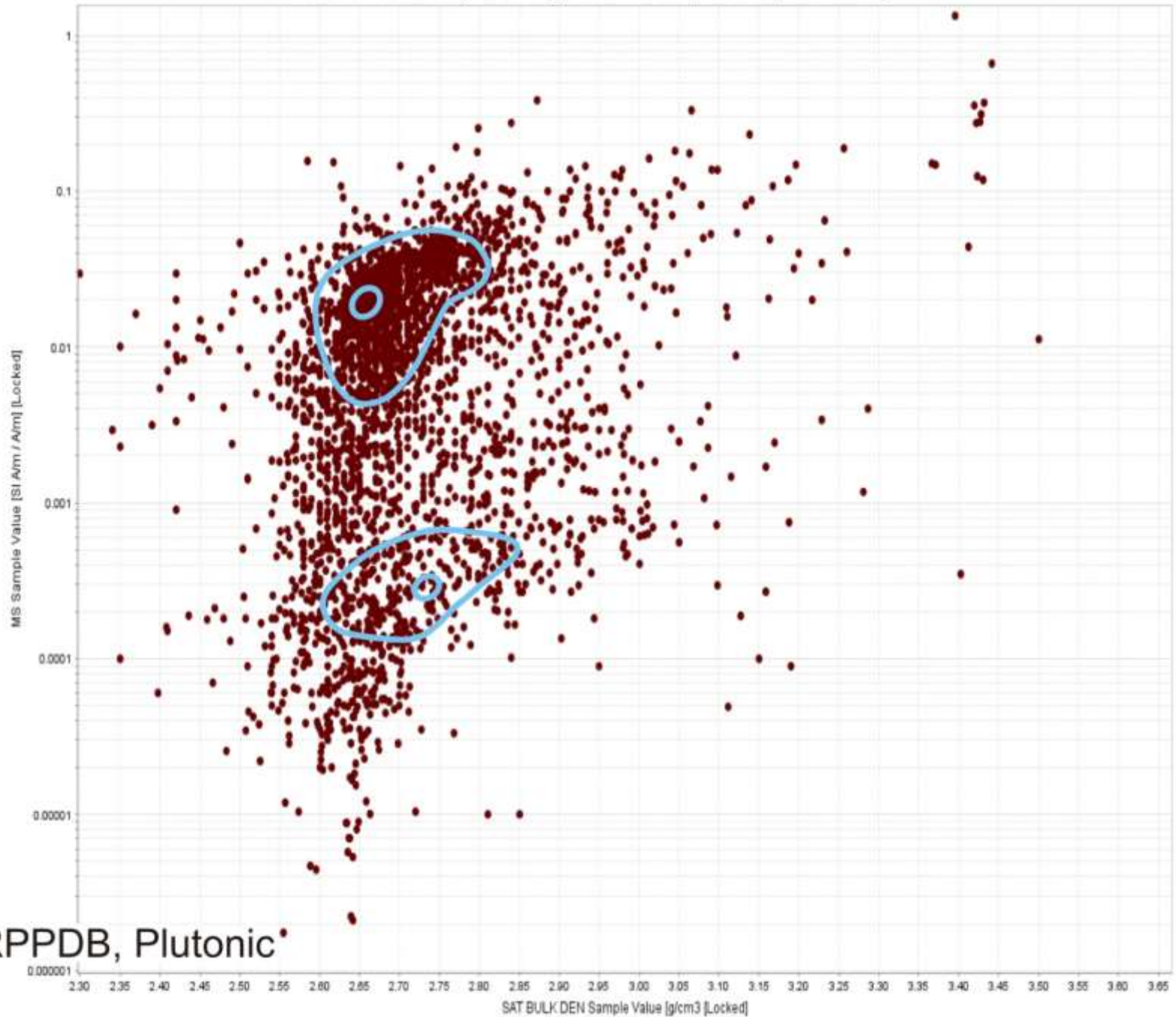
CRPPDB

SAT BULK DEN Sample Value [g/cm³ : MS Sample Value [SI A/m / A/m]



CRPPDB, Volcanic

SAT BULK DEN Sample Value [g/cm3 : MS Sample Value [SI A/m / A/m]

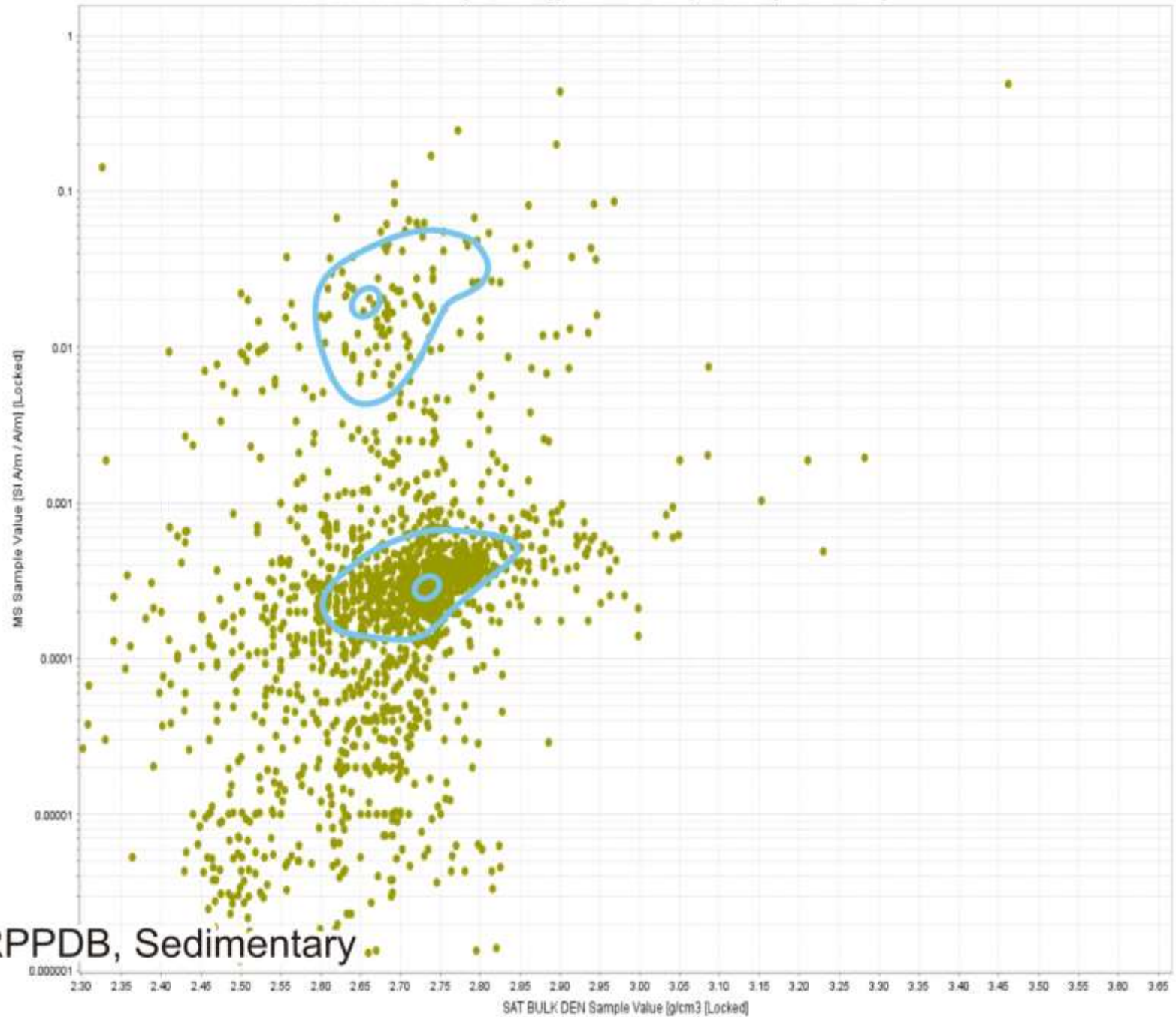


CRPPDB, Plutonic

0.000001

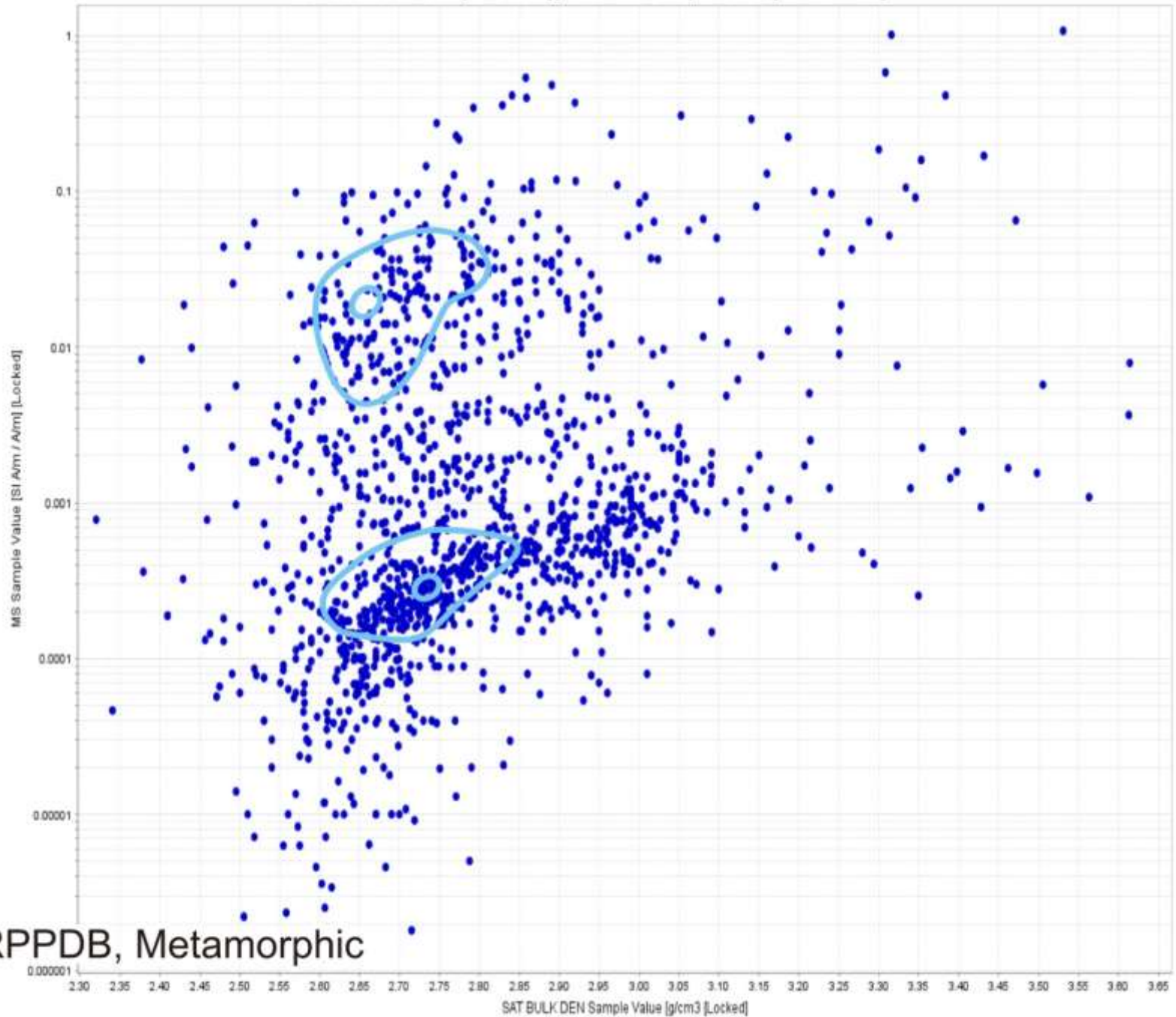
SAT BULK DEN Sample Value [g/cm3] [Locked]

SAT BULK DEN Sample Value [g/cm3 : MS Sample Value [SI A/m / A/m]



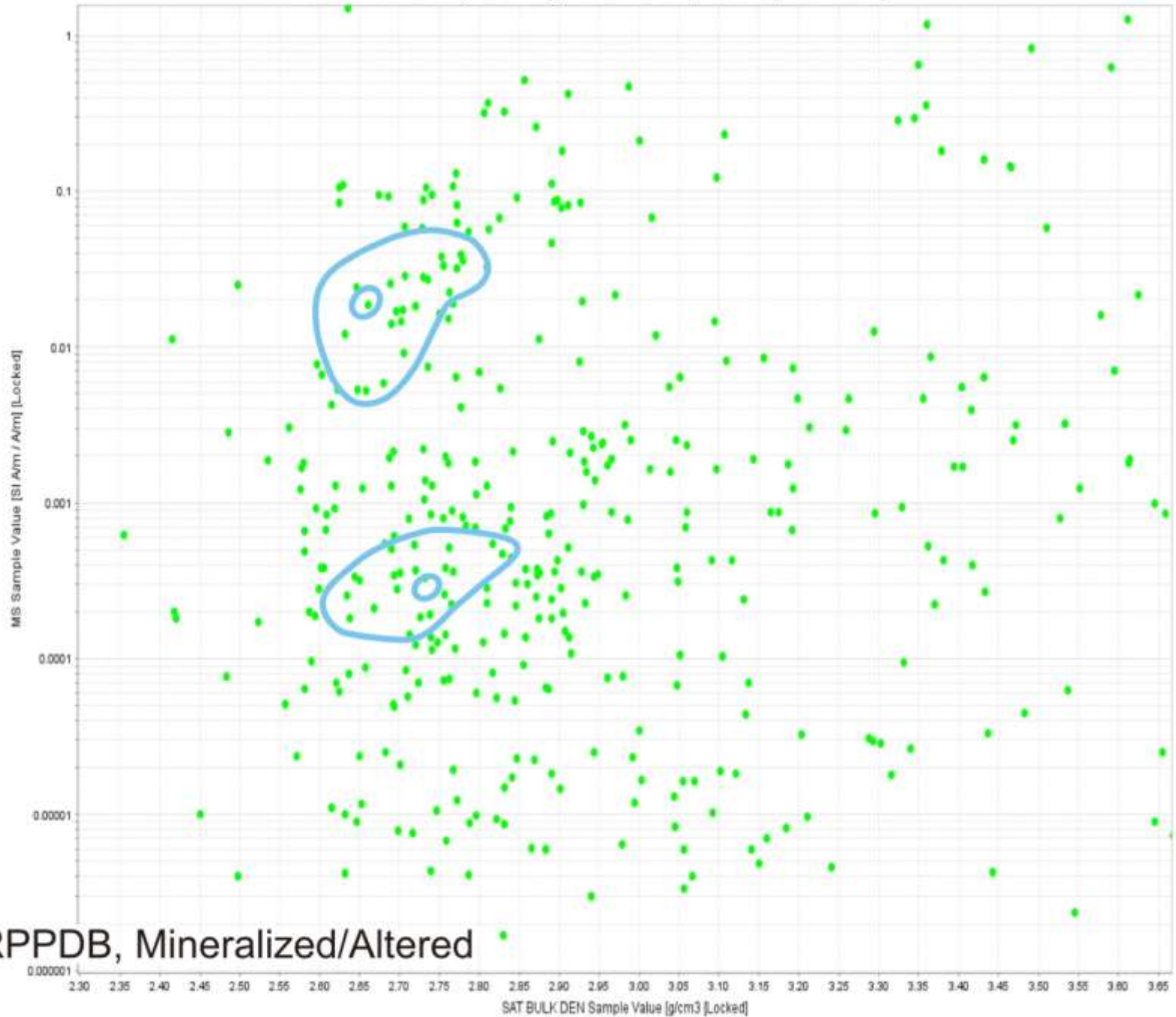
CRPPDB, Sedimentary

SAT BULK DEN Sample Value [g/cm³ : MS Sample Value [SI A/m / A/m]



