Geochemical investigations of iron oxide minerals in the Cloncurry District and carbonate from the Lady Annie Cu deposit, Mt. Isa Inlier, NW Queensland

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Queensland Government

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Acknowledgements

- Geological Survey of Queensland through the Strategic Resources Exploration Program for funding
- CSIRO for providing access to archived samples
- CODES Analytical Laboratories Staff
- Chinova Resources
- Mount Isa Mines

Northwest Queensland mineral geochemistry vectoring project

- Sponsored by the Geological Survey of Queensland through the **Strategic Resources Exploration Program** (SREP)

Our aims:

1. **Deposit 'fingerprinting'** – trace element characterization of hydrothermal alteration minerals proximal to known ore deposits
   - CSIRO sample set – 145 polished mounts from 21 deposits/prospects in the Cloncurry belt
2. **Deposit 'footprints'** – delineating mineral chemistry alteration footprints for IOCG and sediment-hosted deposits
3. **Age dating of non-traditional datable minerals (i.e., calcite, epidote, etc.)**

Strategic Resources Exploration Program

We are investing $27.125 million through the 4-year Strategic Resources Exploration Program to boost exploration and support for resource development projects.

The program funding is helping to expand resource exploration and development for gas and minerals in North West Queensland.

Initiatives funded under the program include:

- $3.6 million to drive exploration for gas in the Georgina, South Nicholson and Isa Super Basins.
- $4.275 million for mineral geophysics to pinpoint the locations of potential new mineral prospects over wide areas.
- $1.45 million for mineral geochemistry programs to identify the type of potential mineral deposits (e.g. copper, lead, zinc) identified from geophysical programs using surface samples.
- $4.95 million for mineral synthesis to develop a comprehensive and integrated understanding of the geology of the North West Minerals Province
- $925,000 to support national research into advanced techniques used in the discovery of mineral deposits in frontier regions.
- $7.125 million for the Geoscience Data Modernisation Program, to modernise legacy systems and enable data driven exploration and resource development opportunities for Queensland

North West Minerals Province

Queensland Government

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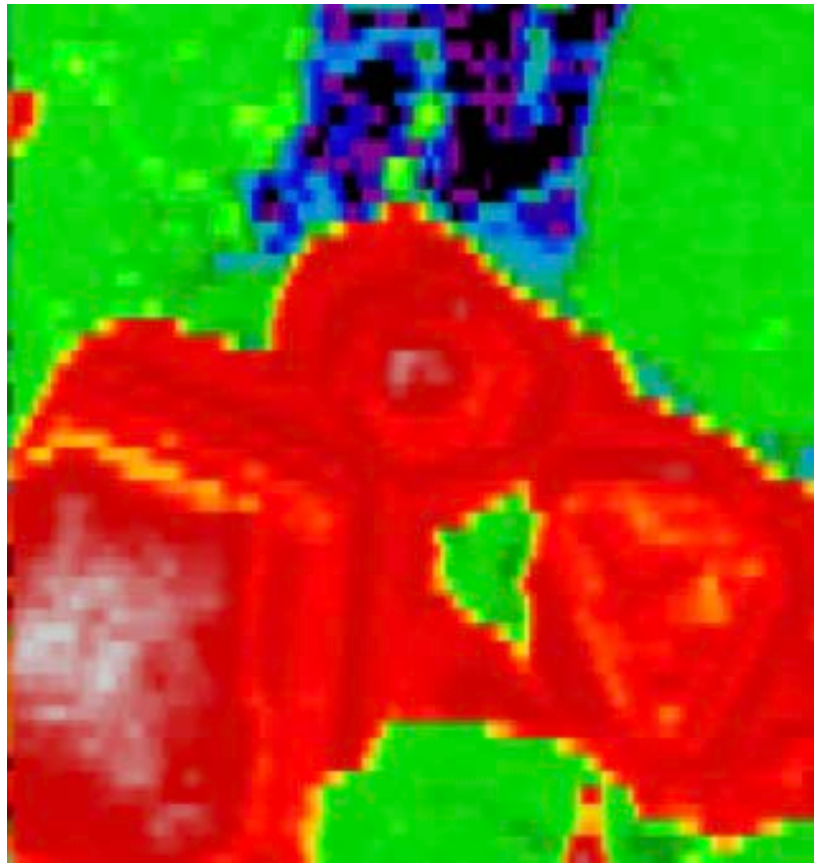
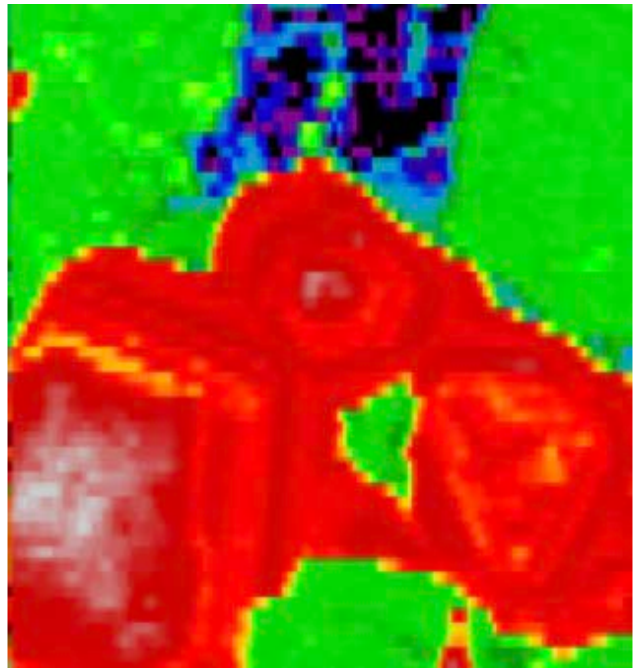
Outline

- Why mineral chemistry?
- Northwest Queensland mineral chemistry studies
  - IOCG –Magnetite and pyrite chemistry
  - Lady Annie carbonate chemistry
- What next?



Mineral geochemistry vectoring

- Many gangue minerals in hydrothermal alteration assemblages are sensitive to changes in fluid chemistry and temperature
  - Sulfides (e.g., pyrite and pyrrhotite)
  - Silicates (chlorite, epidote, quartz)
  - Oxides (hematite, magnetite)
  - Carbonates (dolomite, calcite)
  - Phosphates (apatite)



- These characteristics enable us to provide "fingerprints" and "footprints" of deposits, and aid mineral exploration by measuring the chemistry of individual mineral species

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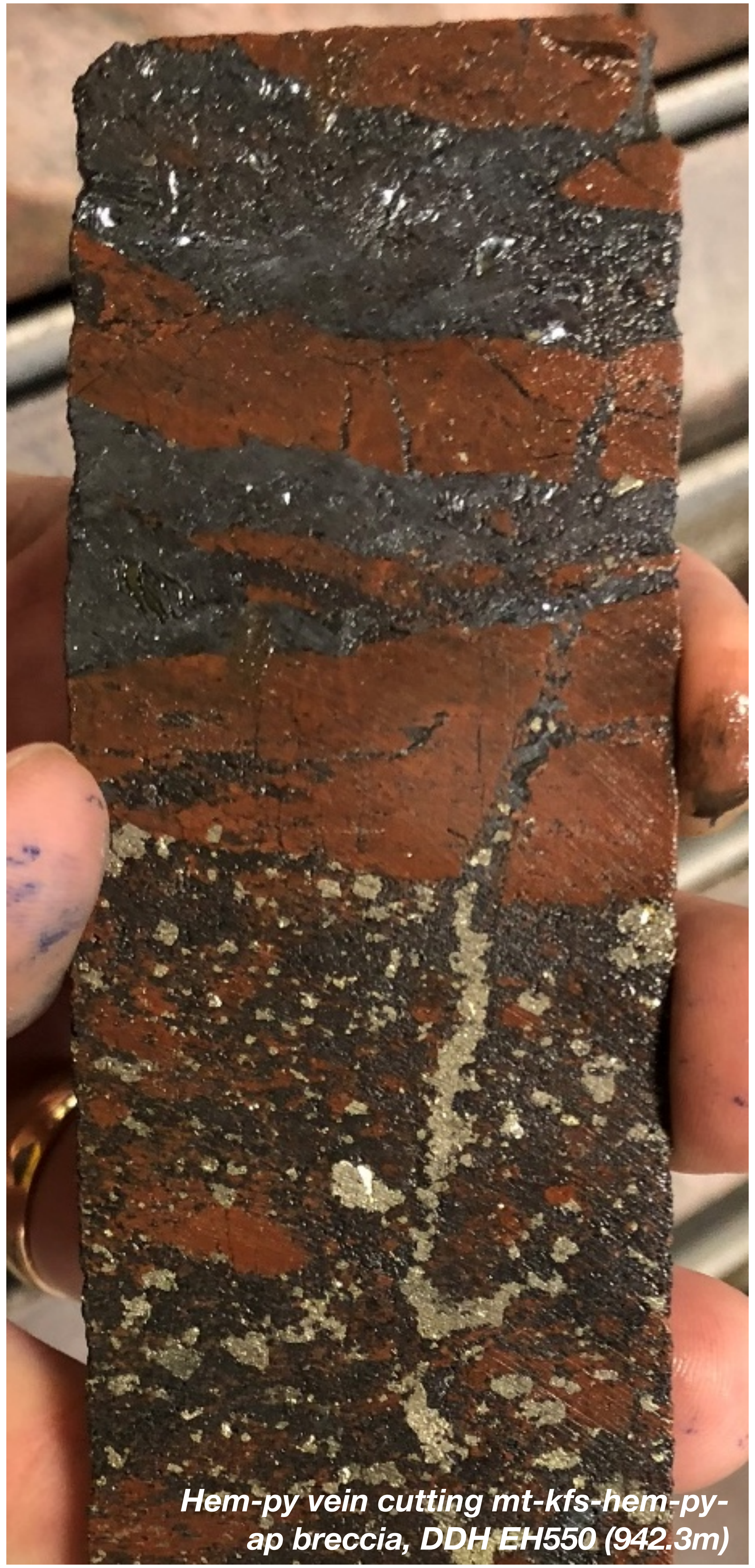
CODES – world leaders in mineral chemistry

- Through a series of AMIRA projects over 15 years, CODES has demonstrated the utility of mineral chemistry in porphyry-epithermal exploration
- Particular focus on the "green rock" environment – vectoring within propylytic alteration
- IOCG and sediment-hosted deposits have large alteration footprints
- How can we use mineral chemistry to vector within these?