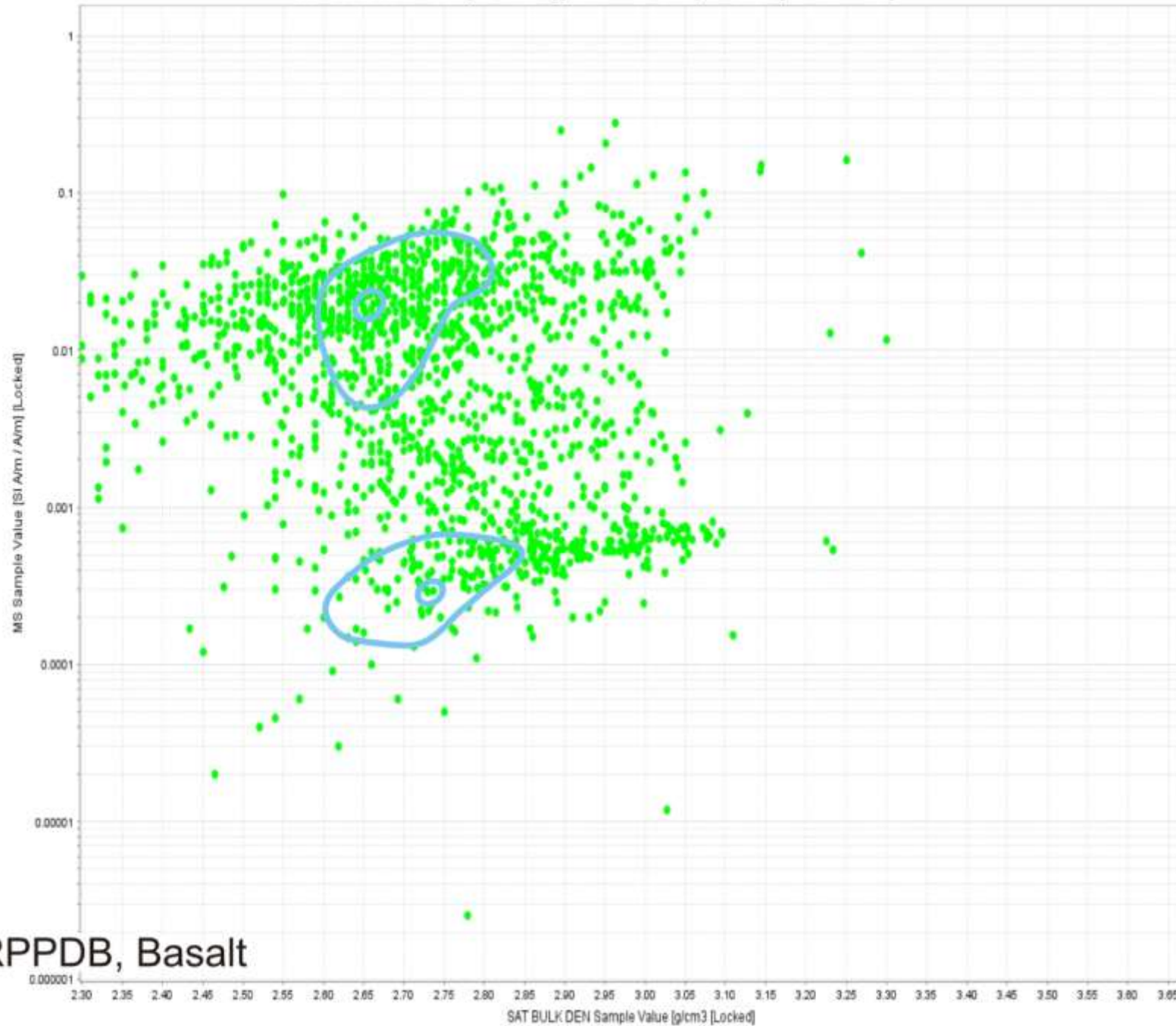
CRPPDB, Metamorphic

SAT BULK DEN Sample Value [g/cm3 : MS Sample Value [SI A/m / A/m]

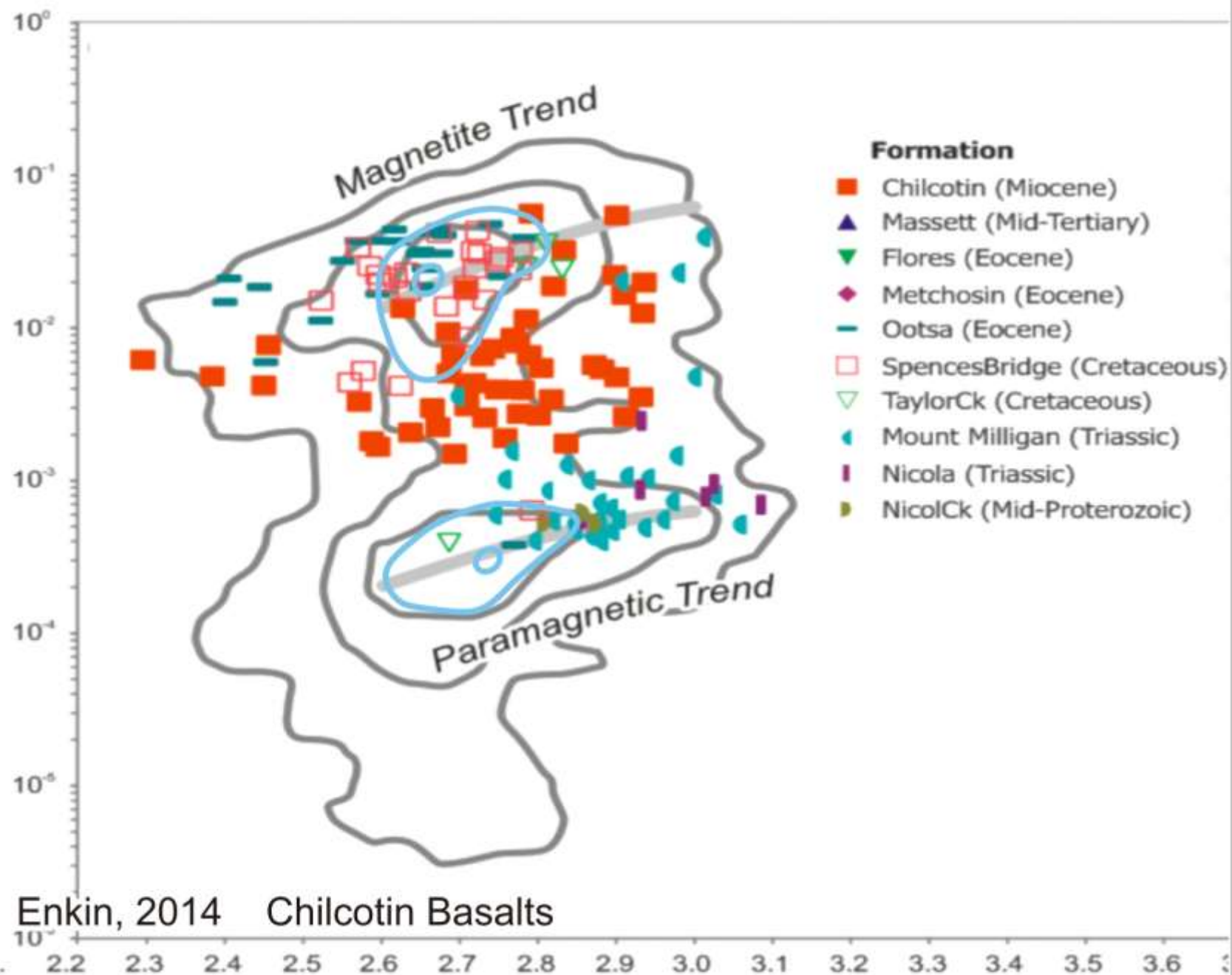


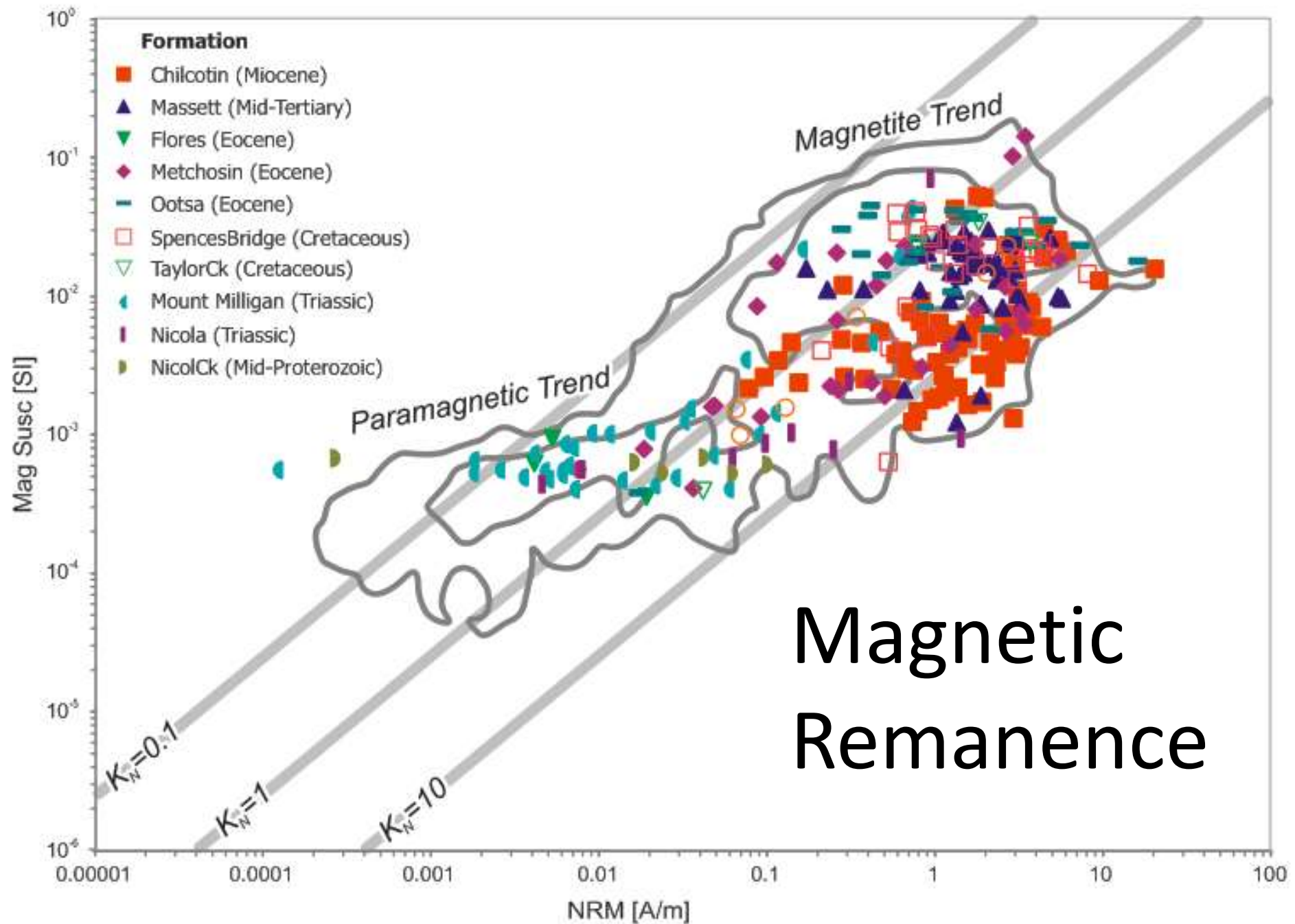
CRPPDB, Mineralized/Altered

SAT BULK DEN Sample Value [g/cm3 : MS Sample Value [SI A/m / A/m]

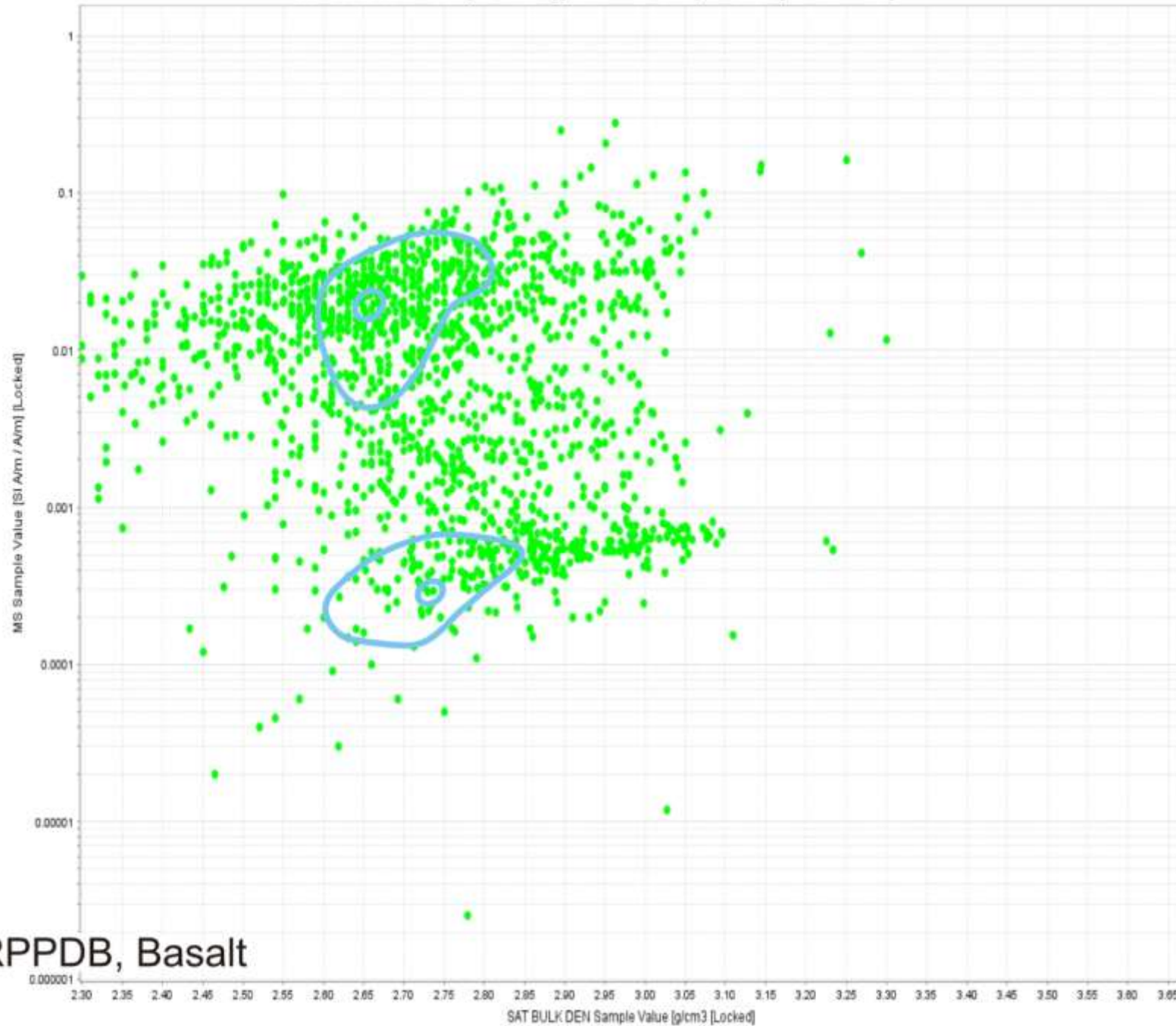


CRPPDB, Basalt



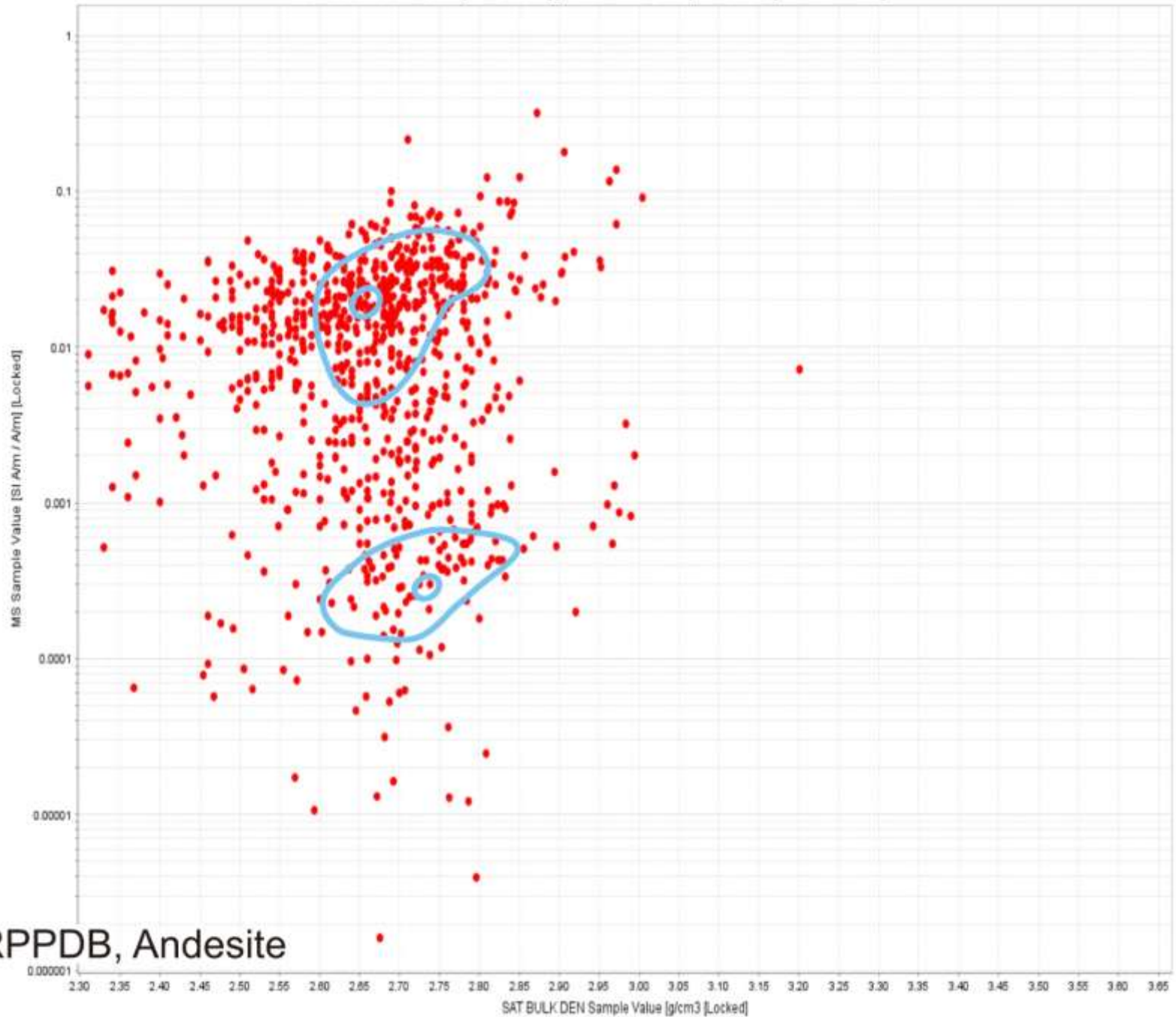


SAT BULK DEN Sample Value [g/cm³ : MS Sample Value [SI A/m / A/m]



CRPPDB, Basalt

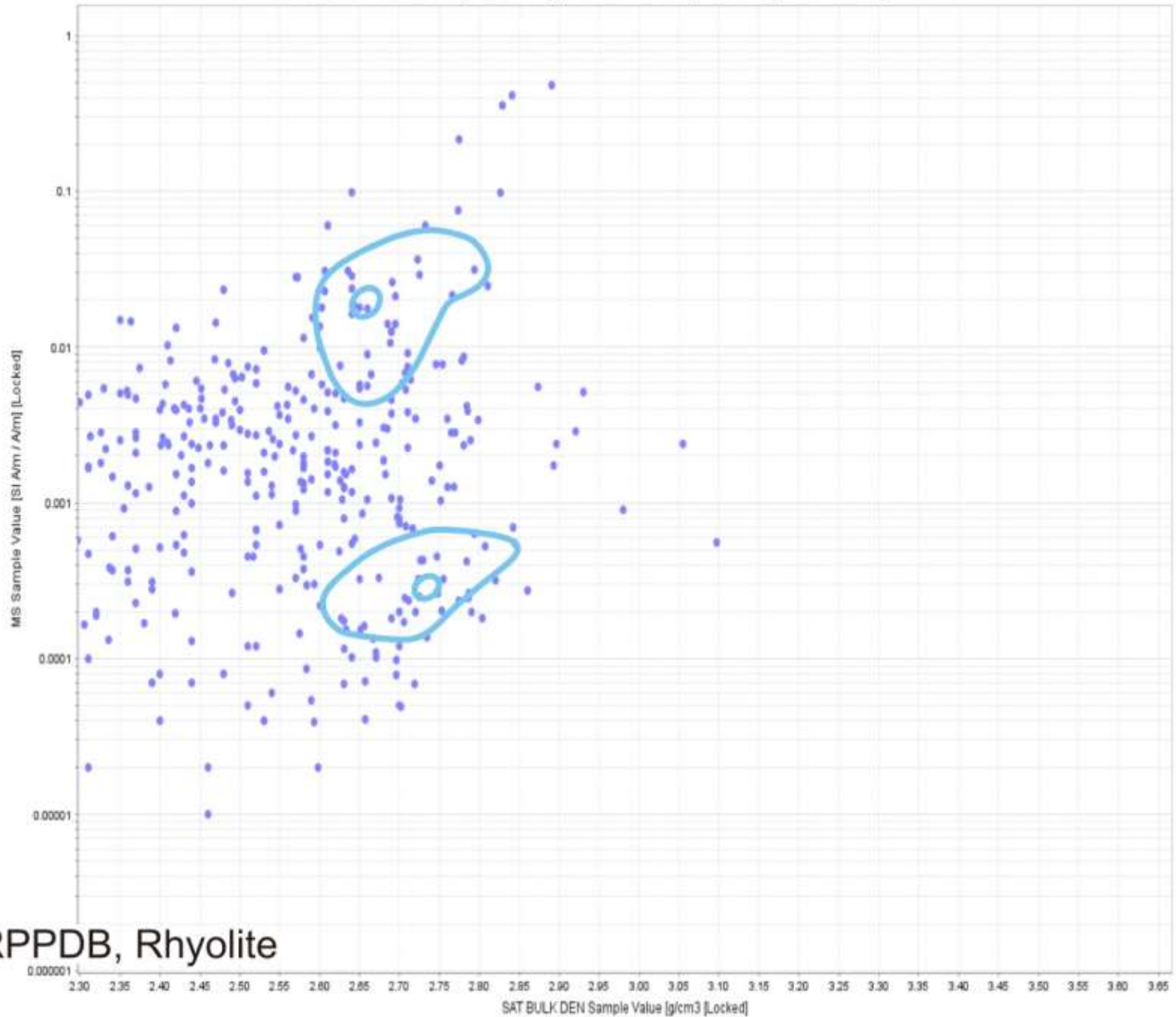
SAT BULK DEN Sample Value [g/cm3 : MS Sample Value [SI A/m / A/m]



CRPPDB, Andesite

0.000001 2.30 2.35 2.40 2.45 2.50 2.55 2.60 2.65 2.70 2.75 2.80 2.85 2.90 2.95 3.00 3.05 3.10 3.15 3.20 3.25 3.30 3.35 3.40 3.45 3.50 3.55 3.60 3.65
SAT BULK DEN Sample Value [g/cm3] [Locked]

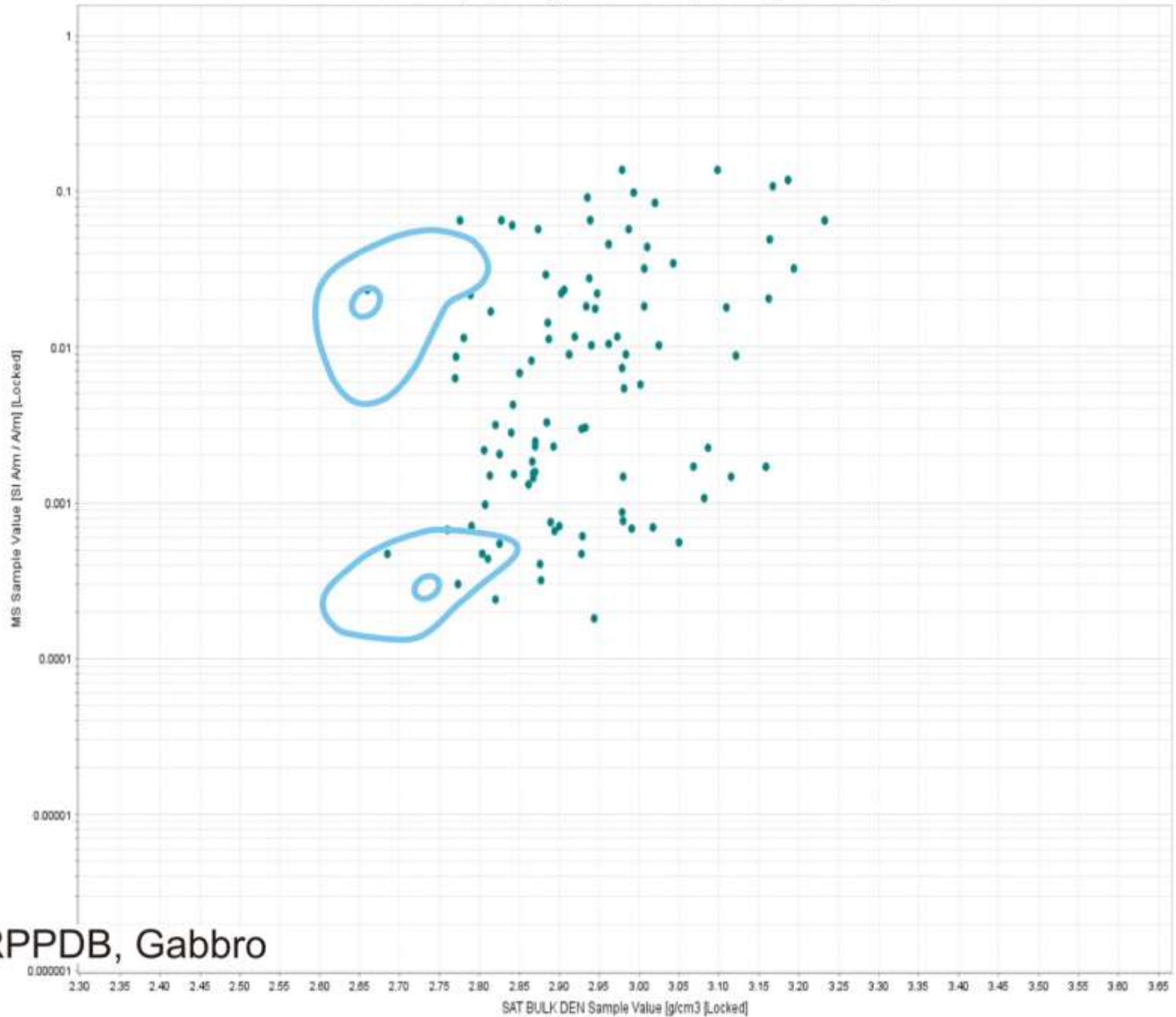
SAT BULK DEN Sample Value [g/cm³ : MS Sample Value [SI A/m / A/m]



CRPPDB, Rhyolite

0.000001 2.30 2.35 2.40 2.45 2.50 2.55 2.60 2.65 2.70 2.75 2.80 2.85 2.90 2.95 3.00 3.05 3.10 3.15 3.20 3.25 3.30 3.35 3.40 3.45 3.50 3.55 3.60 3.65
SAT BULK DEN Sample Value [g/cm³] [Locked]

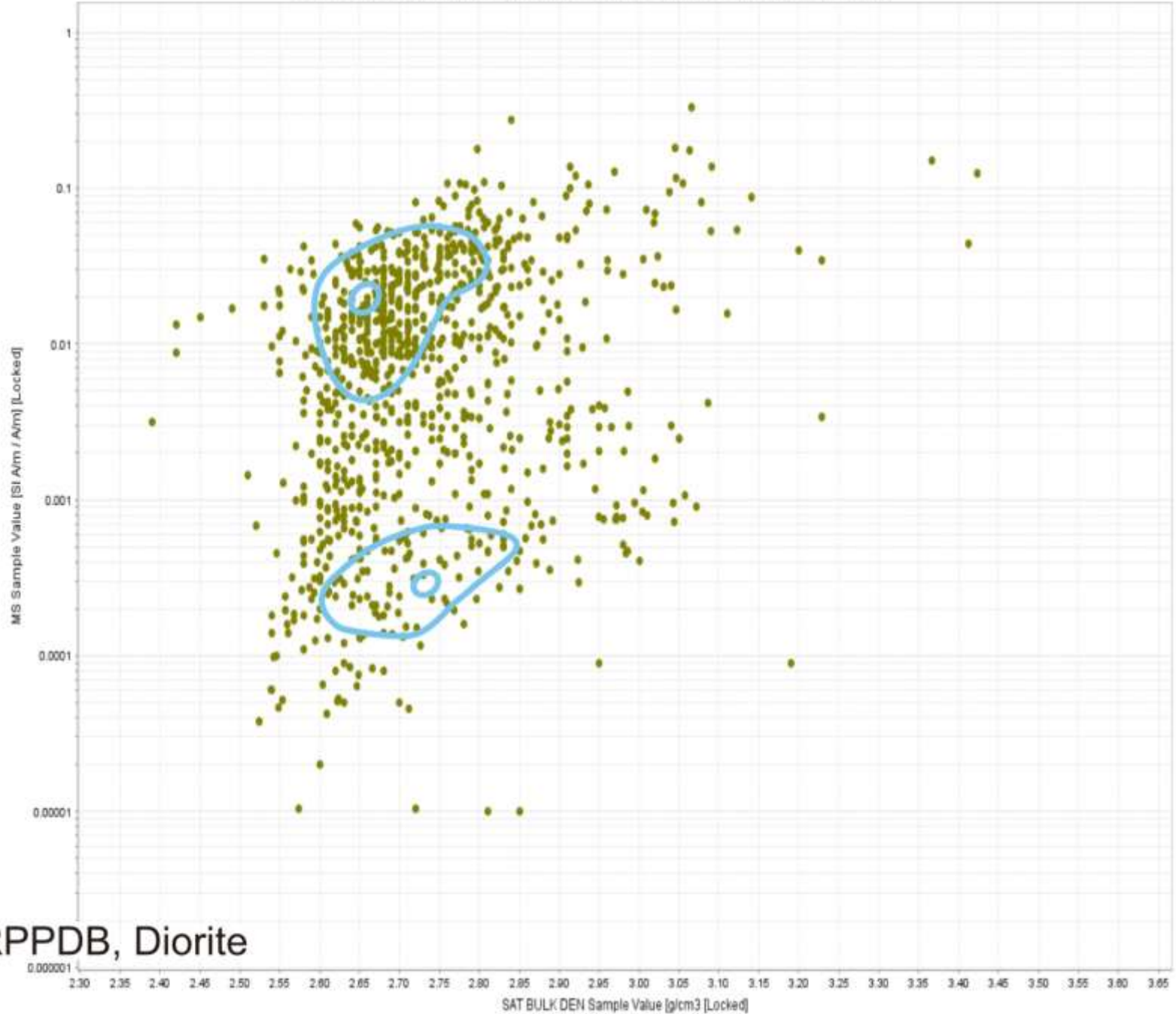
SAT BULK DEN Sample Value [g/cm3 : MS Sample Value [SI A/m / A/m]