Hem-py vein cutting mt-kfs-hem-py-ap breccia, DDH EH550 (942.3m)

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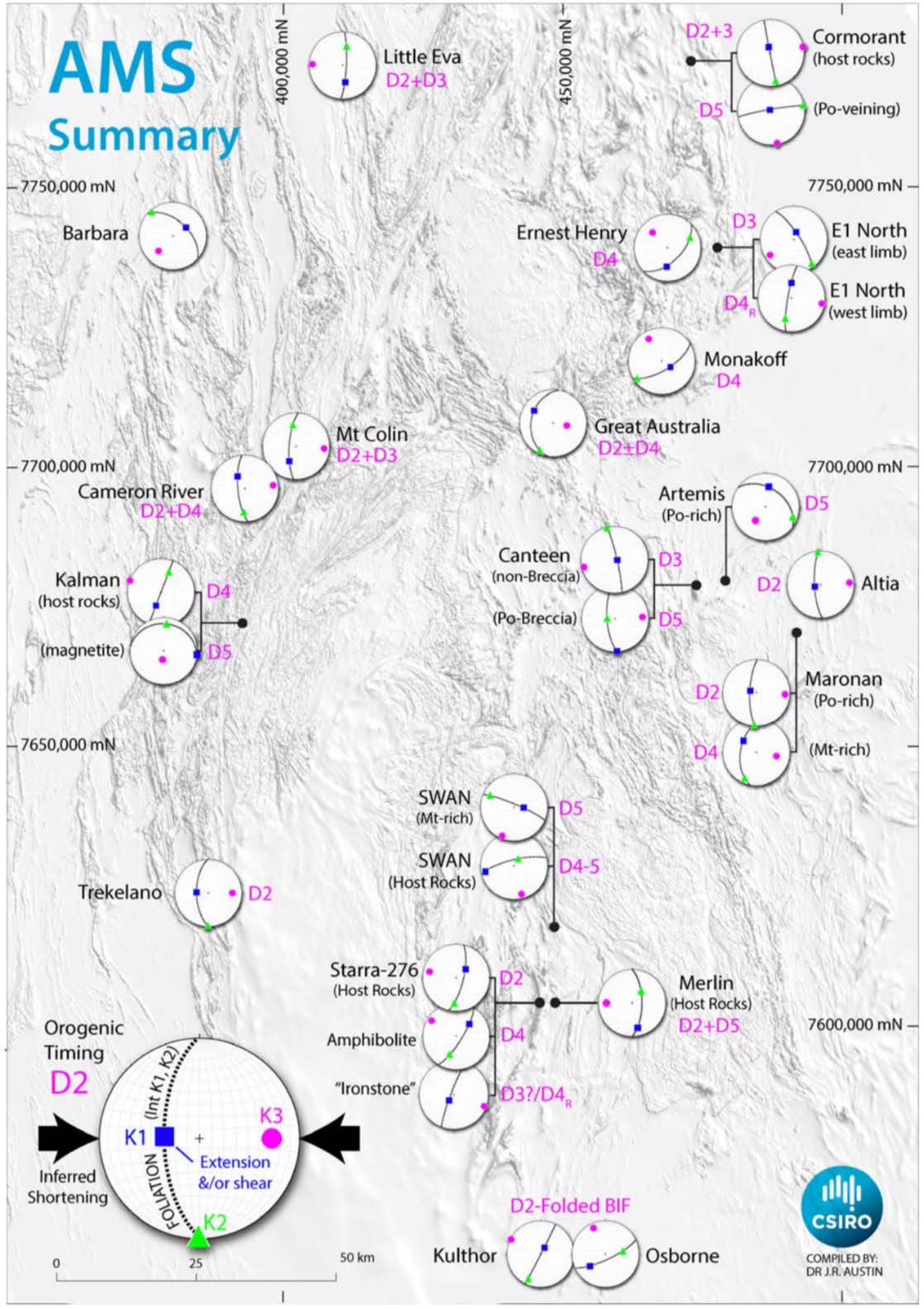
Sample location

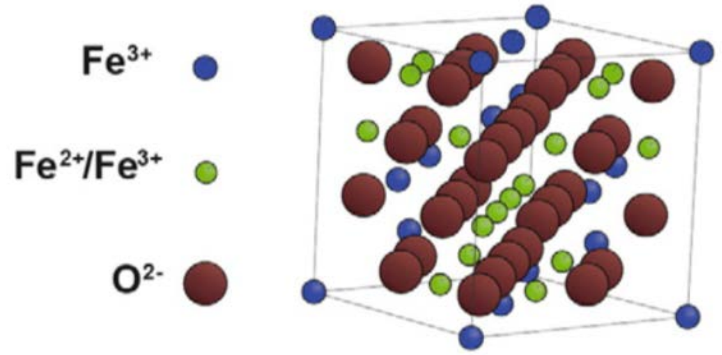
- Samples provided by CSIRO
  - Obtained during the UNCOVER Cloncurry project
- Magnetite from 14 deposits
- Pyrite from 16 deposits



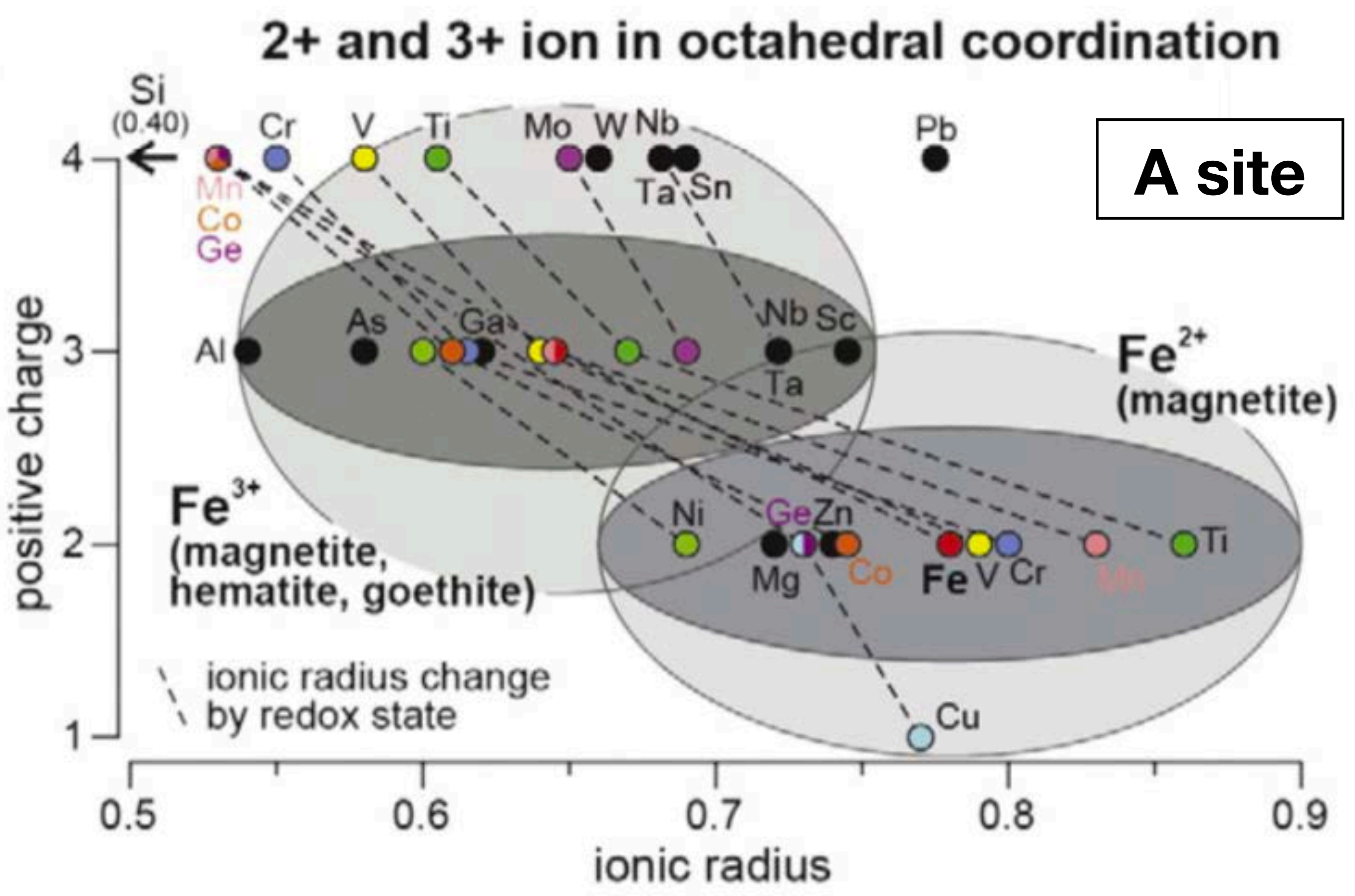
From Austin et al., 2016

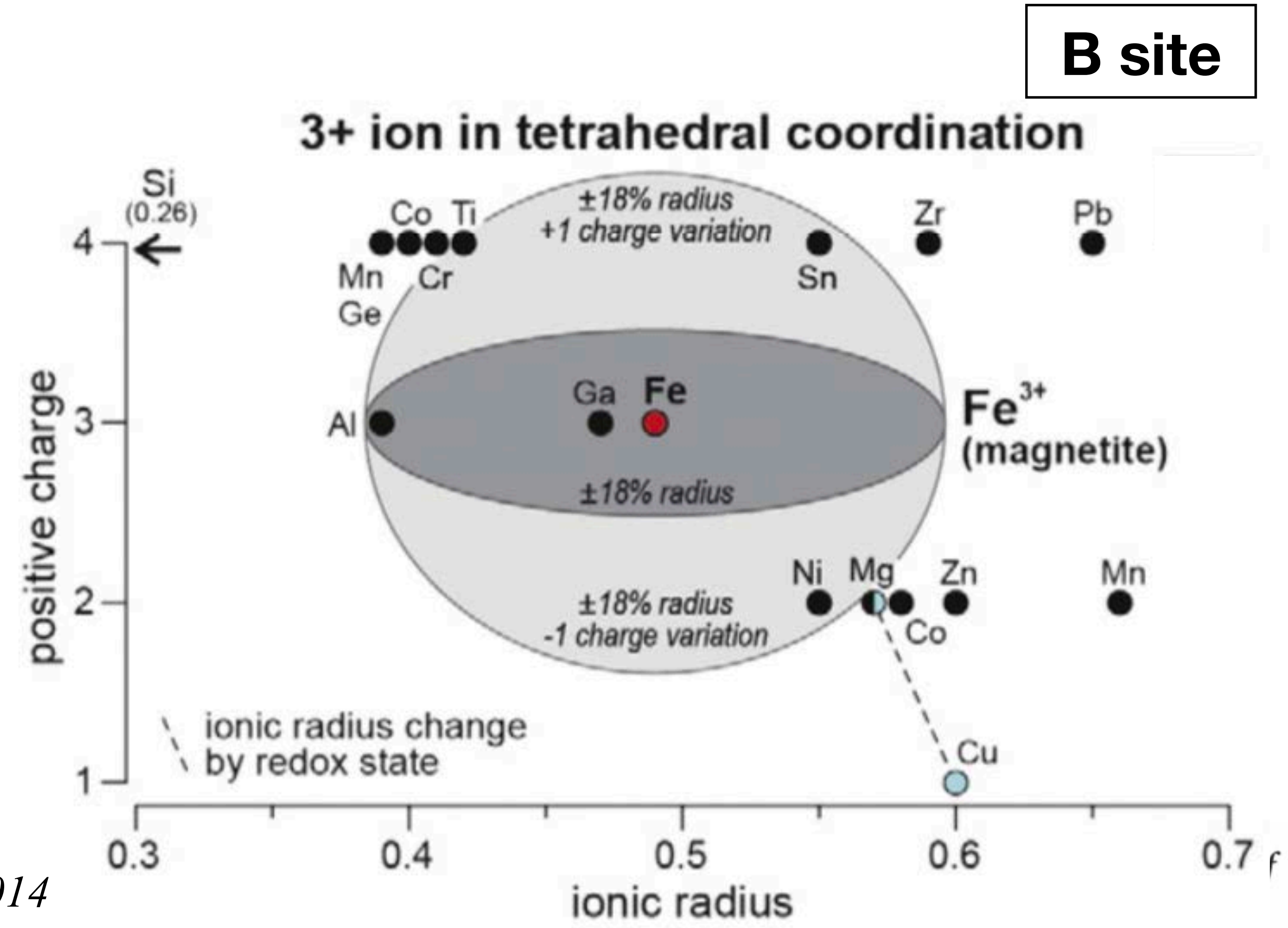
Magnetite chemistry

- Magnetite has an inverse spinel structure with the general stoichiometry AB_2O_4