CRPPDB, Gabbro

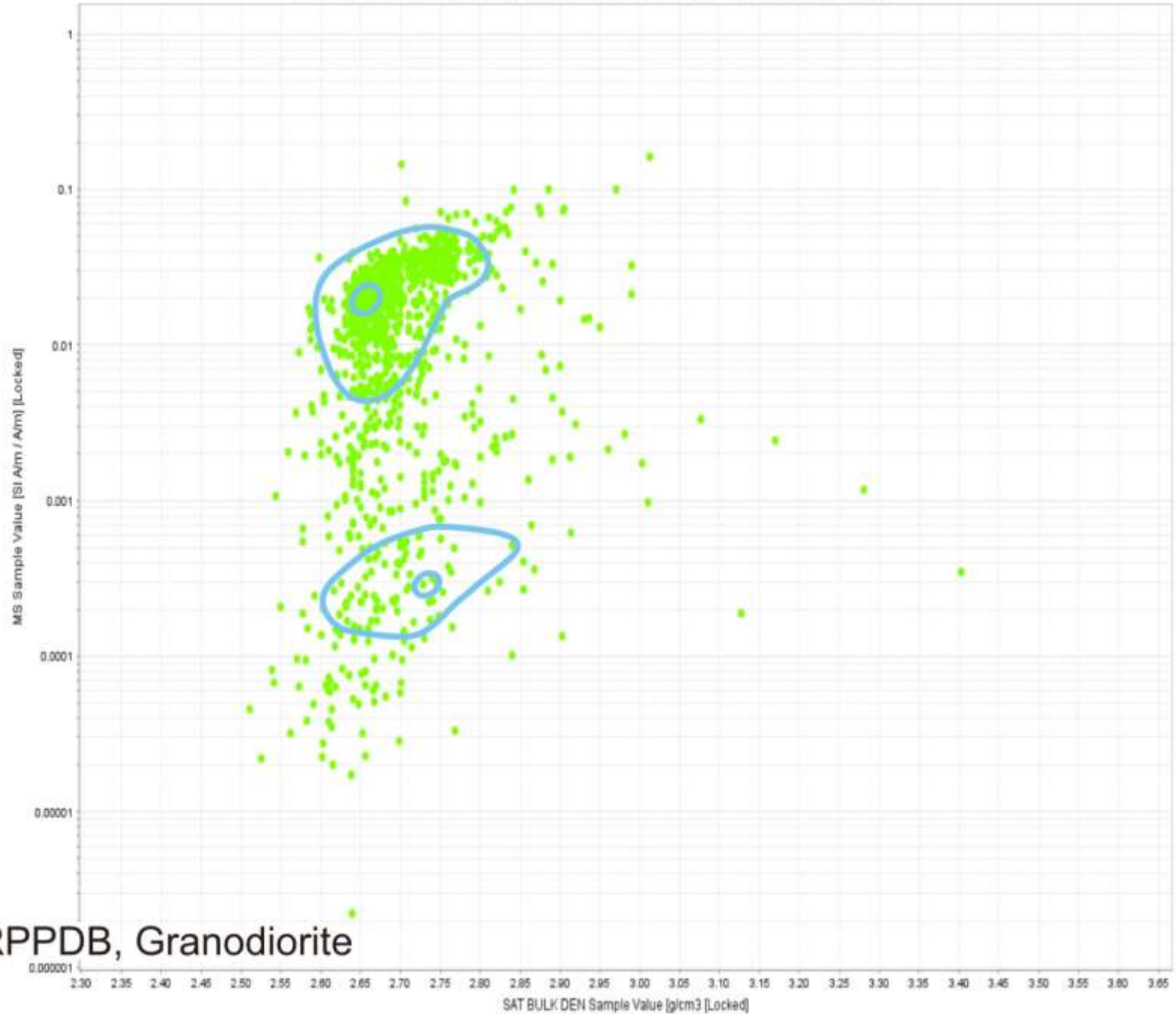
0.000001 2.30 2.35 2.40 2.45 2.50 2.55 2.60 2.65 2.70 2.75 2.80 2.85 2.90 2.95 3.00 3.05 3.10 3.15 3.20 3.25 3.30 3.35 3.40 3.45 3.50 3.55 3.60 3.65
SAT BULK DEN Sample Value [g/cm3] [Locked]

SAT BULK DEN Sample Value [g/cm3 : MS Sample Value [SI A/m / A/m]



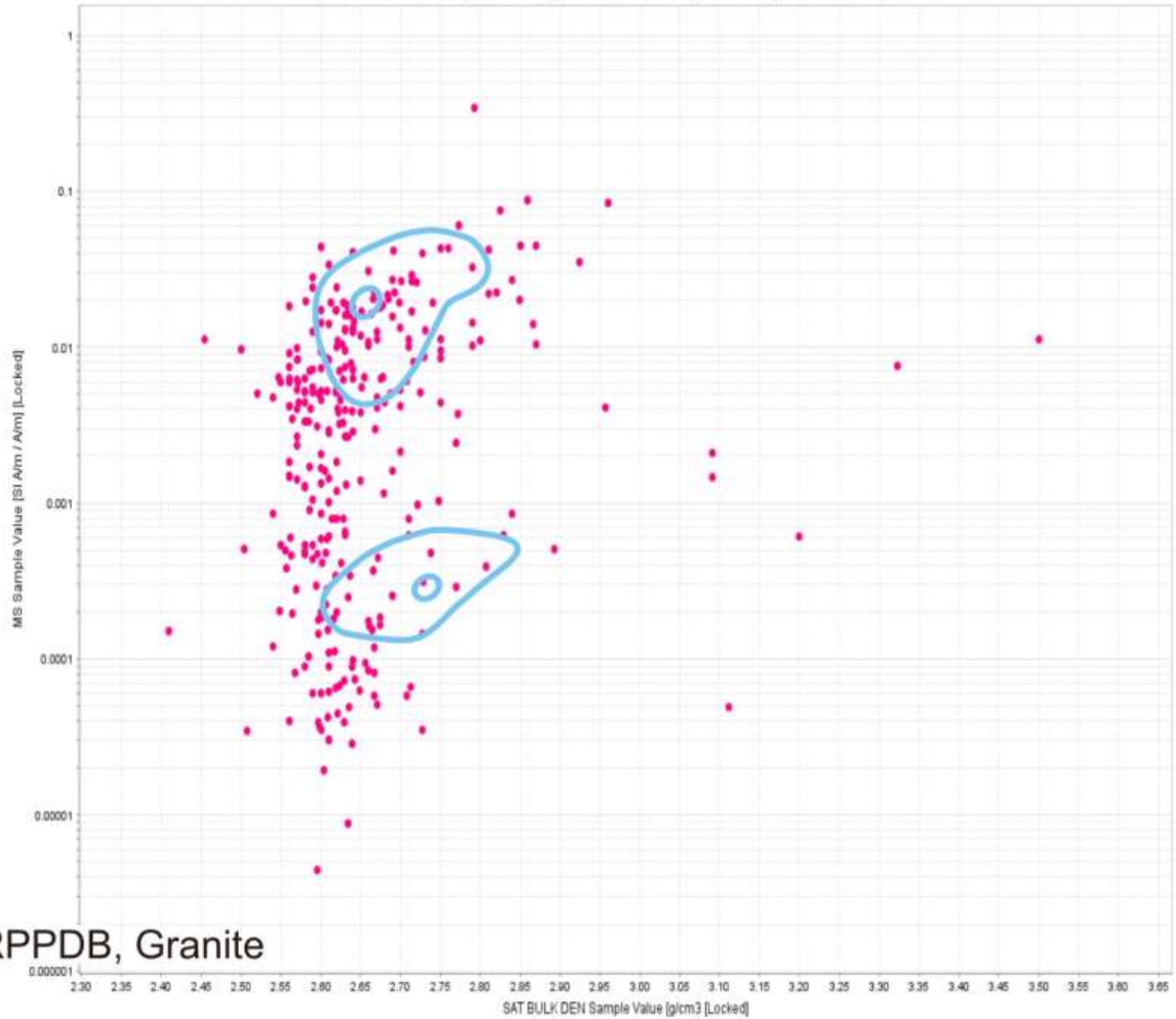
CRPPDB, Diorite

SAT BULK DEN Sample Value [g/cm3 : MS Sample Value [SI A/m / A/m]

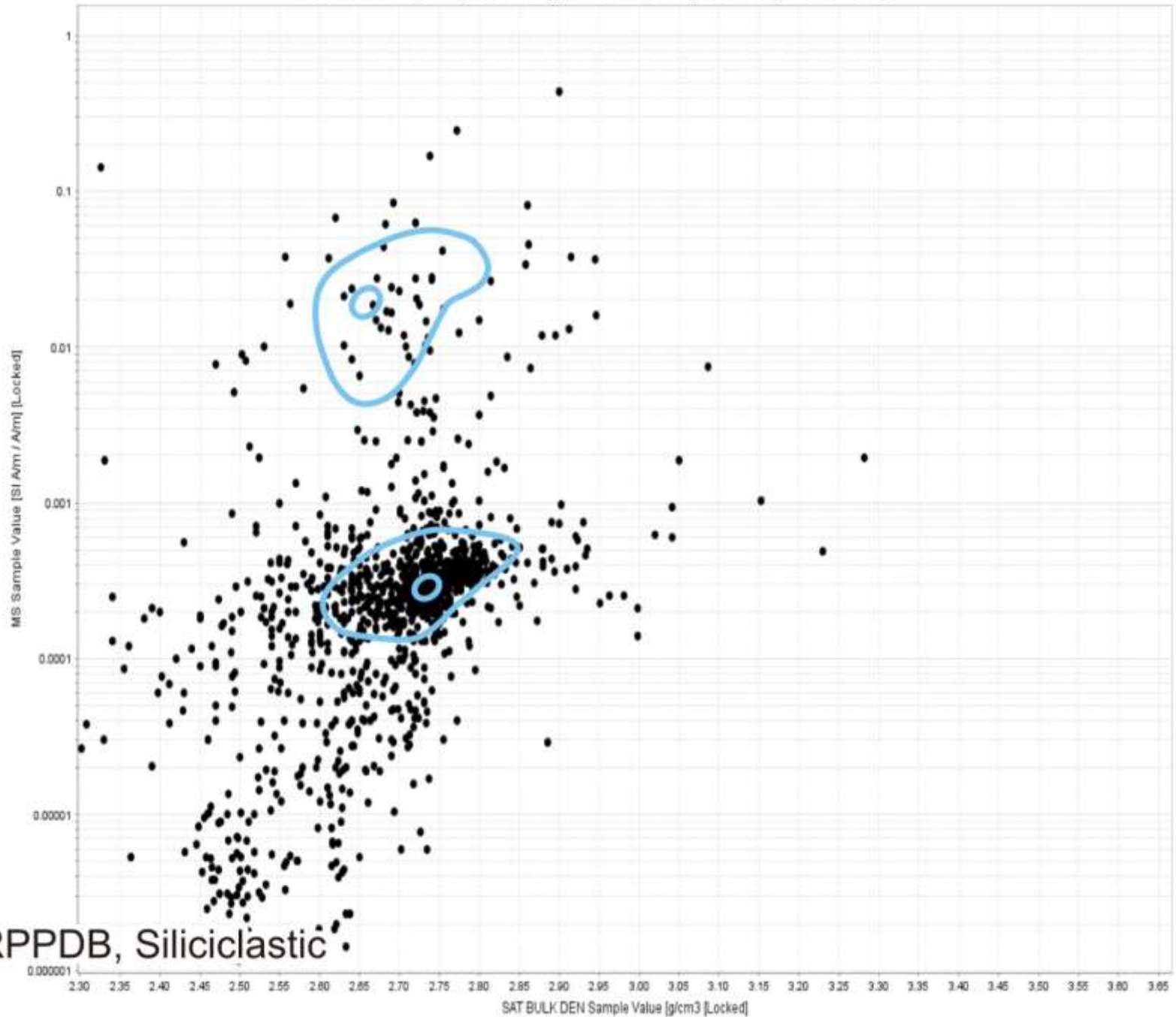


CRPPDB, Granodiorite

SAT BULK DEN Sample Value [g/cm3 : MS Sample Value [SI A/m / A/m]

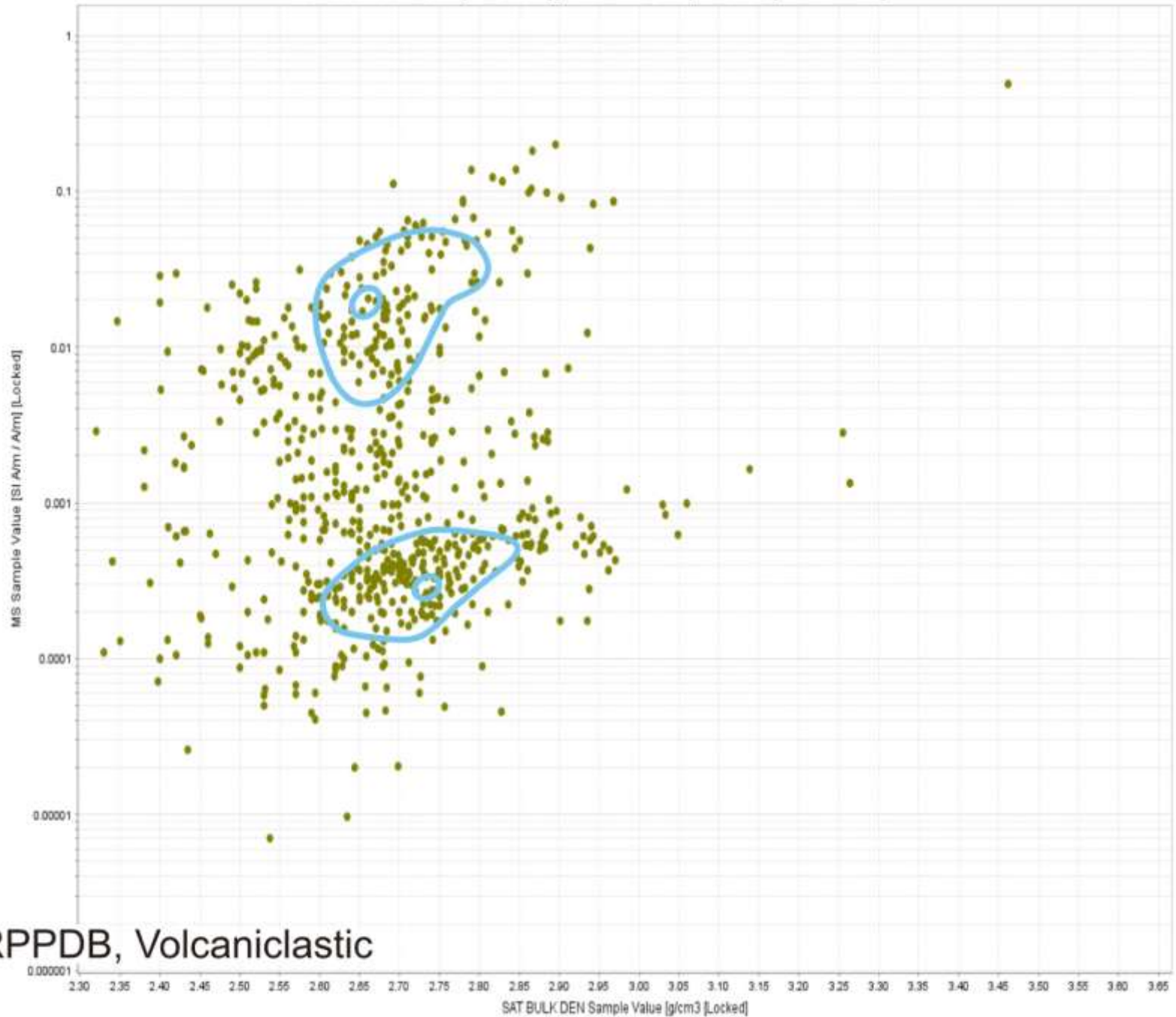


SAT BULK DEN Sample Value [g/cm3 : MS Sample Value [SI A/m / A/m]



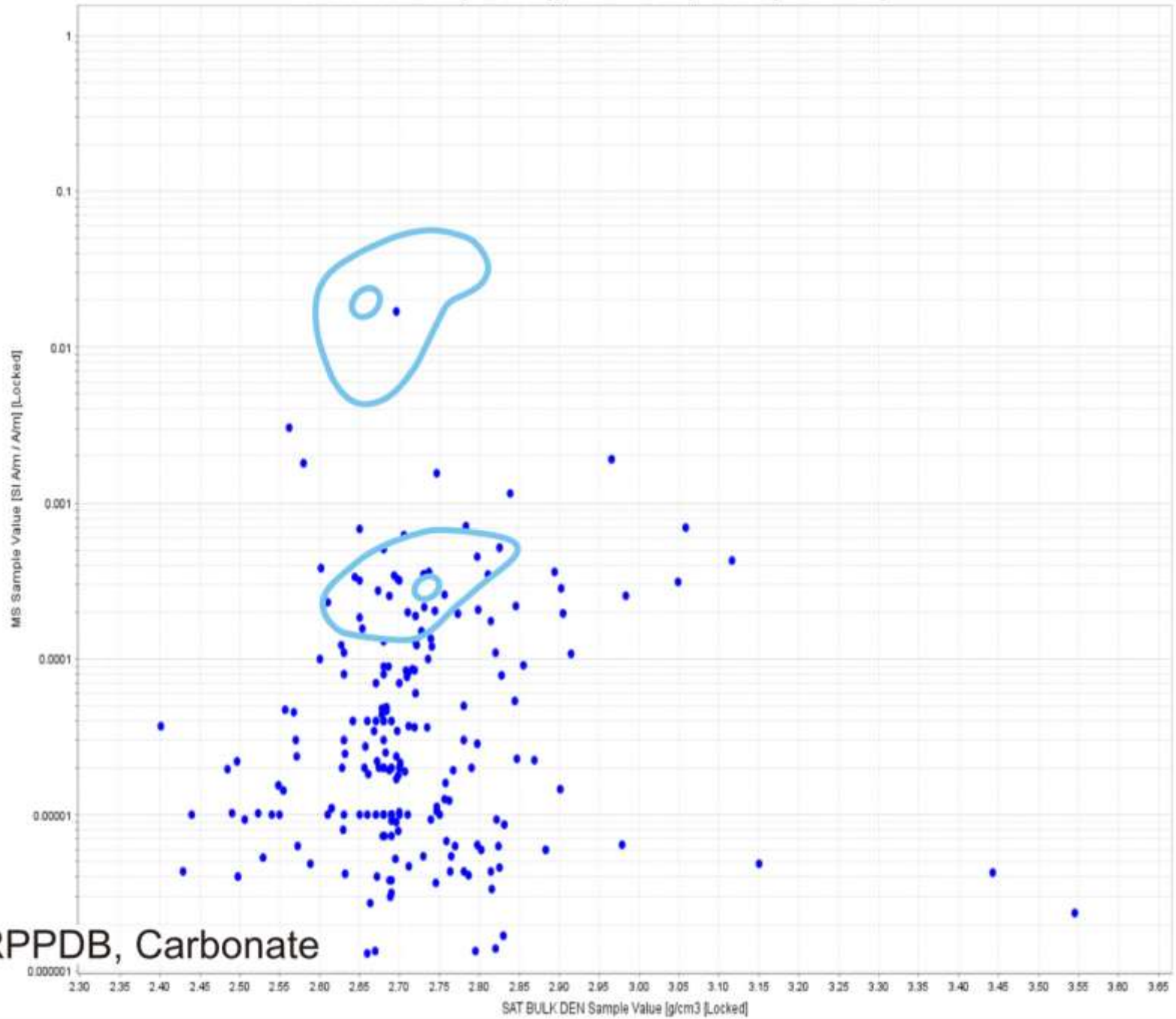
CRPPDB, Siliciclastic

SAT BULK DEN Sample Value [g/cm³ : MS Sample Value [SI A/m / A/m]

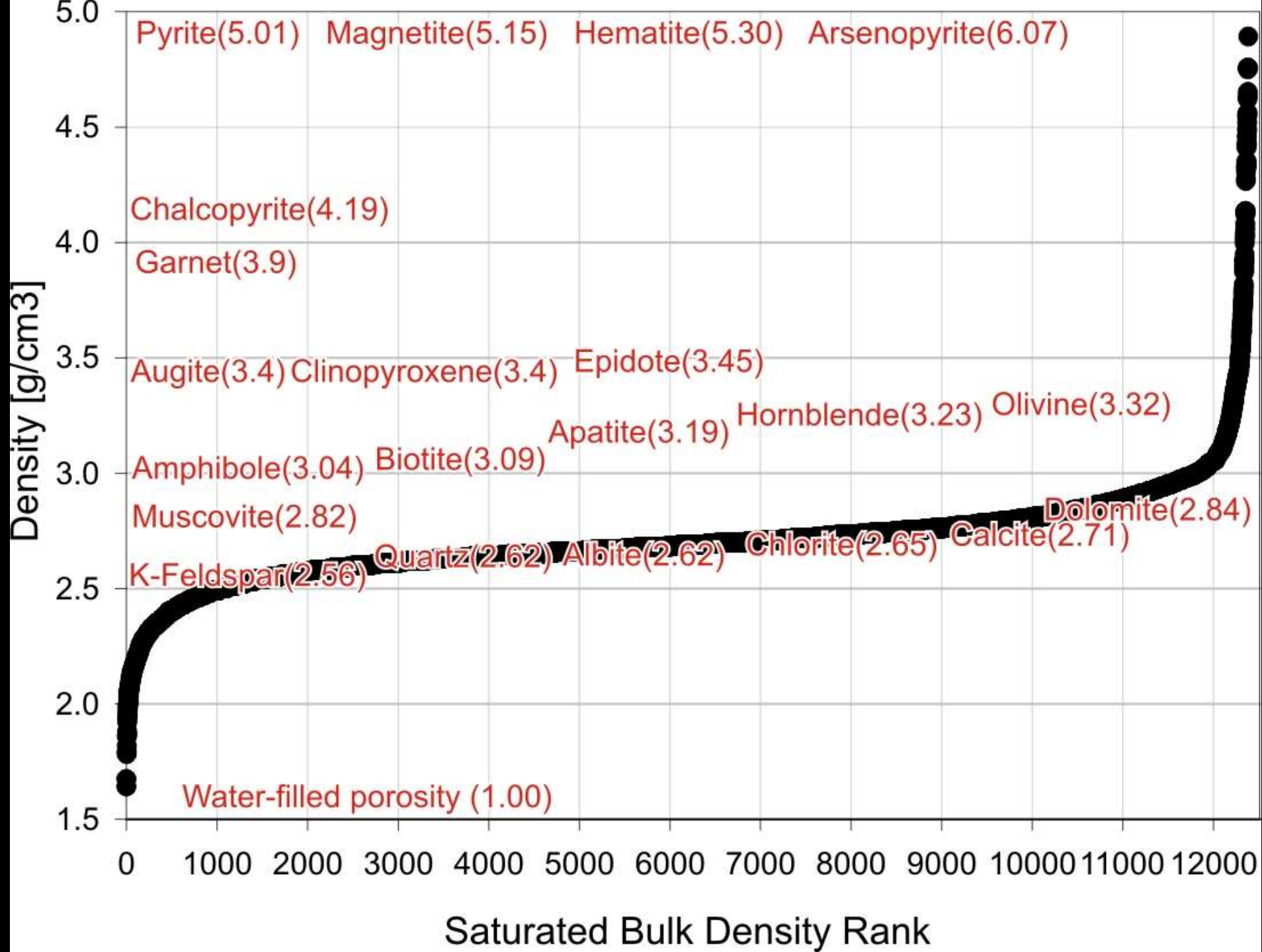


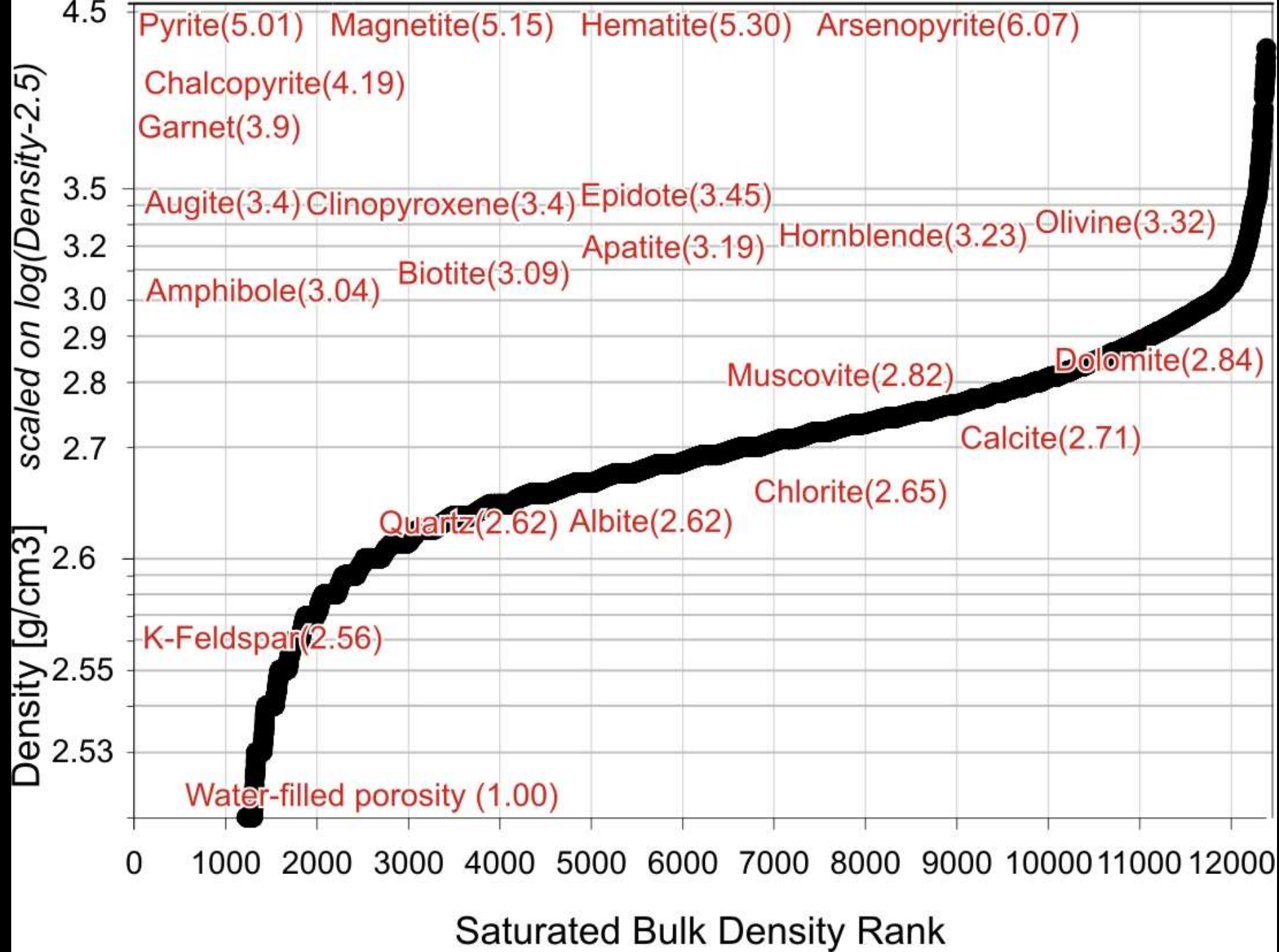
CRPPDB, Volcaniclastic

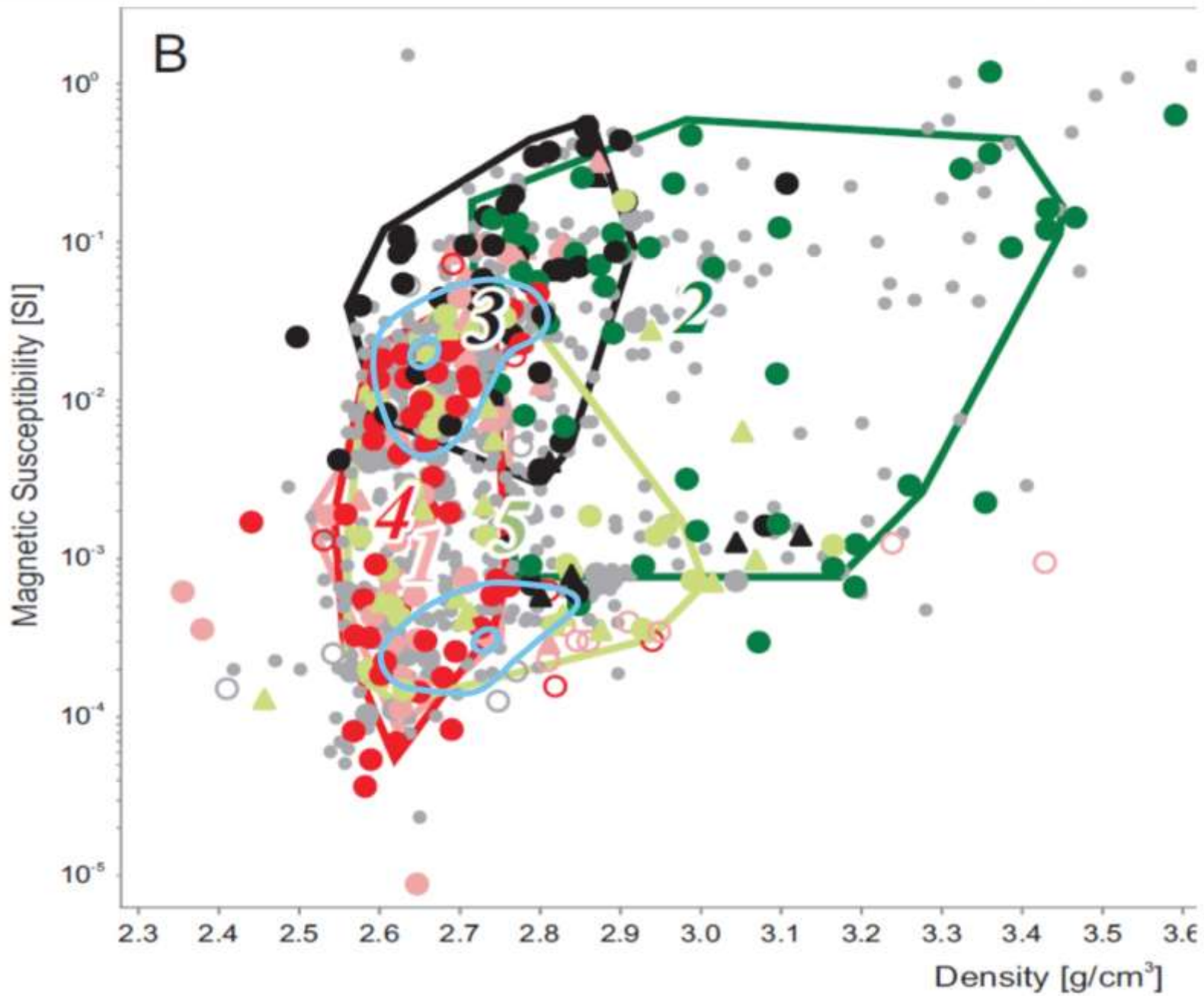
SAT BULK DEN Sample Value [g/cm3 : MS Sample Value [SI A/m / A/m]



CRPPDB, Carbonate







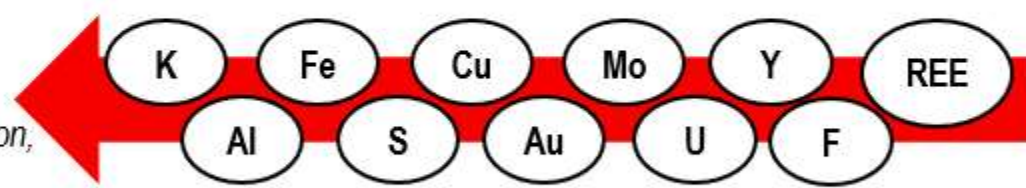
Enkin, Corriveau and Hayward, 2016, Great Bear IOCG

(LT) K-Fe à hématite



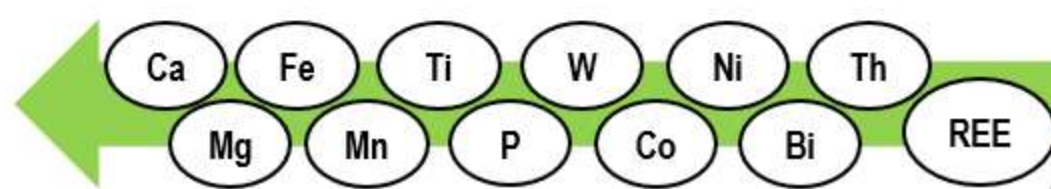
(HT) K-Fe

Biotite, Feldspath-K, Magnétite, Sulfures, Épidote, Carbonates, Zircon, Fluorite, Monazite, Xénotime



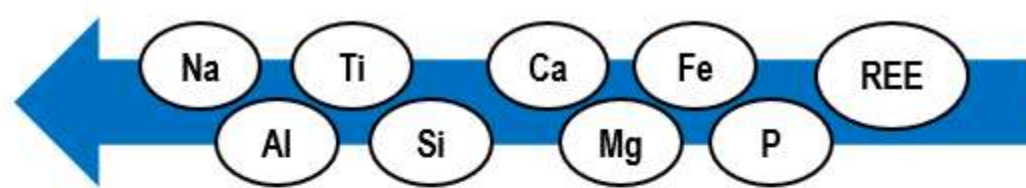
Ca-Fe

Amphibole, Magnétite, Apatite Titanite, Allanite, Augite, Scheelite, Monazite, Carbonates