  - **"A"** represents a divalent (2^+) cation such as Mg, Fe, Ni, Mn, Co, or Zn
  - **"B"** represents a trivalent (3^+) cation such as Al, Fe, Cr, V, Mn, or Ga
  - Ti^{4+} can also occupy the B site when substitution is coupled with a divalent cation

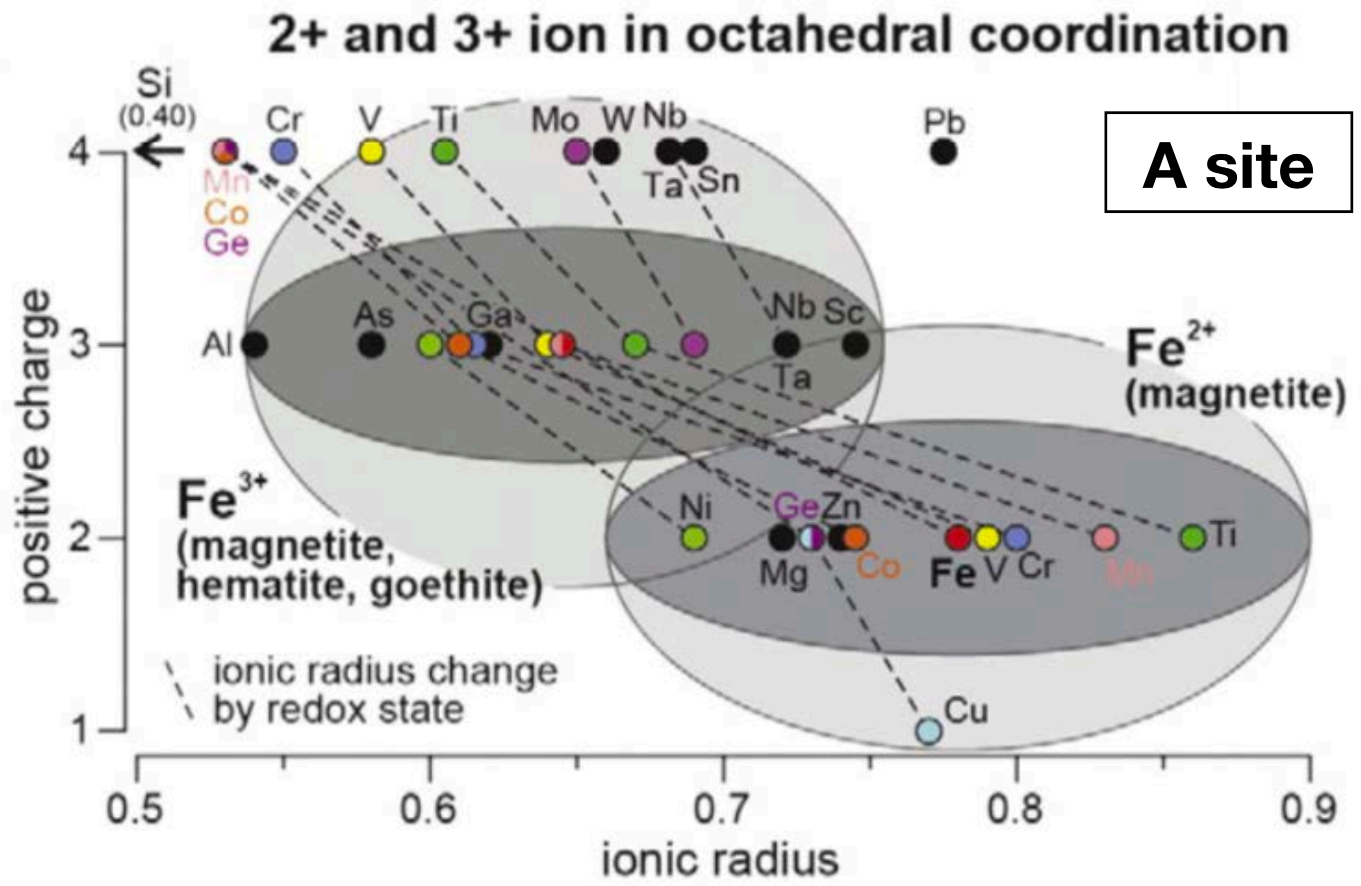


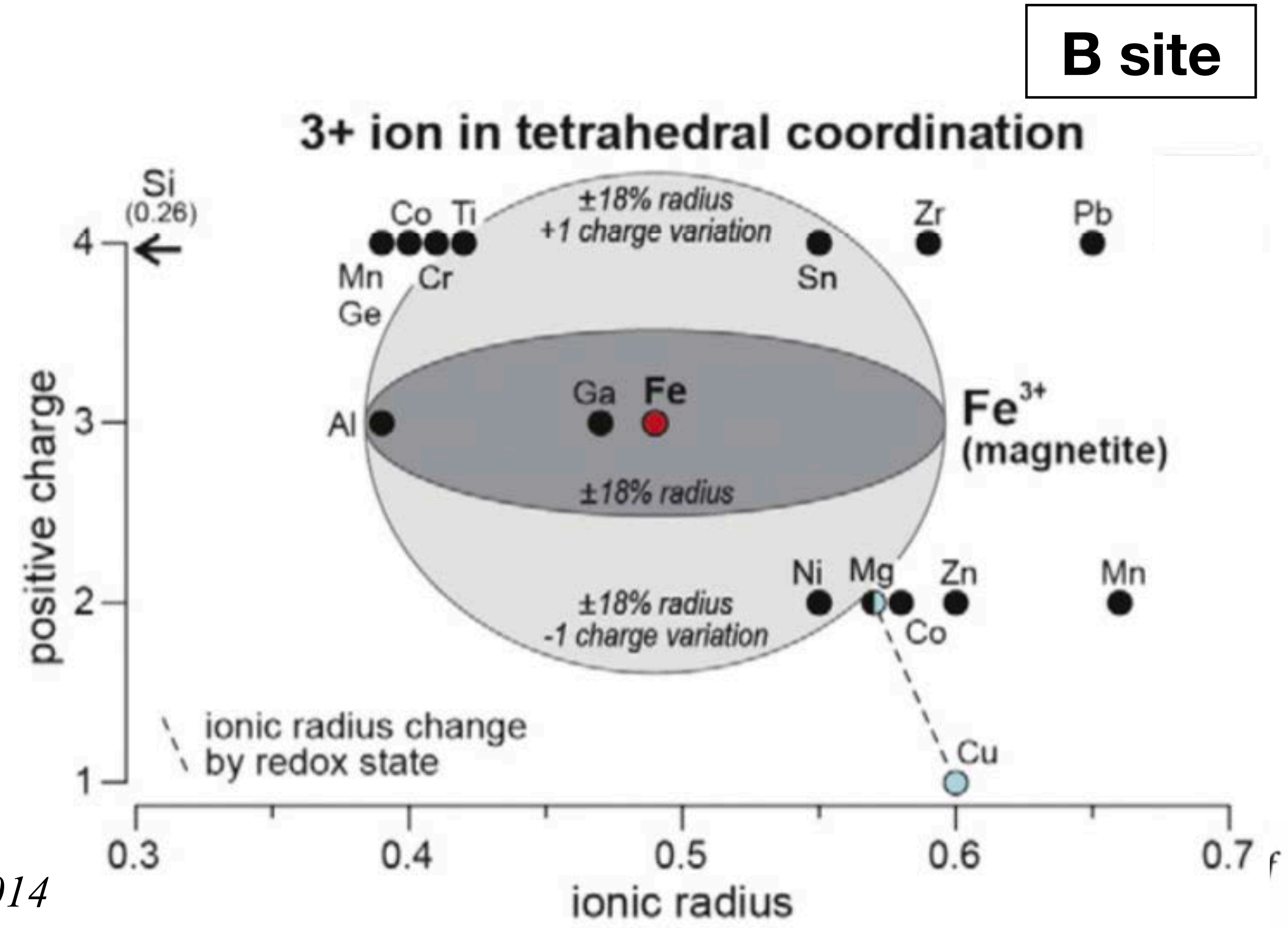


From Nadoll et al., 2014

Magnetite chemistry

- Substitution may be due to:
  - Oxidation state (more + = more oxidised):
    - V (+5, +4, +3)
    - Cr (+4, +2)
    - Mn (+4, +2)
  - Temperature:
    - Ti (high at high T°)
    - Al (high at high T°)