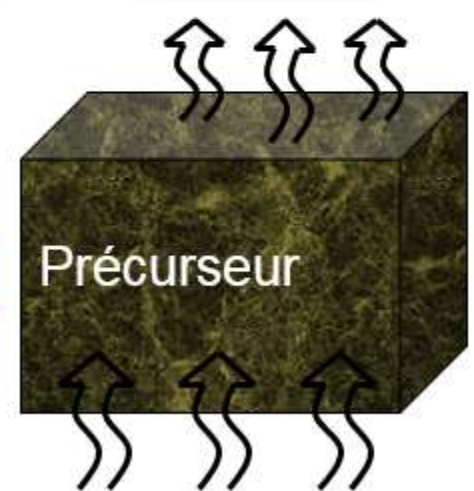
Na-Ca-Fe

Albite, Amphibole, Magnétite, Apatite, Titanite, Allanite, Barite, Zircon



Na

Albite, Scapolite, Titanite, Zircon, Rutile, Apatite



(HT) K-Fe (< 300 m)

Biotite, Feldspath-K, Magnétite, Sulfures, Fluorite, Épidote, Carbonates, Zircon, Monazite, Xénotime

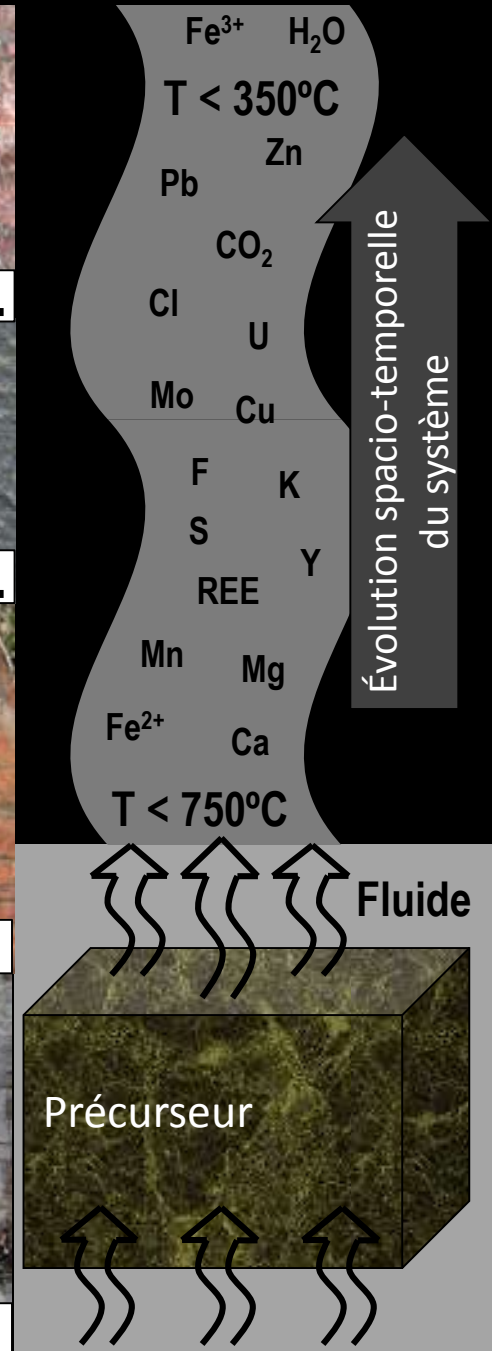
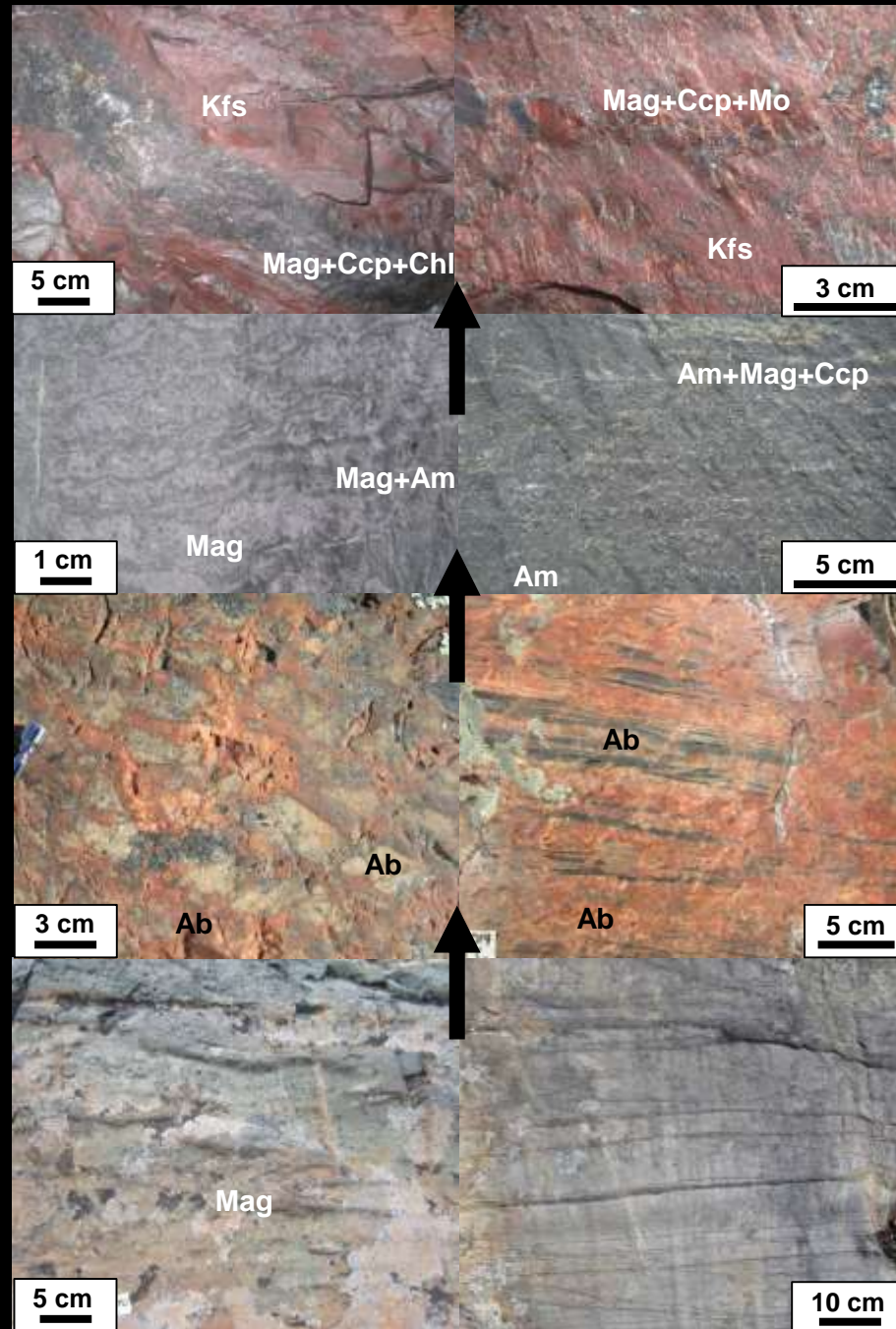
Ca-Fe (< 1 km)

Amphibole, Magnétite, Apatite Titanite, Allanite, Augite, Scheelite, Monazite, Carbonates

Na (< 4 km)

Albite, Scapolite, Titanite, Zircon, Rutile, Apatite

Précurseur
(métasiltstone)



Distal to heat source
Lower Temperature, Shallow, Late

IOCG

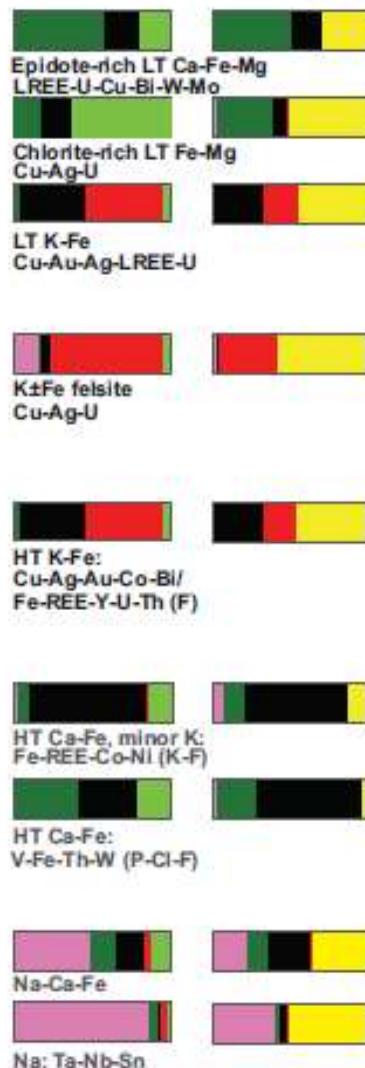
Thermal core
High Temp., Deeper, Earlier

IOA

Alteration Facies

- ⑥ Si Qz veins, silicification
Crowfoot, Echo Bay, Hook Island
<250°C
- ⑤ LT K-Fe-H-CO₂
Hem-Kfs/Ms-Cb-Chl-sulfides
Immediate host to Hem-Cu-Au
Sue Dianne, Southern Breccia, Terra, Mile,
Brooke, K2, Hook Island, Hoy, Hottah, Duke
Hydrothermal breccia
- ④ Mag-to-hem transition
K-felsite Kfs
Brooke, Port Radium, Birchtree, Mile, Terra
K-skarn Cpx-Grt-Kfs-sulfides
Mile
Immediate host to Mag-Cu-Au
Hydrothermal breccia
- ③ HT K-Fe
Mag-BtKfs-sulfides
Immediate host to Mag-Cu-Au
NICO, Sue Dianne ↓, Brooke, Cole, Fab,
deVries, Hump, Ham, Terra, Echo Bay,
Southern Breccia, Duke, Mar
Hydrothermal breccia
- ② HT Ca-Fe ± Mg (+ skarn)
Amp-Mag ± Cpx-Ap-Ttn
Wallrocks of Mag-Ap (IOA) deposits
Outer zones of (Fe)-Cu-Au
Regional scale, largely barren in sulfides
NICO, K2 ↓, Mag Hill, Port Radium ↓, Fab,
JLD, Ron, Terra, Hottah, Grouard, Duke, Nod
Incipient hydrothermal brecciation
Ductile deformation
- ① Na ± Ca (albitites)
Ab, Scp, Qz, Zrn, Rt
<600°C Southern Breccia, Mag Hill-Des Monts, Port
Radium, JLD, Terra, Grouard, South of Duke,
Structural breccia

Molar proportions



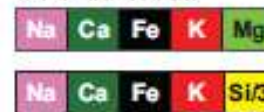
Incoming/outgoing fluid metal budget

- Fluid 6:
outflow after facies 5
Recharge: Sr, Si, ±Ba
Discharge: K, Fe, Mg, Ca,
Mo, Cu, Au, Ag, LREE, etc. +
new brines metal budget
- Fluid 5:
outflow after facies 4
Recharge: all elements +
new brines metal budget
Discharge: K (tourmaline
veins ?)
- Fluid 4:
outflow after facies 3
Recharge: Na, Ca, Mg, Mn,
etc. + new brines metal budget
Discharge: K, Fe, Cu, Ag, Au,
Co, Bi, V, REE, etc.
- Fluid 3:
outflow after facies 2
Recharge: Na, K, Mn, etc. +
new brines metal budget
Discharge: Ca, Fe, V, Th,
Co, Ni, W / HREE, LREE
- Fluid 2:
outflow after facies 1
Recharge: nearly all mobile
elements and REE but Na
Discharge: Na (relative
enrichment Nb, Ta, Ti, Zr, Sn)
- Hypersaline Fluid 1 + metal
budget

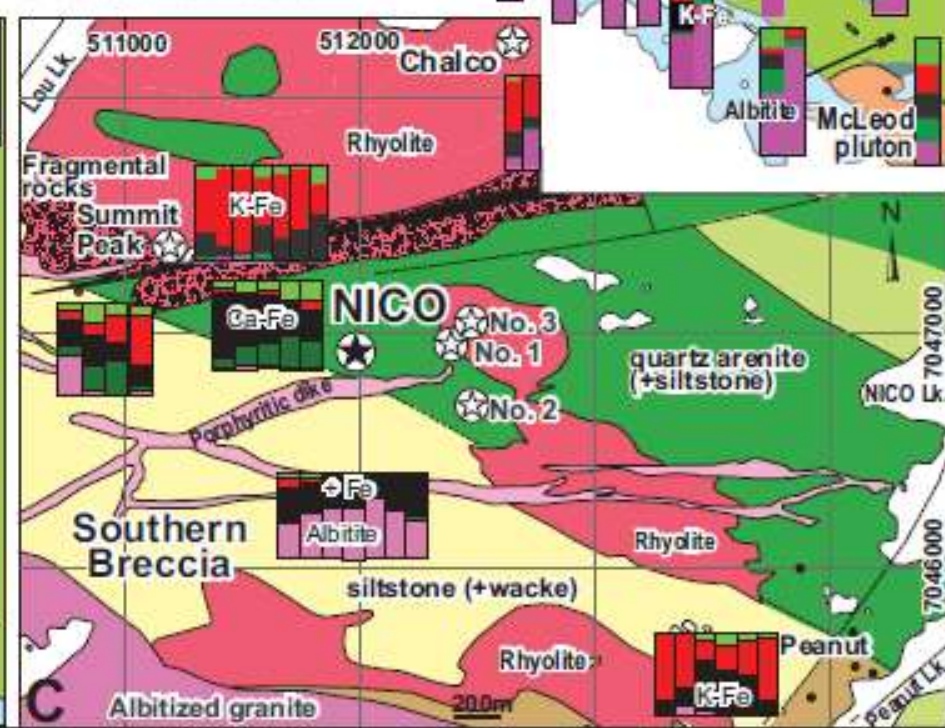
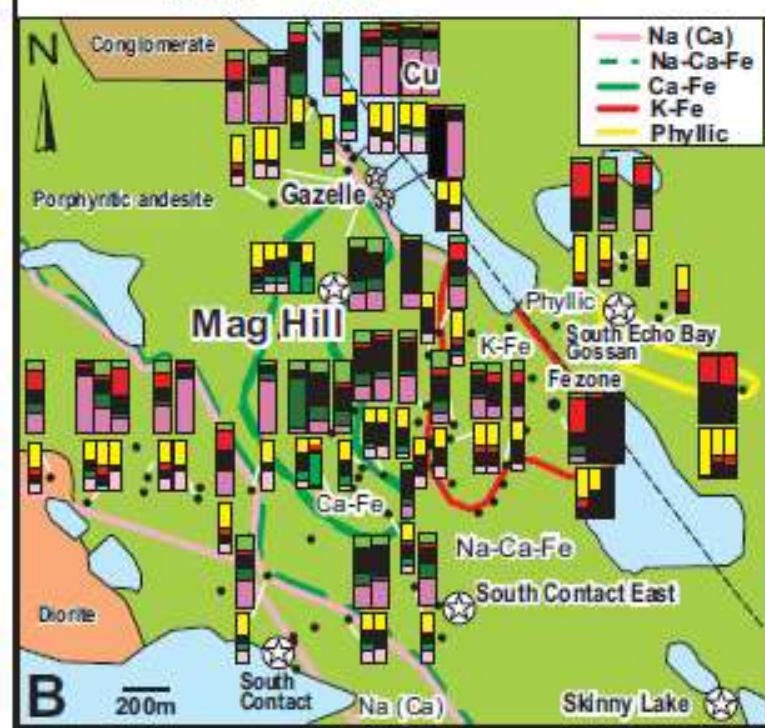
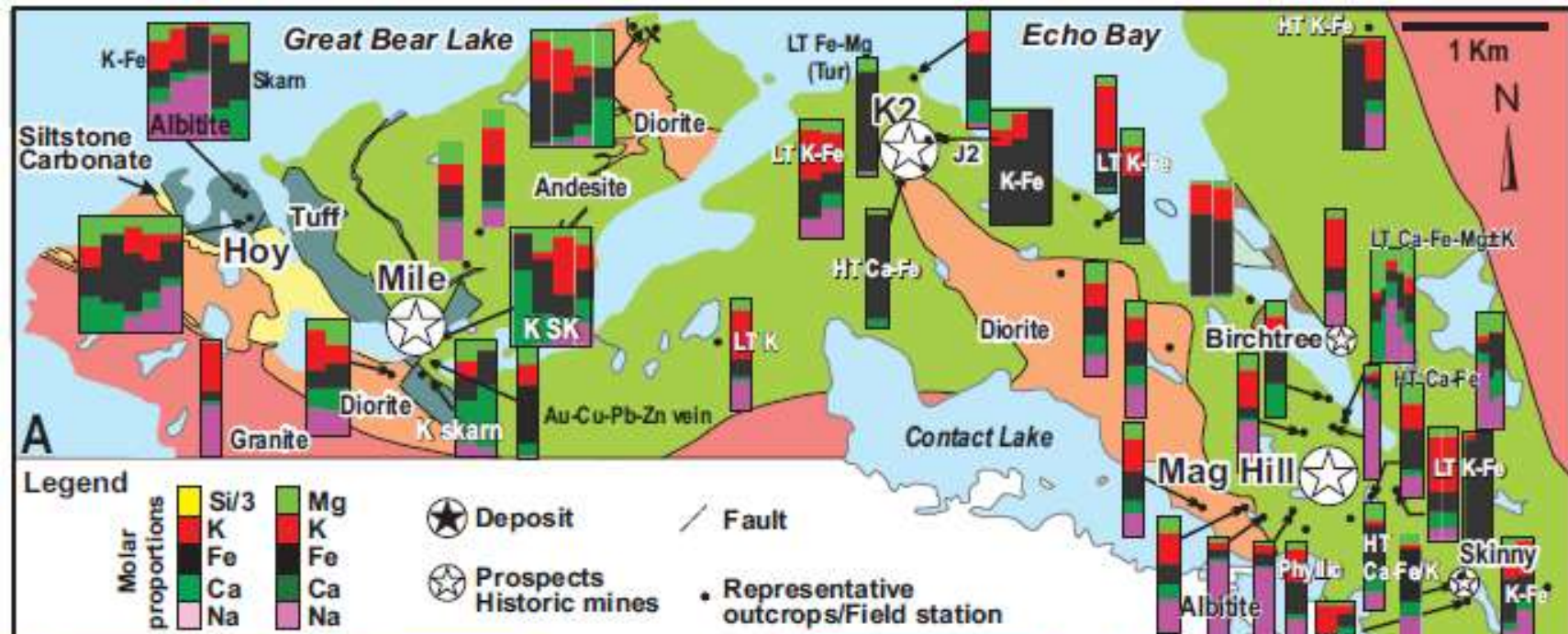
Deposits / Targets