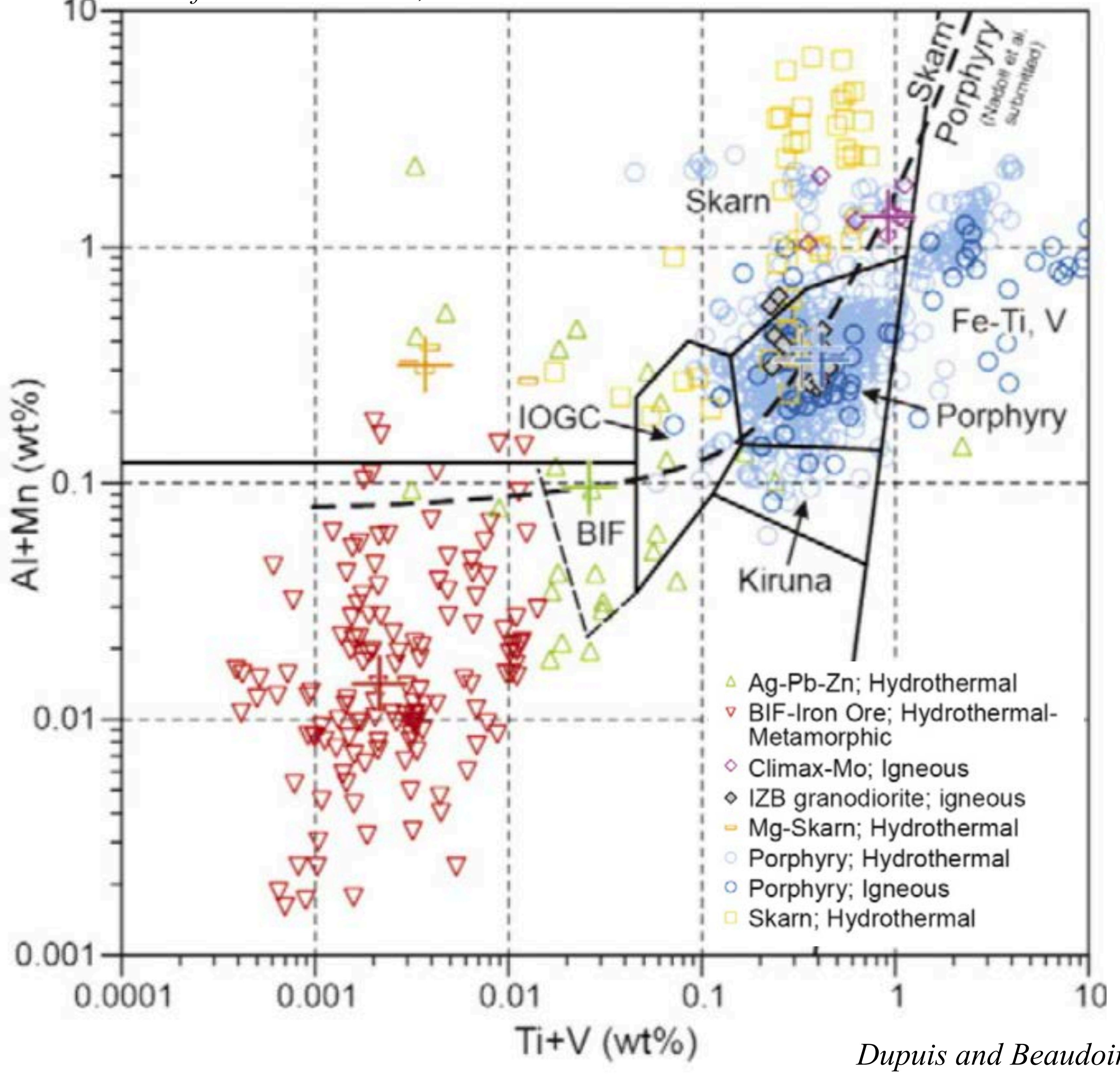




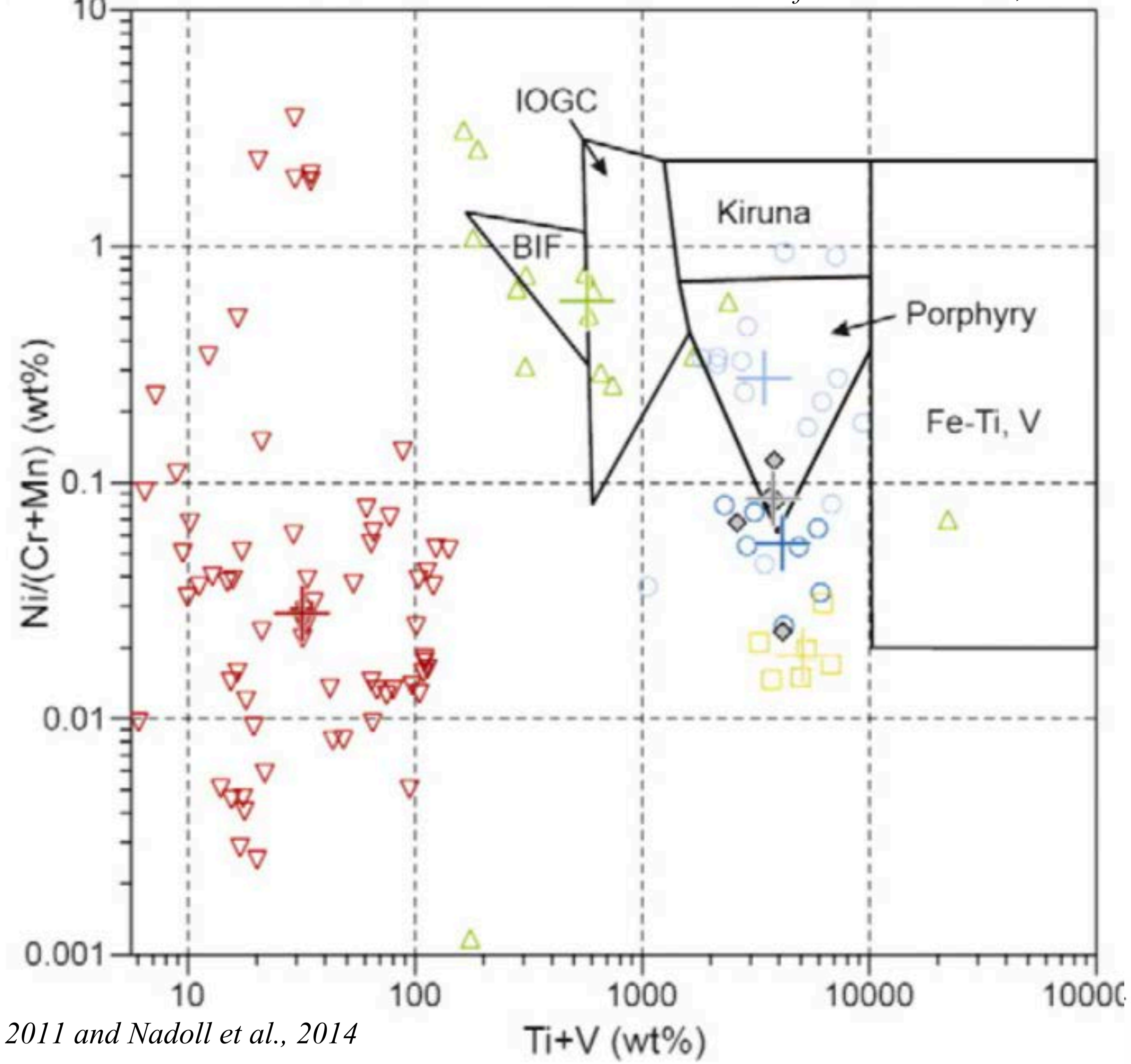
From Nadoll et al., 2014

Discrimination diagrams

Data from Nadoll et al., 2014



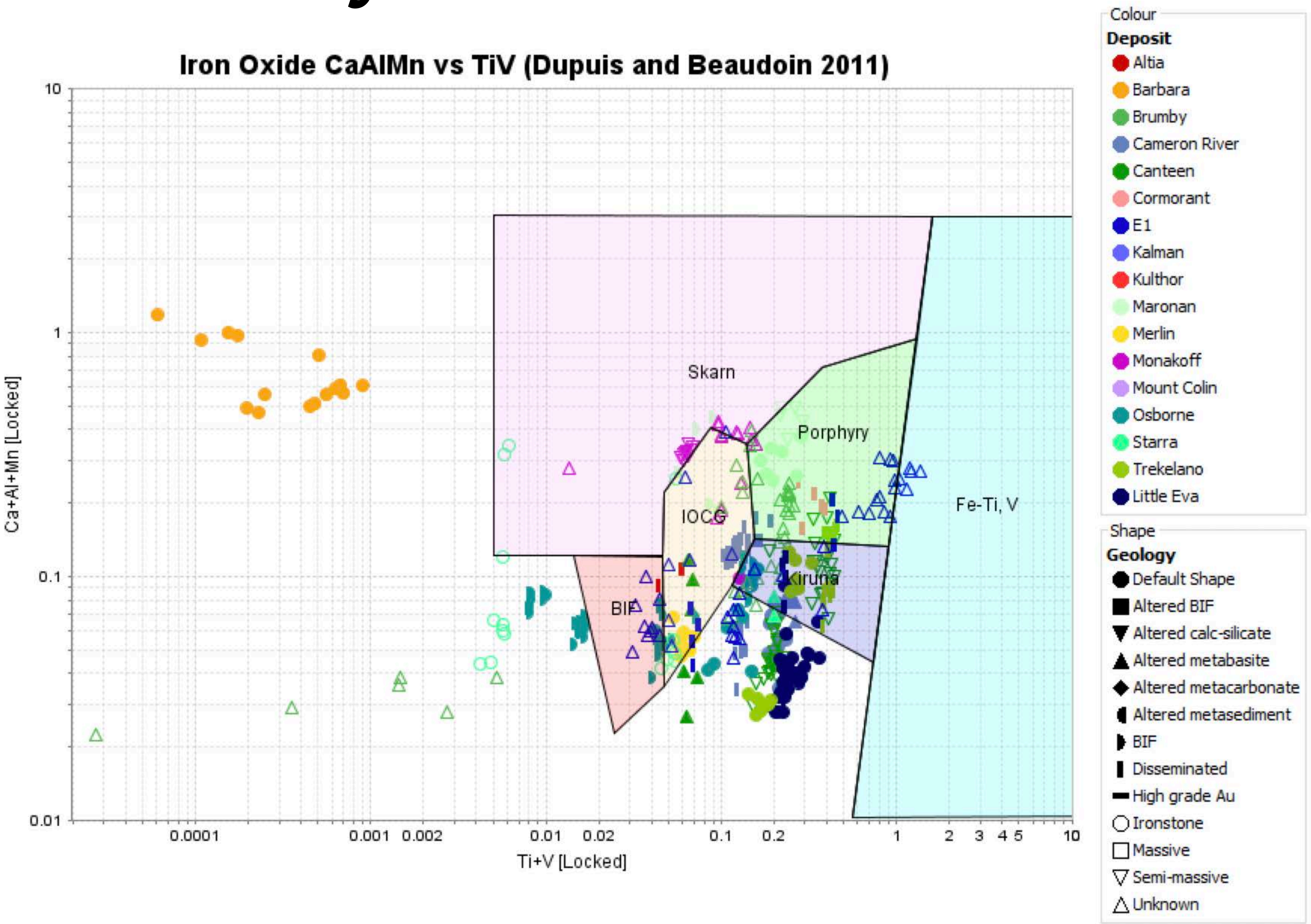
Data from Nadoll et al., 2014



Dupuis and Beaudoin, 2011 and Nadoll et al., 2014

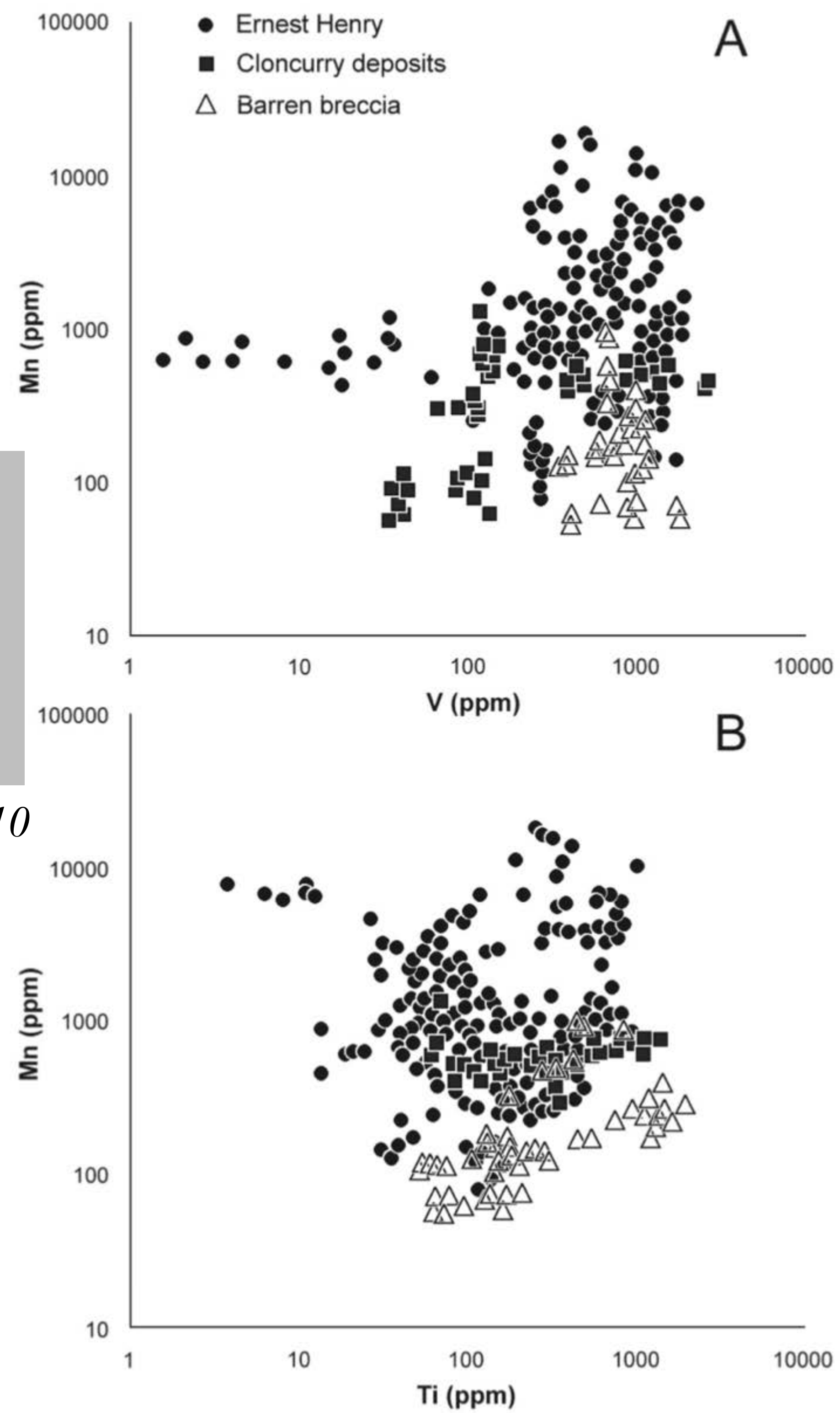
Cloncurry IOCG

- Implies that magnetite in Eastern Succession IOCGs has diverse origin