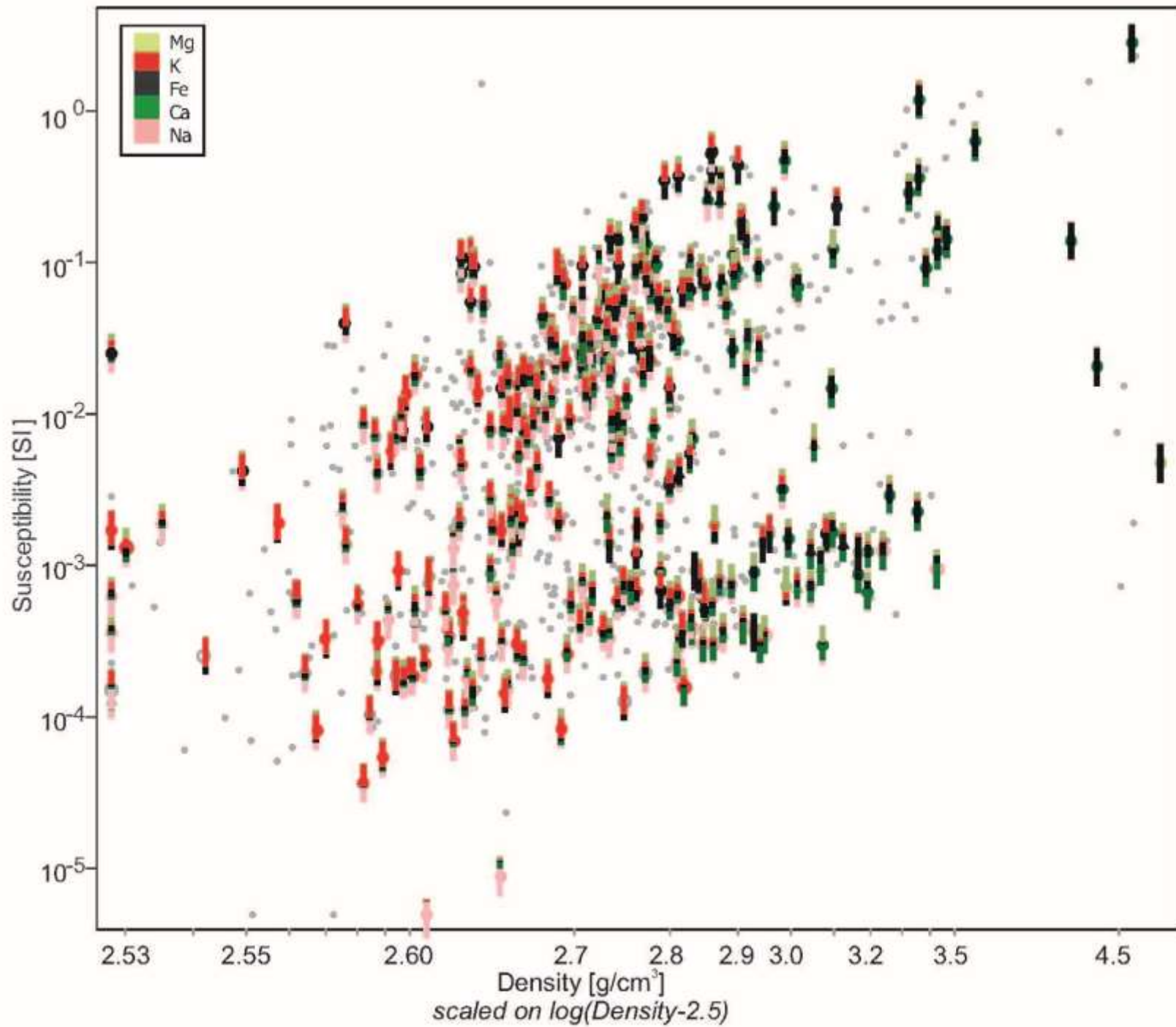
- Epithermal
- Hematite-group IOCG
Cu-Au-Ag-REE-U-Mo-PGE ...
Olympic Dam type
+ Albitite-hosted U
- Polymetallic skarns in IOCG
Cu-Pb-Zn-polymetallic
Mag-to-hem-group IOCG
+ Albitite-hosted U
- Magnetite-group IOCG
Cu-Au-Co-Bi-...
Cloncurry type (+Carajas)
- IOA Magnetite-apatite
Fe, P, V, Th, REE
Kiruna type and affiliated
iron oxide-specialized metal
deposits

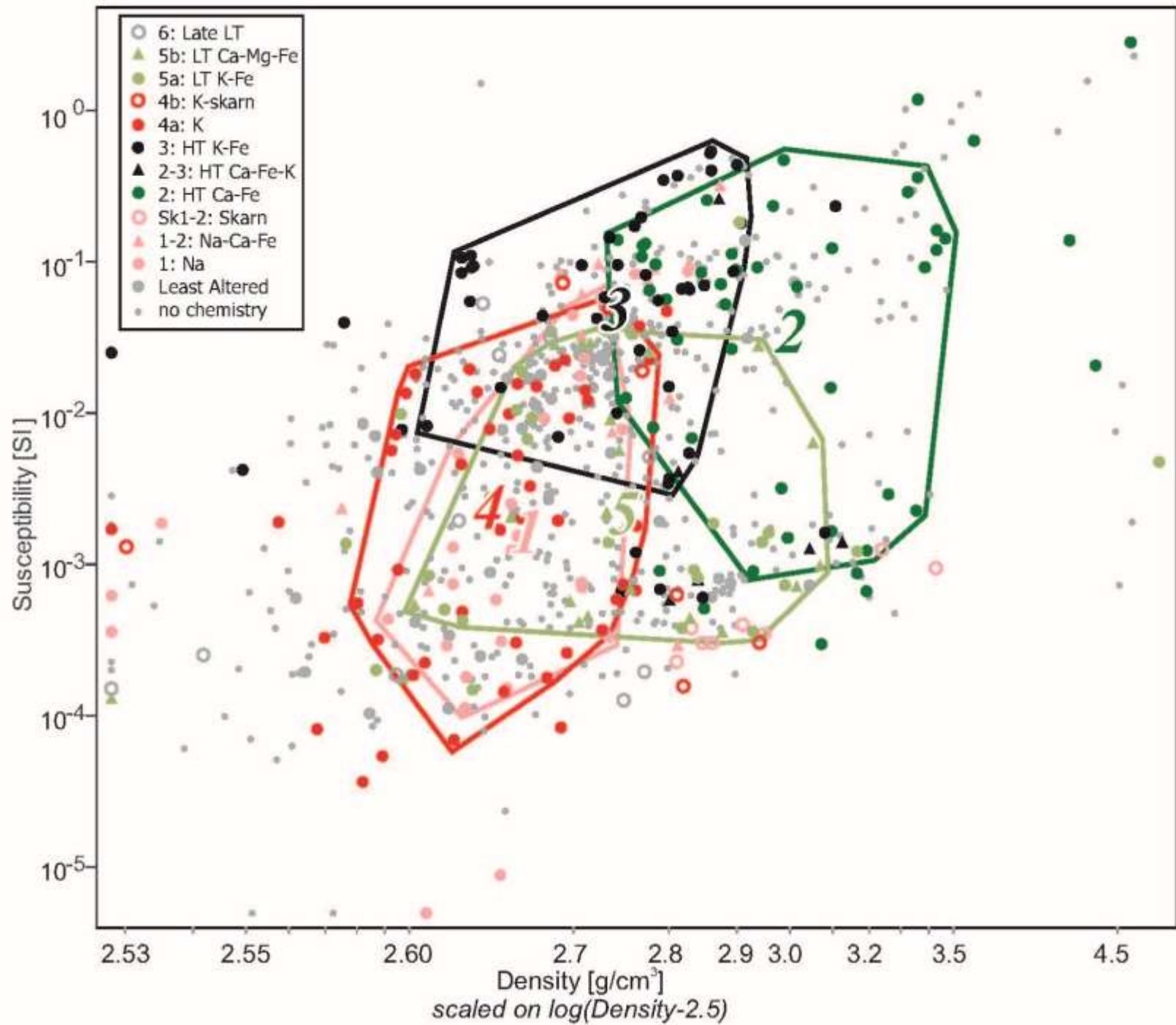
Molar barcodes

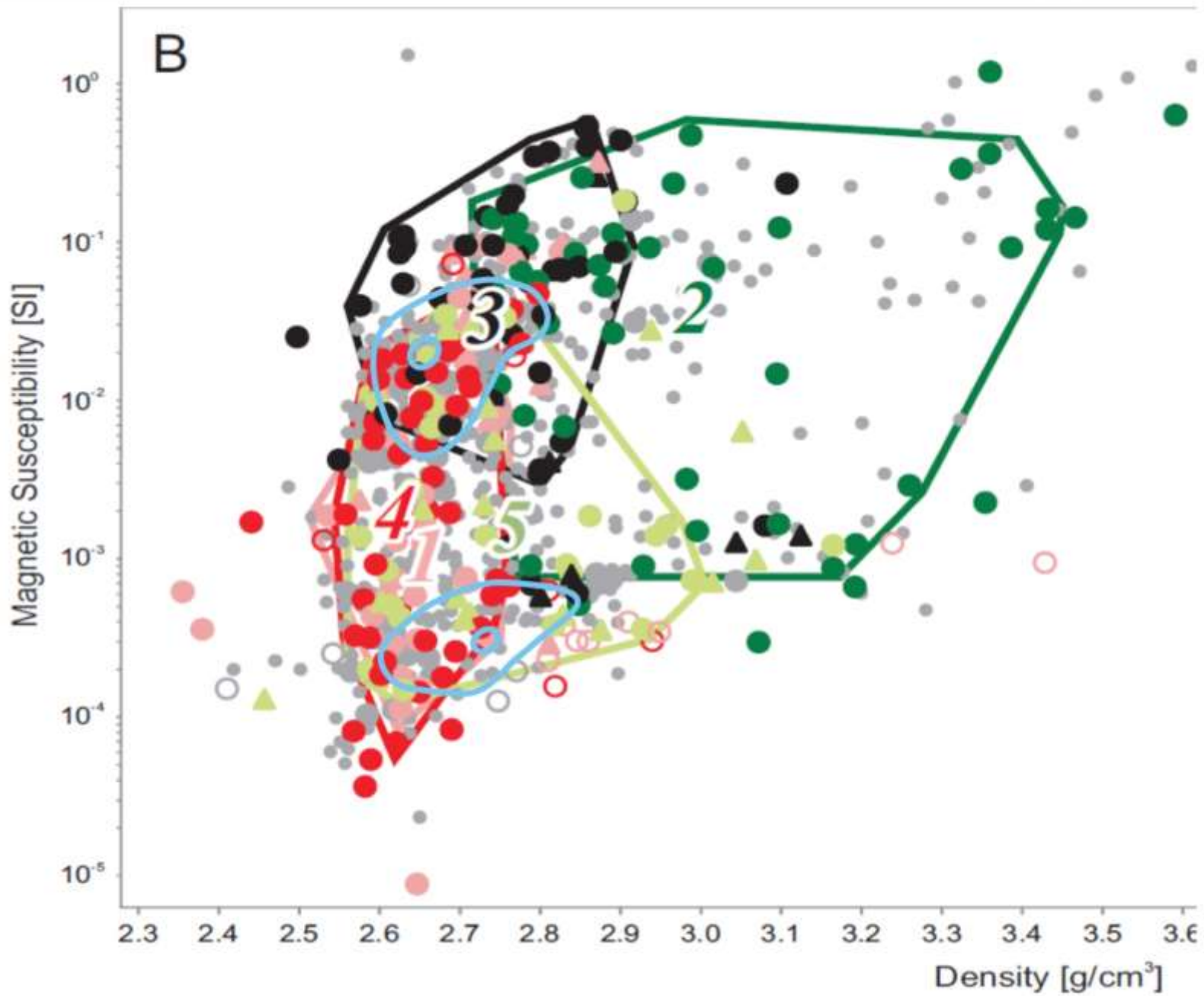


↓ Drilling results







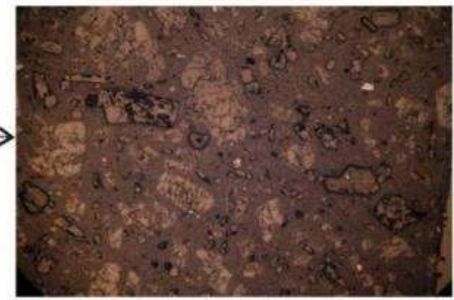
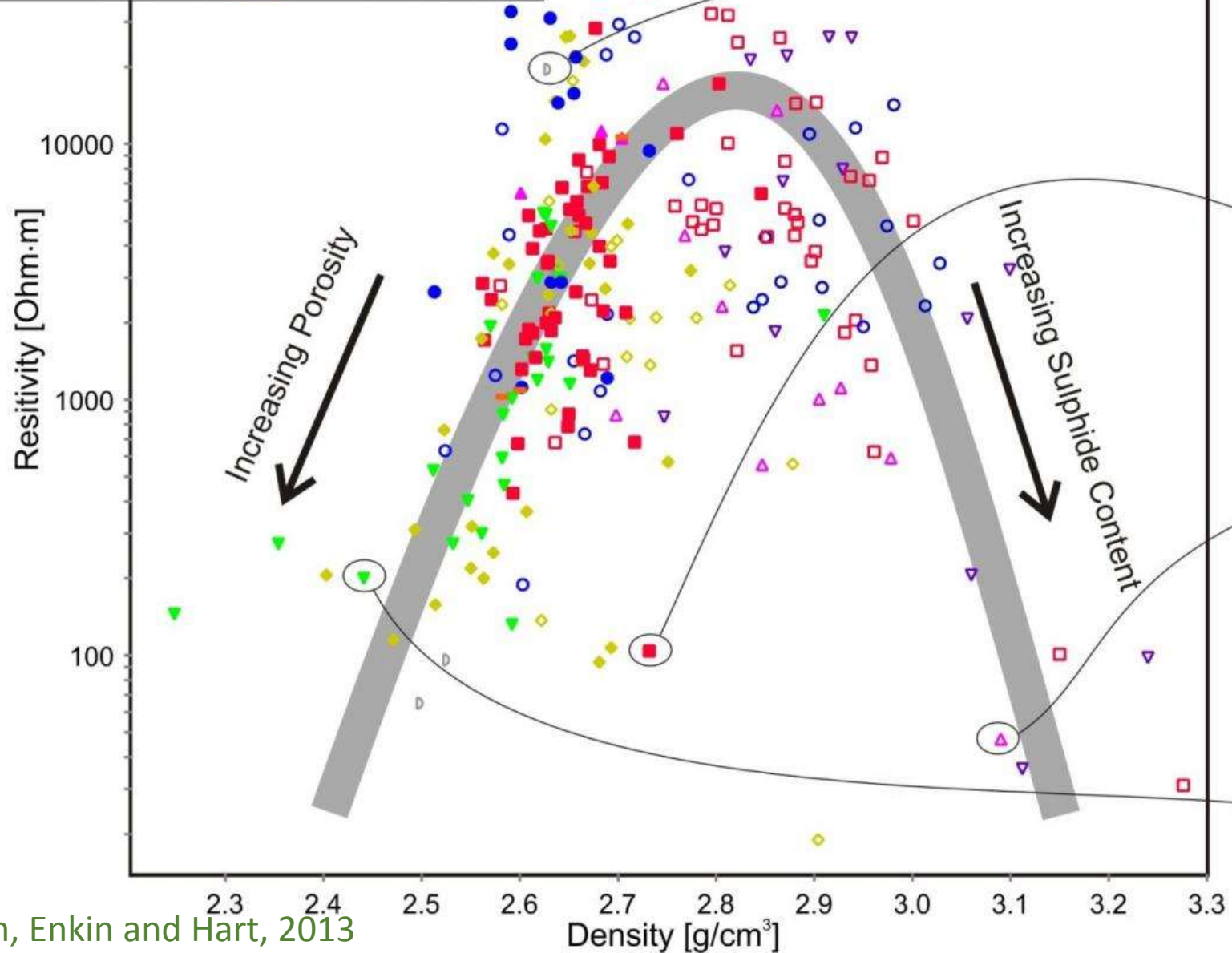


Enkin, Corriveau and Hayward, 2016, Great Bear IOCG

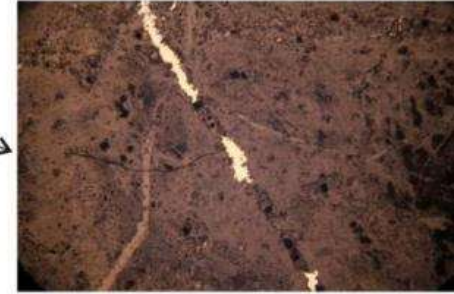
Electric Properties

Resistivity
and
Chargeability

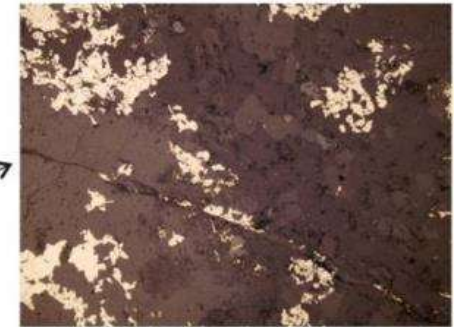
- Least Altered Volcanic ○
- Least Altered Plutonic ●
- Extrusive Equiv. BFP ▽
- Albitic Volcanic ▲
- Albitic Plutonic ▼
- Propylitic Volcanic ▽
- Argillic Plutonic/BFP ▼
- Phyllic Volc/Sed ◇
- Phyllic Plutonic/BFP ▼
- Potassic o/p Phyllic BFP ▭
- Potassic Volc/Sed □
- Potassic Plutonic/BFP ▼



Bell 019



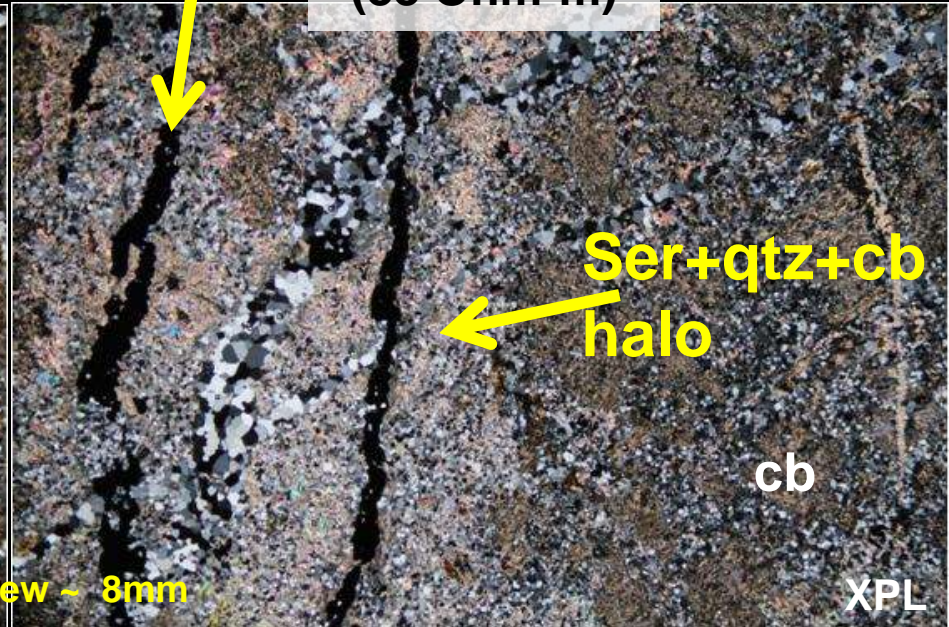
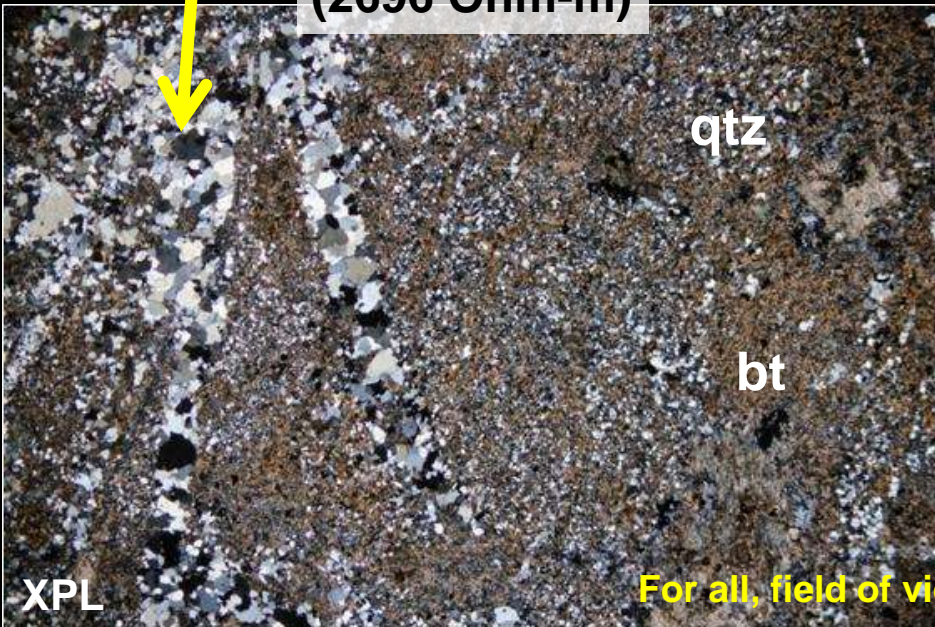
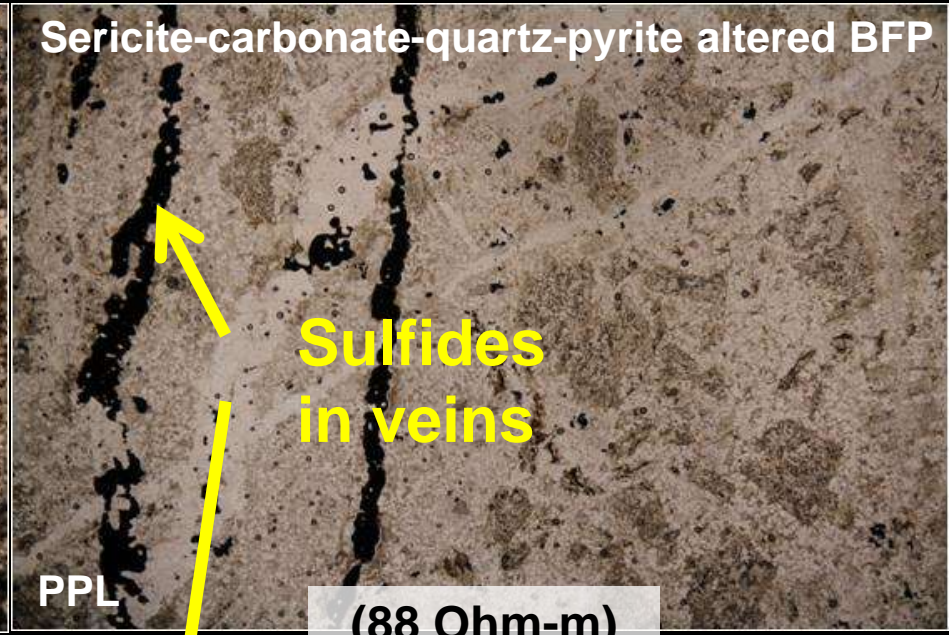
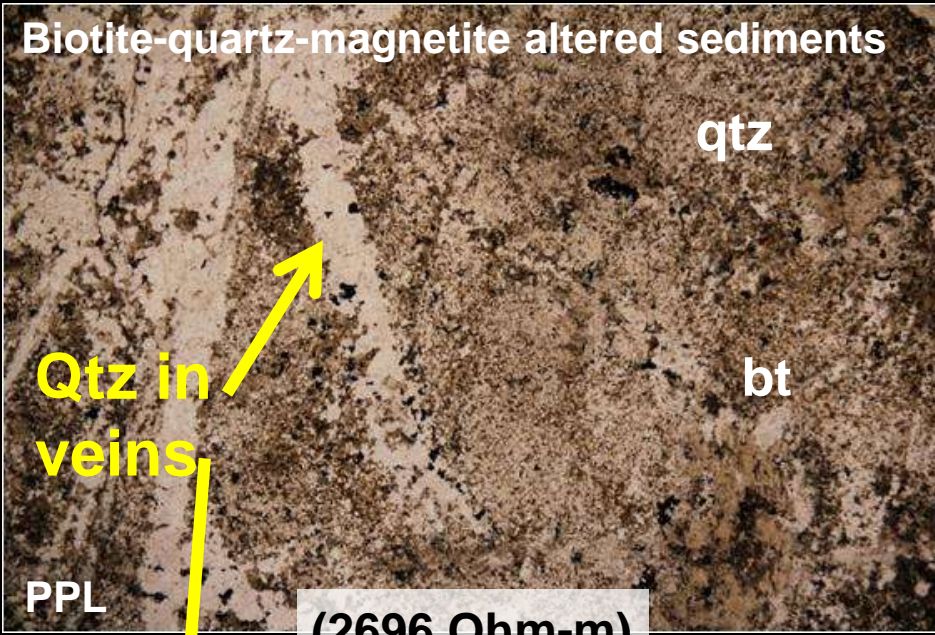
Bell 043

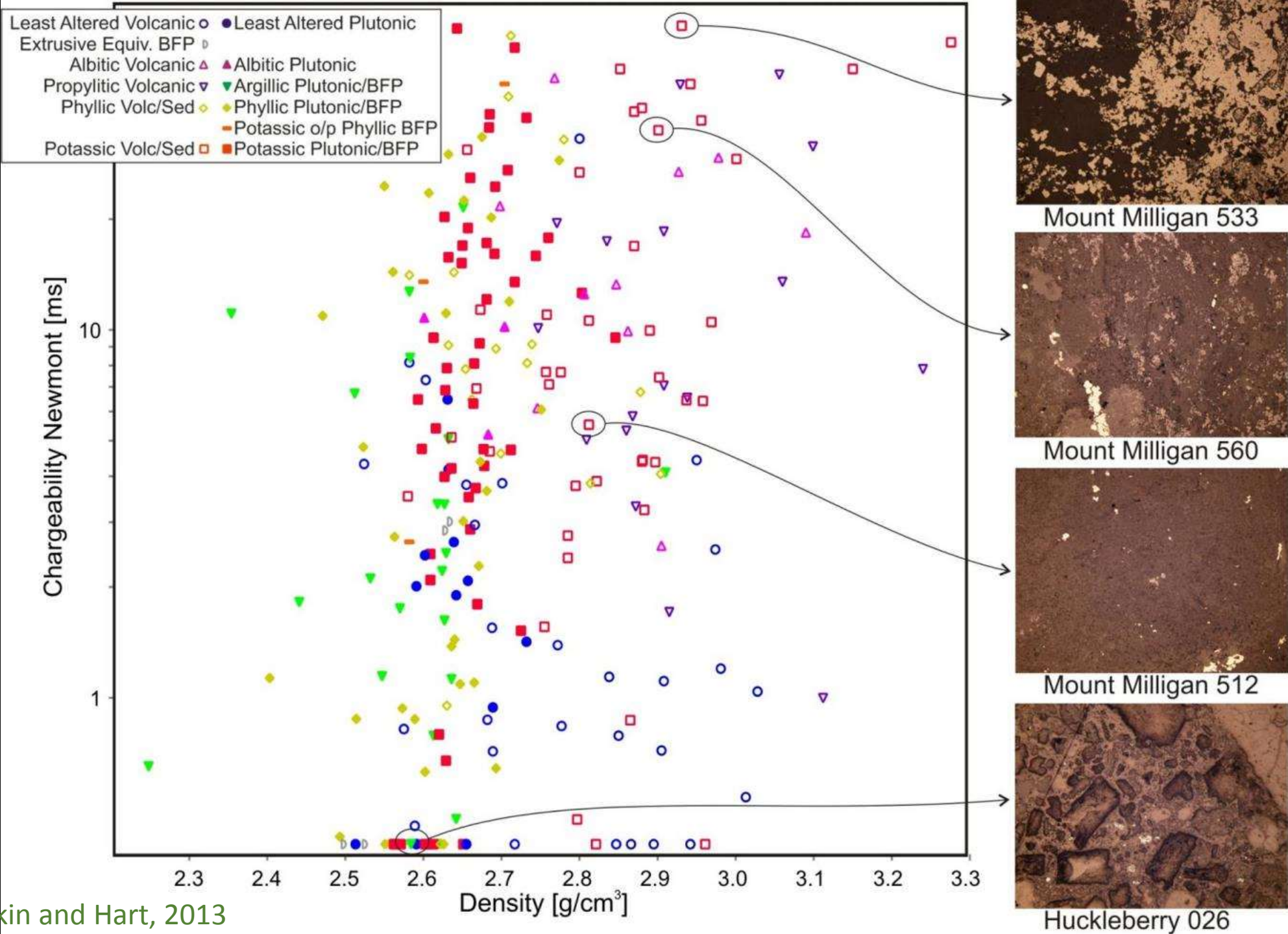


Mount Milligan 507.1



Morrison 030





Petrophysical Distributions

- Know the typical distributions
- Understand the mineral and textural controls
- Measure physical properties in the lab or in situ
- Recognize the importance of exotic distributions
- Apply petrophysical constraints to geophysical inversions