- Potential to fingerprint high T, of magnetite forming in from more oxidised fluids in alteration assemblages?

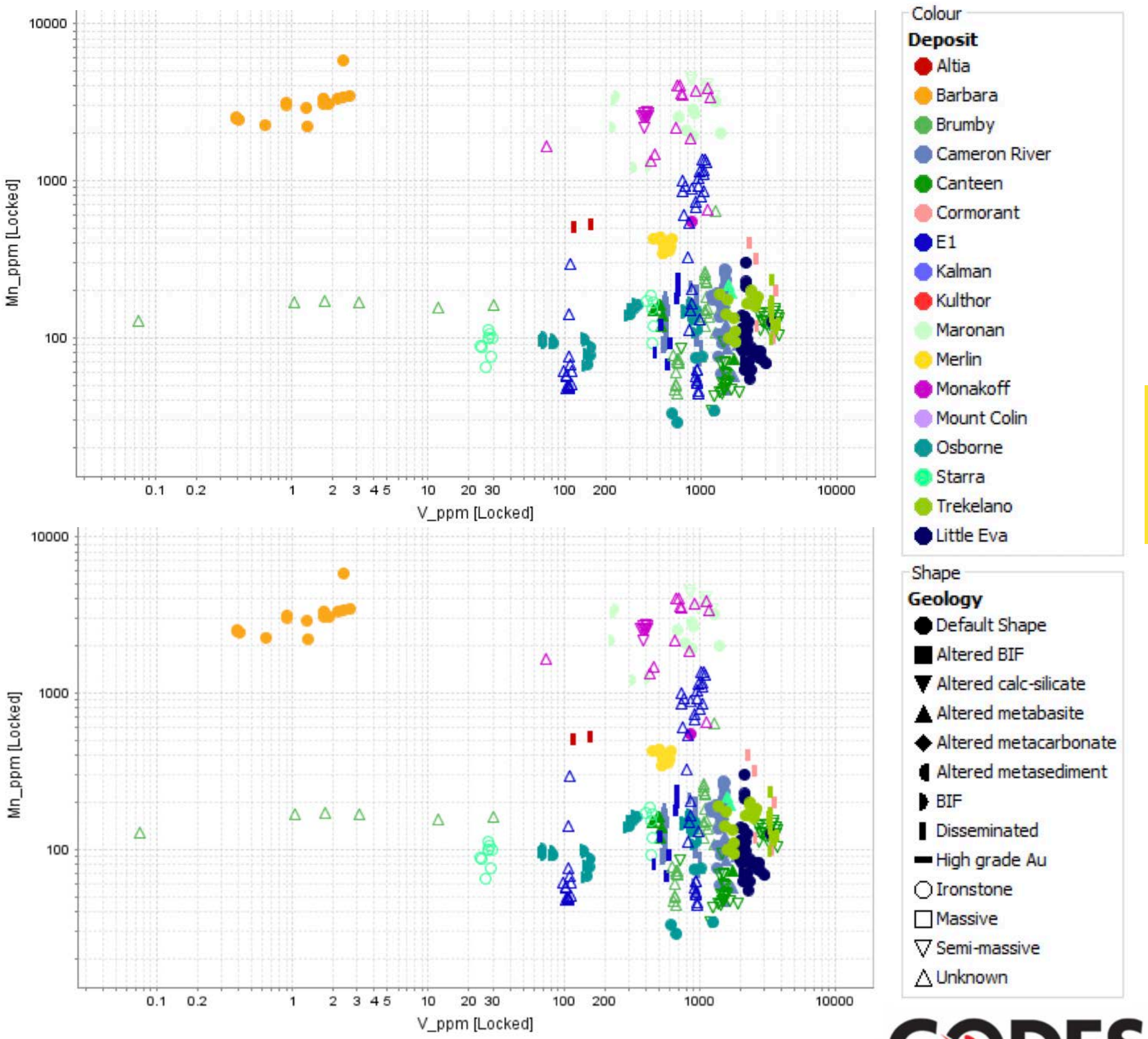


Magnetite chemistry

Ernest Henry magnetite



From Rusk et al., 2010



Cloncurry magnetite

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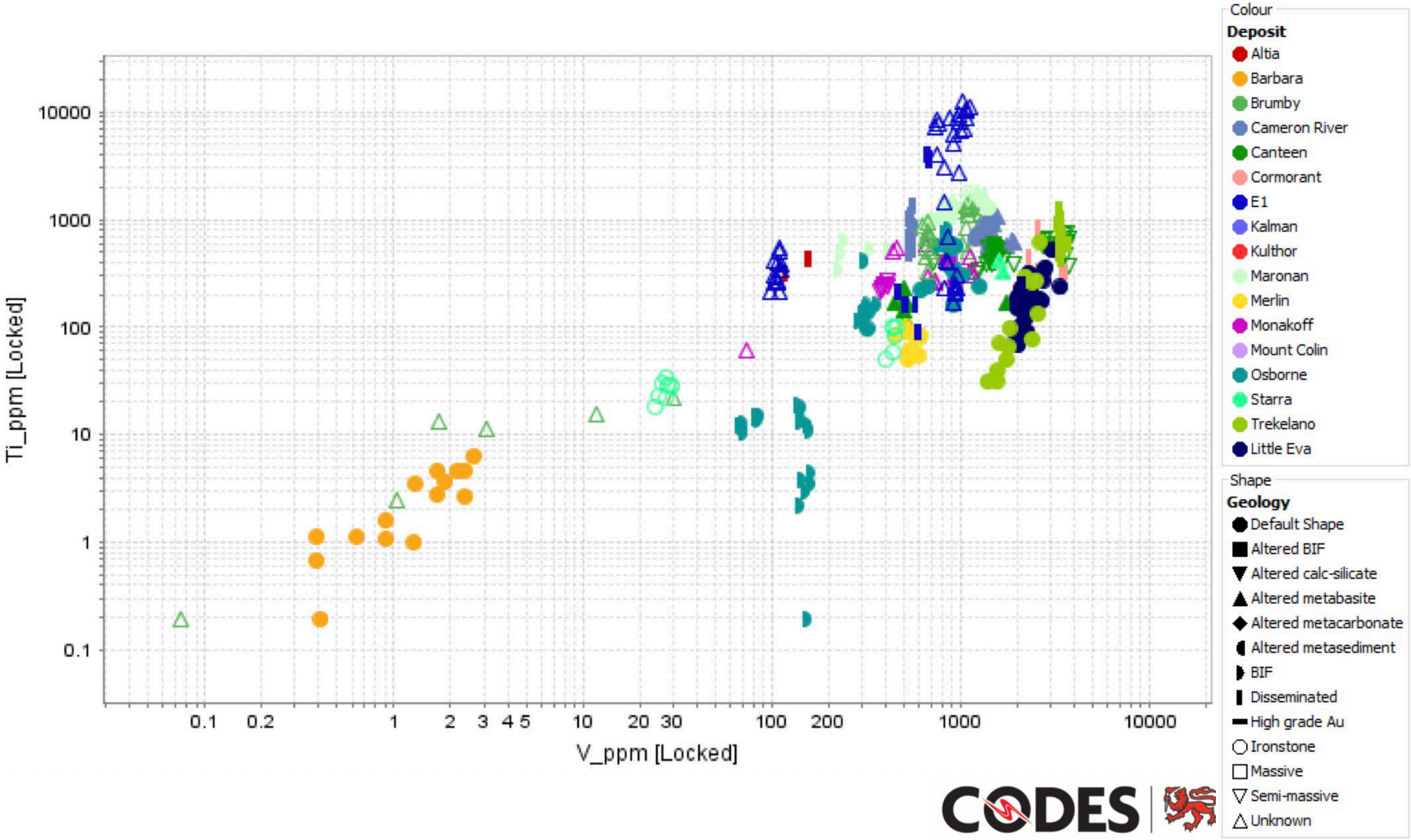
Magnetite chemistry

- Temperature and oxidation state controls magnetite chemistry in the Cloncurry district

- More work is needed to fully understand the mechanisms



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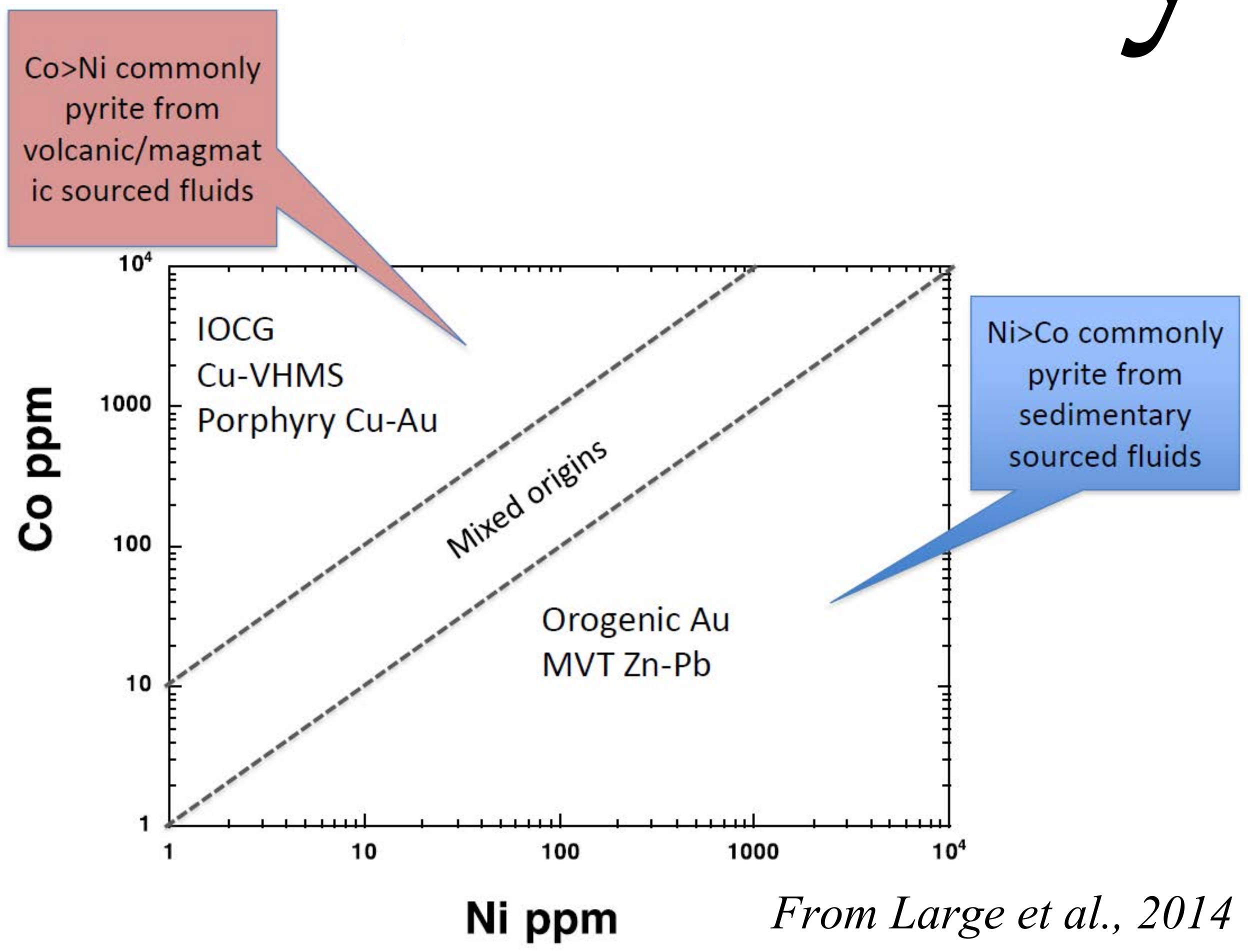
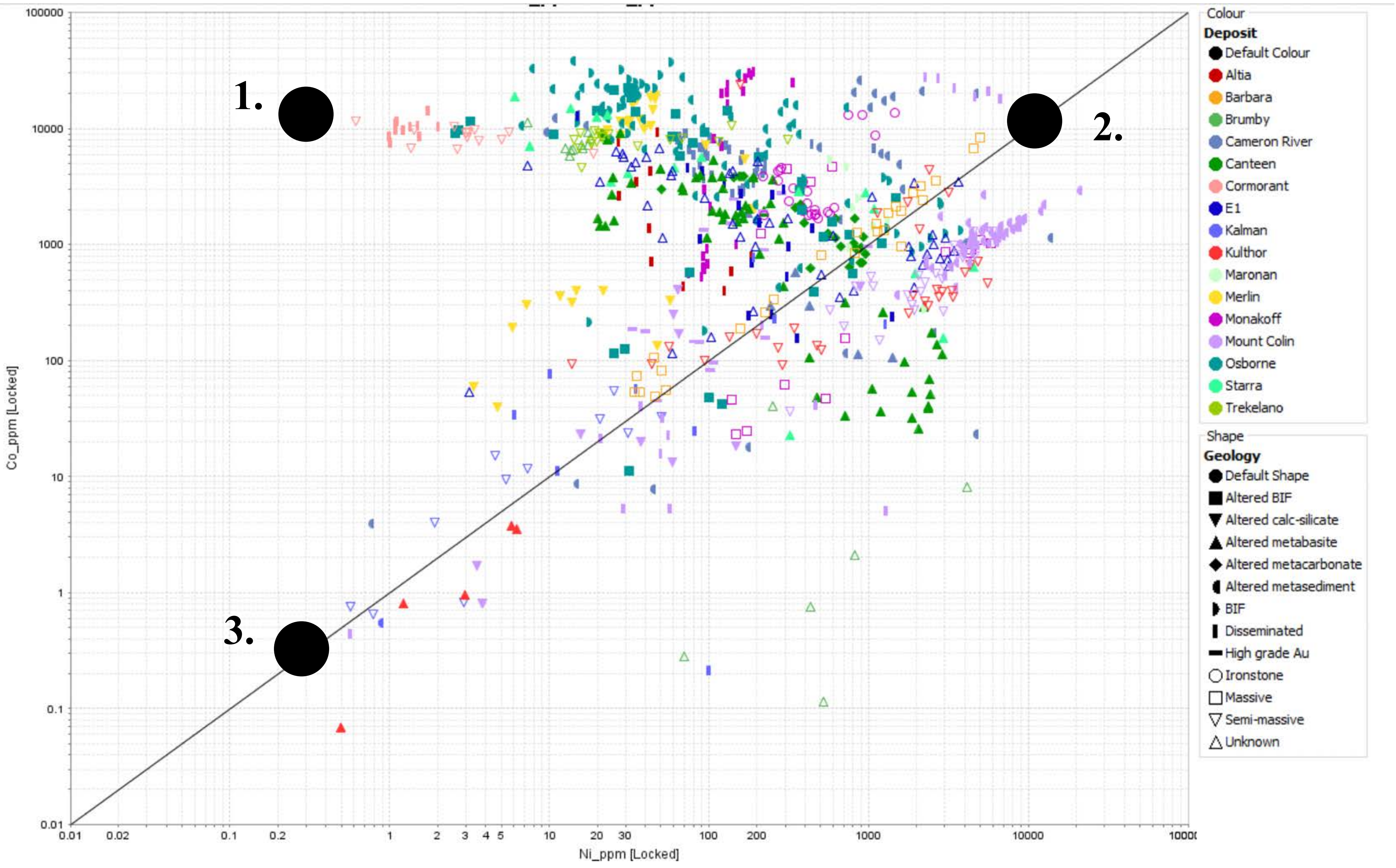
Pyrite chemistry



From Large et al., 2014



- 3 end members:
  1. Co-rich
  2. Ni-Co-rich
  3. Ni-Co-poor

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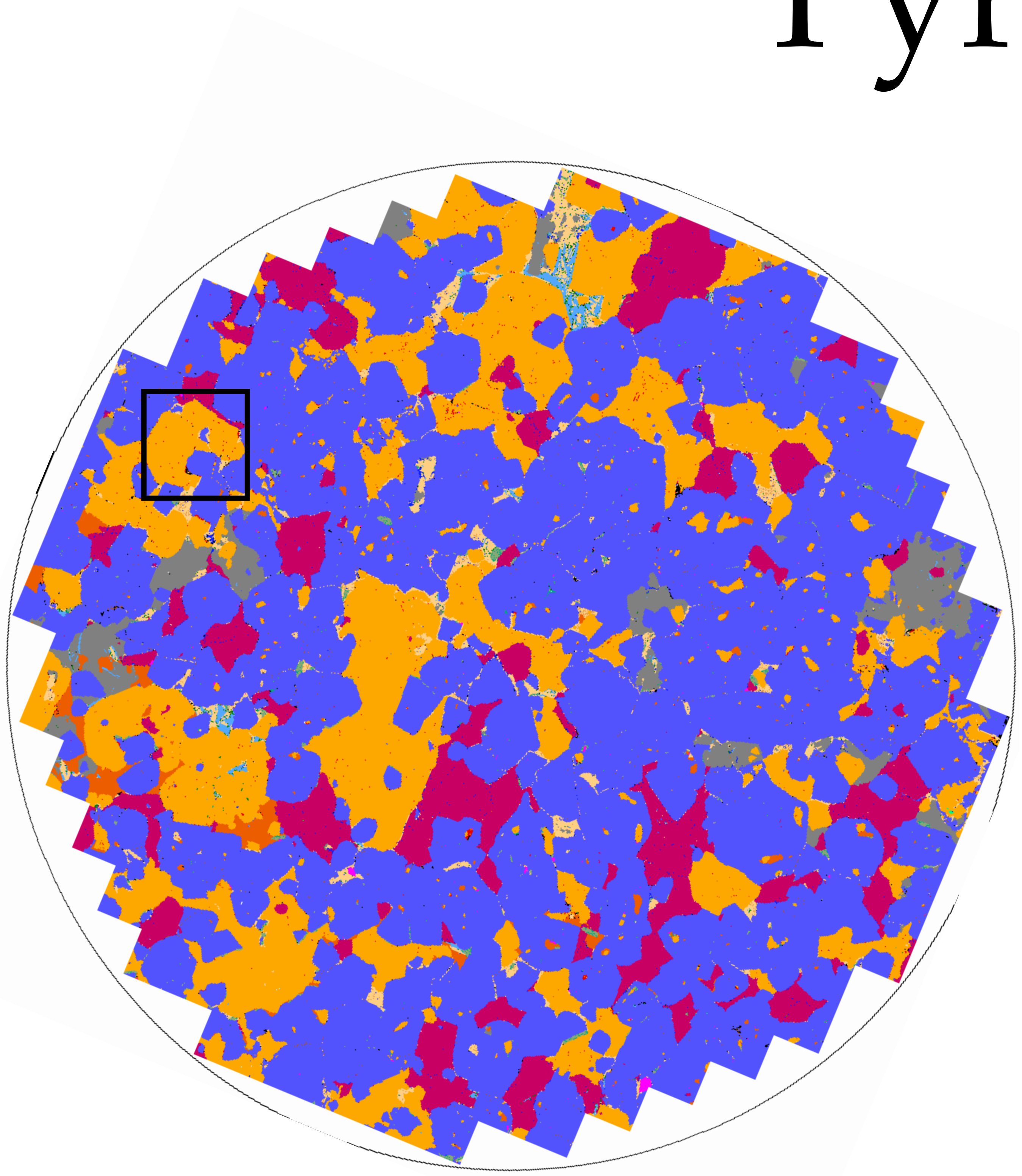
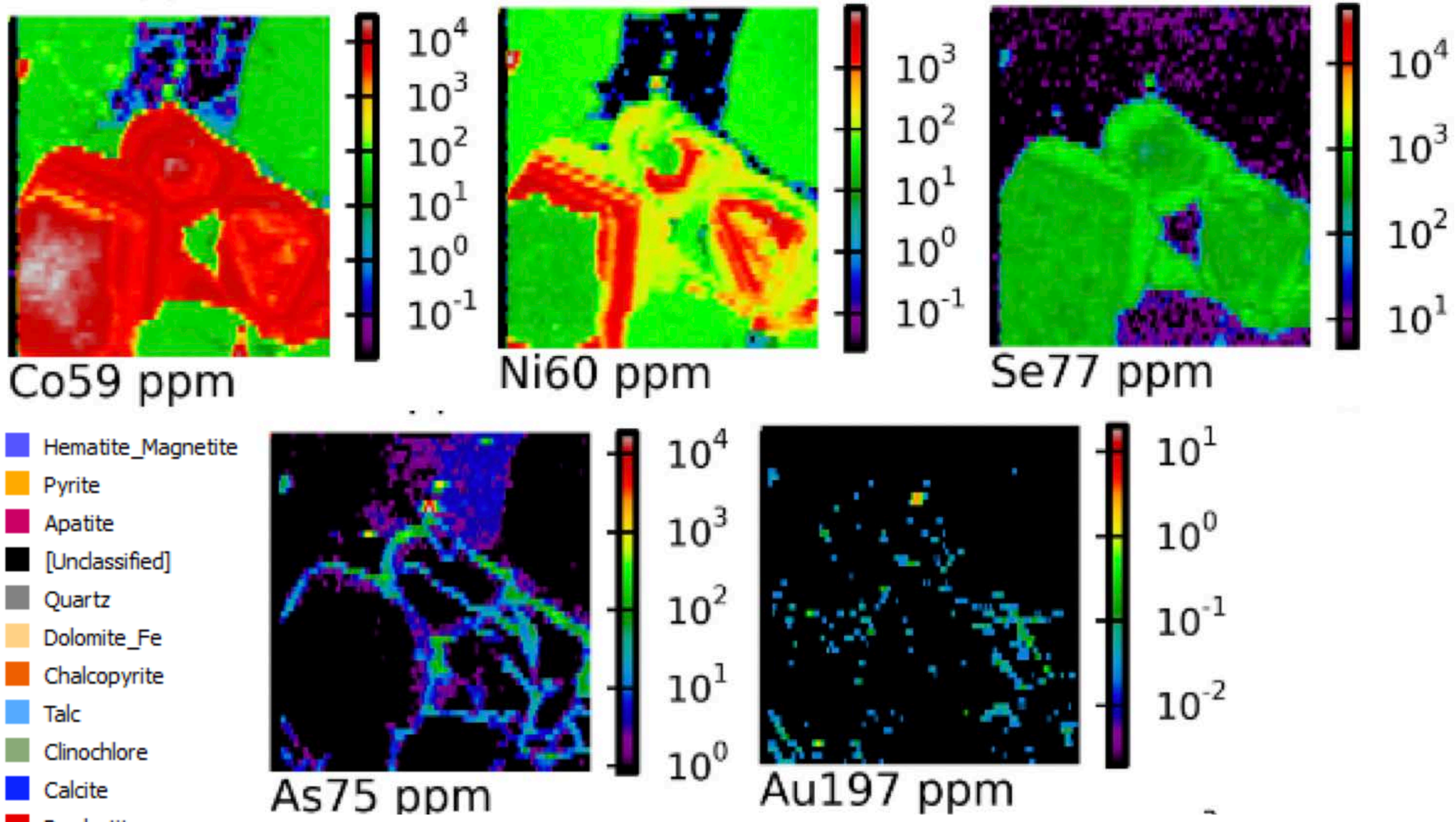
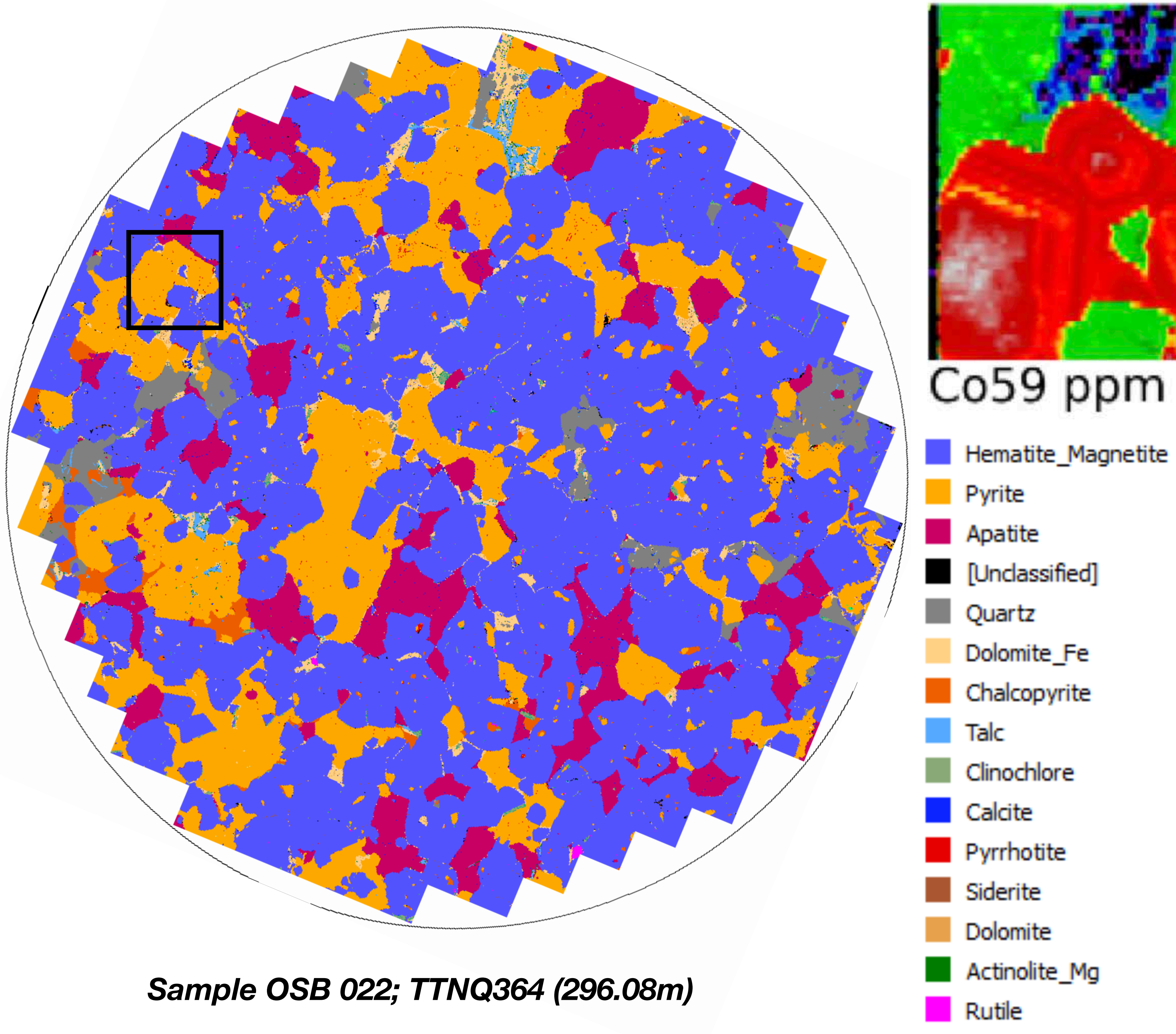
Pyrite chemistry



Sample OSB 022; TTNQ364 (296.08m)



Pyrite chemistry



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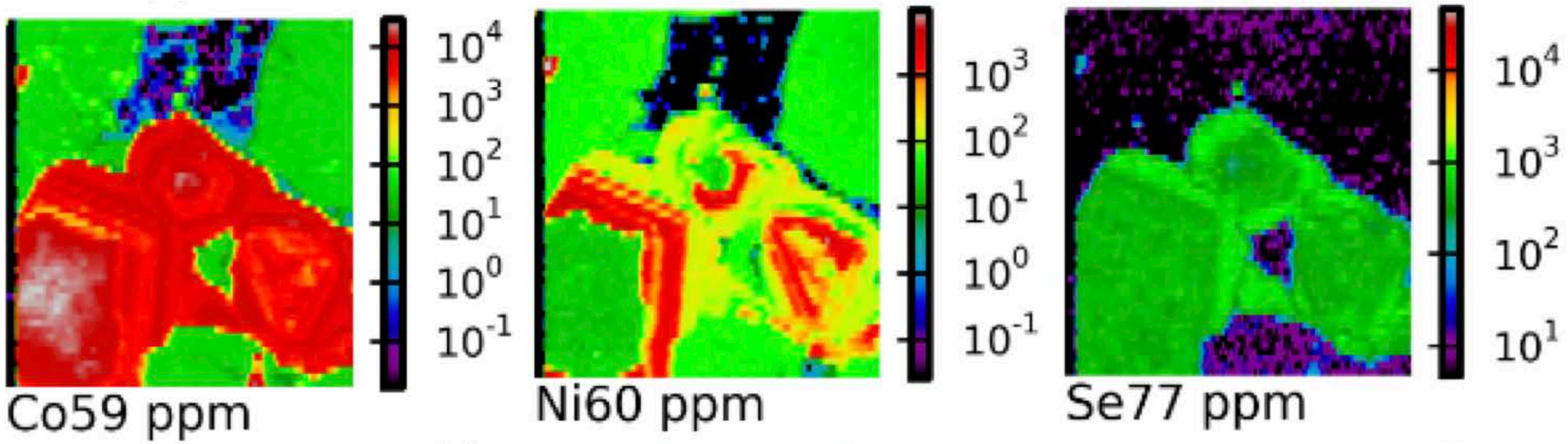
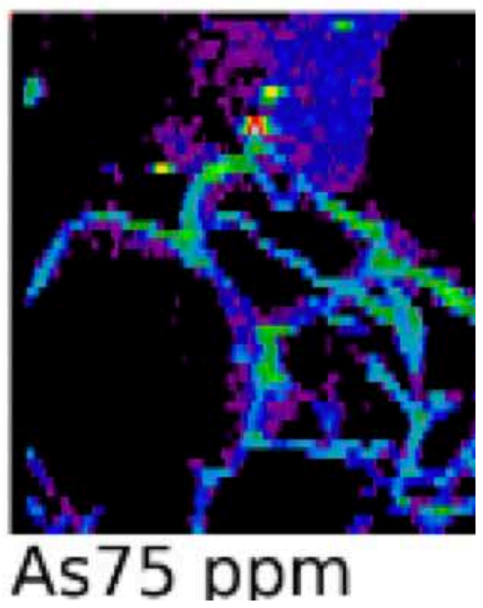
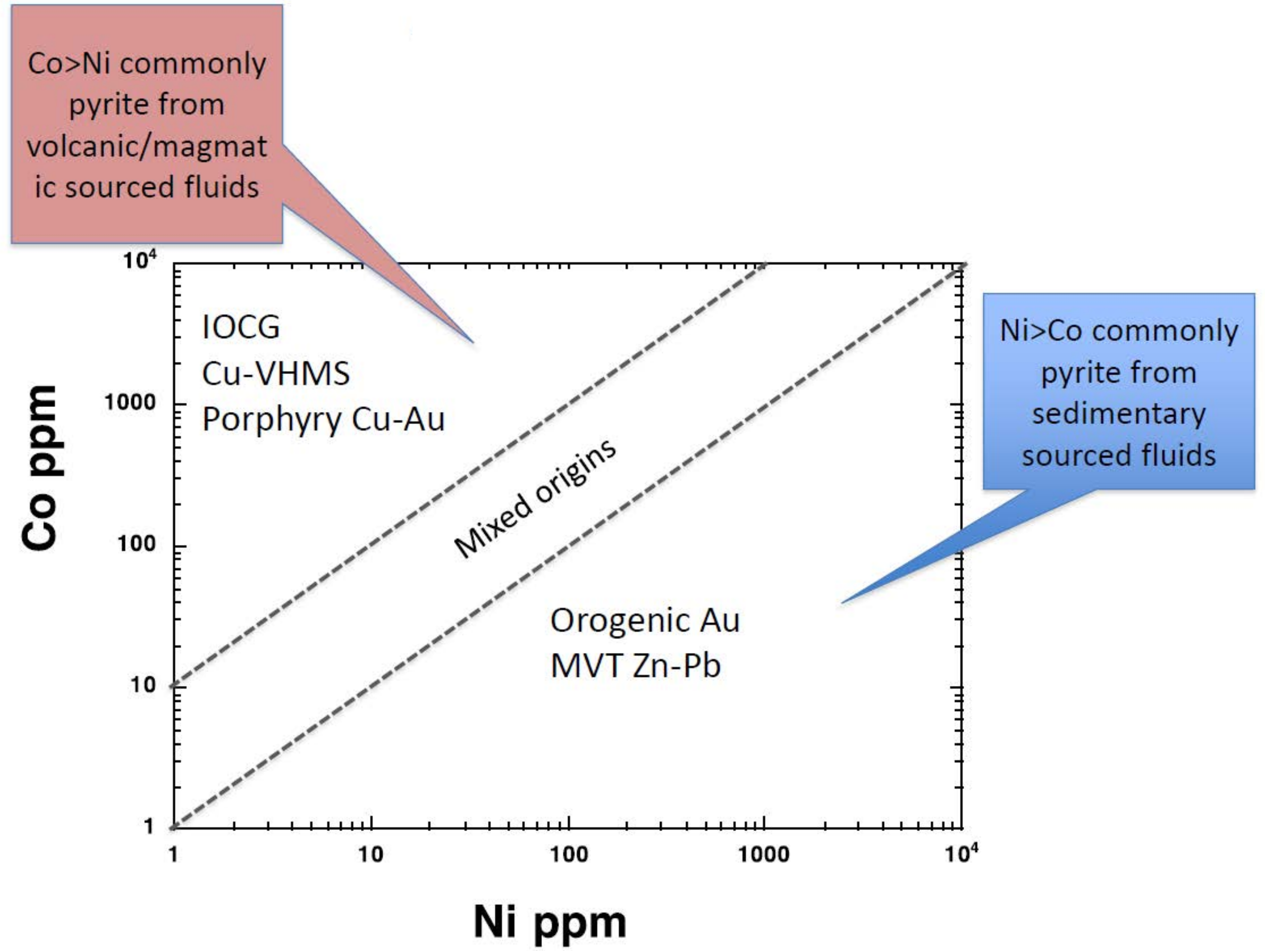
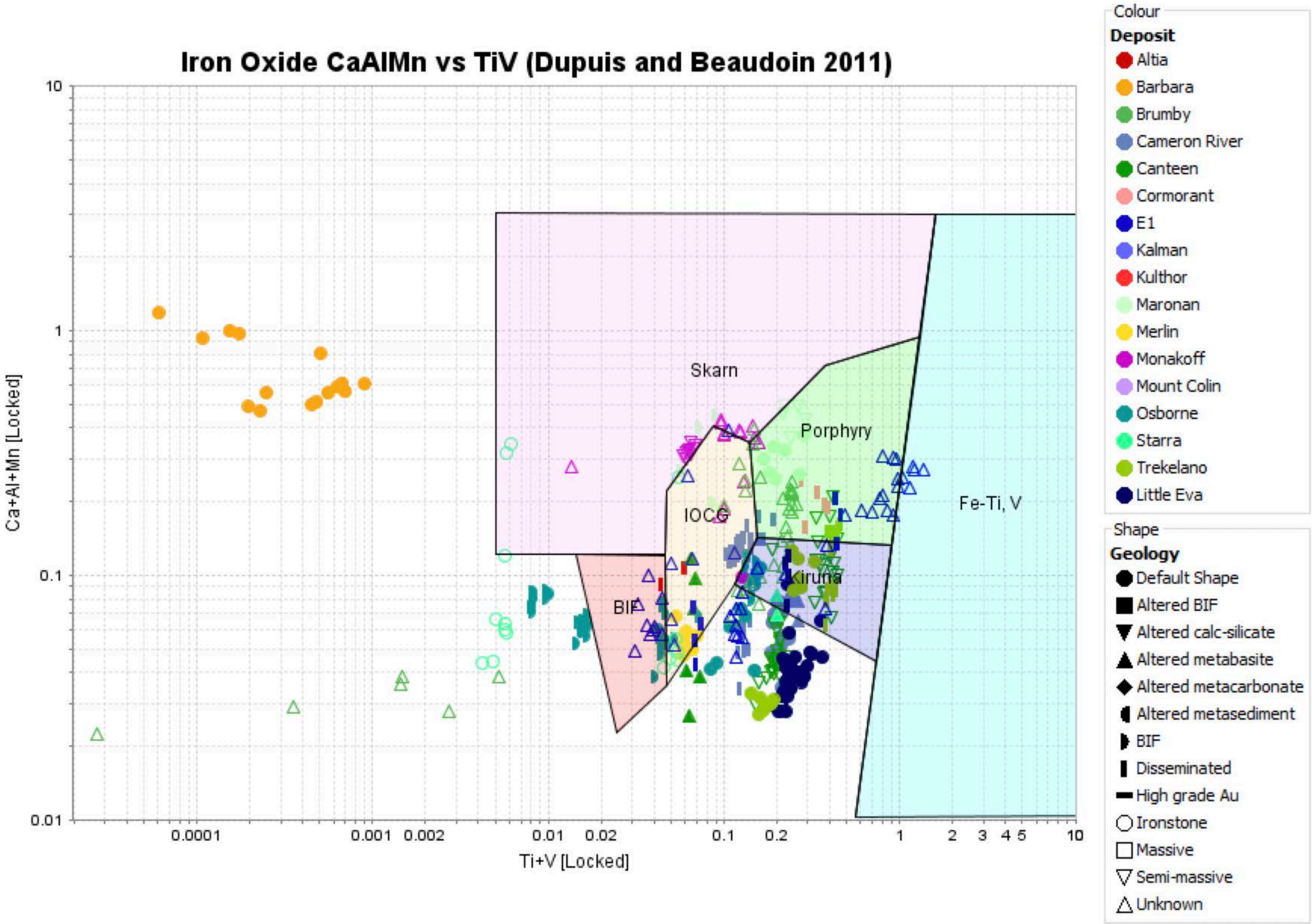


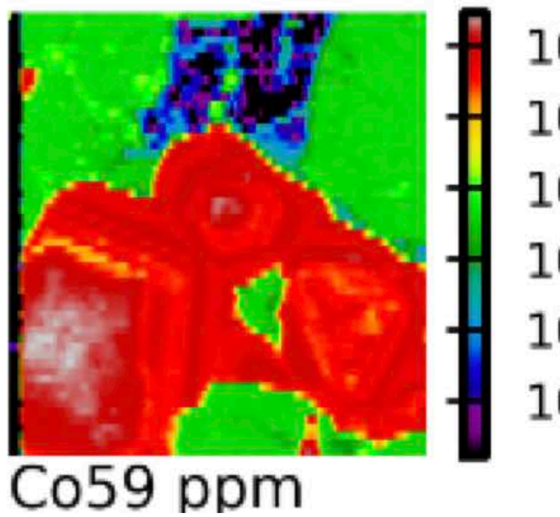


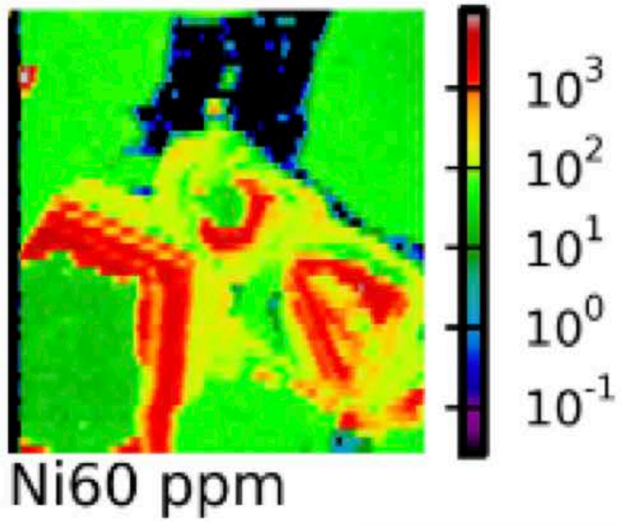


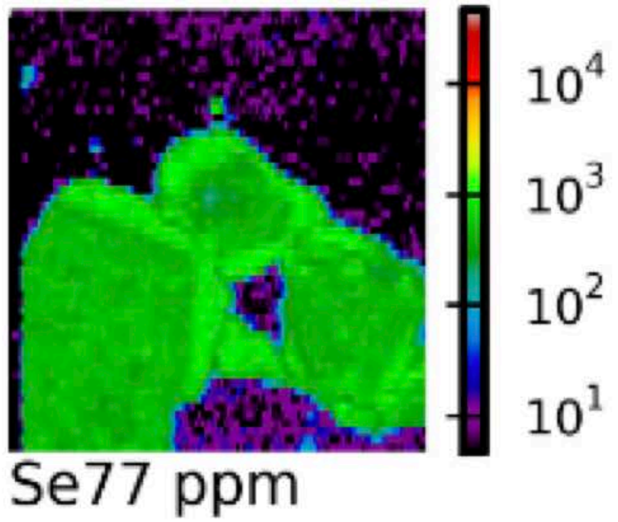
Magnetite and pyrite chemistry summary

- Current magnetite discrimination diagrams does not accurately discriminate magnetite types in Cloncurry area
- Magnetite chemistry suggest the deposits form at different T and oxidation state
- Pyrite chemistry shows pulse of of Co- and Ni-rich (high-T?) fluids







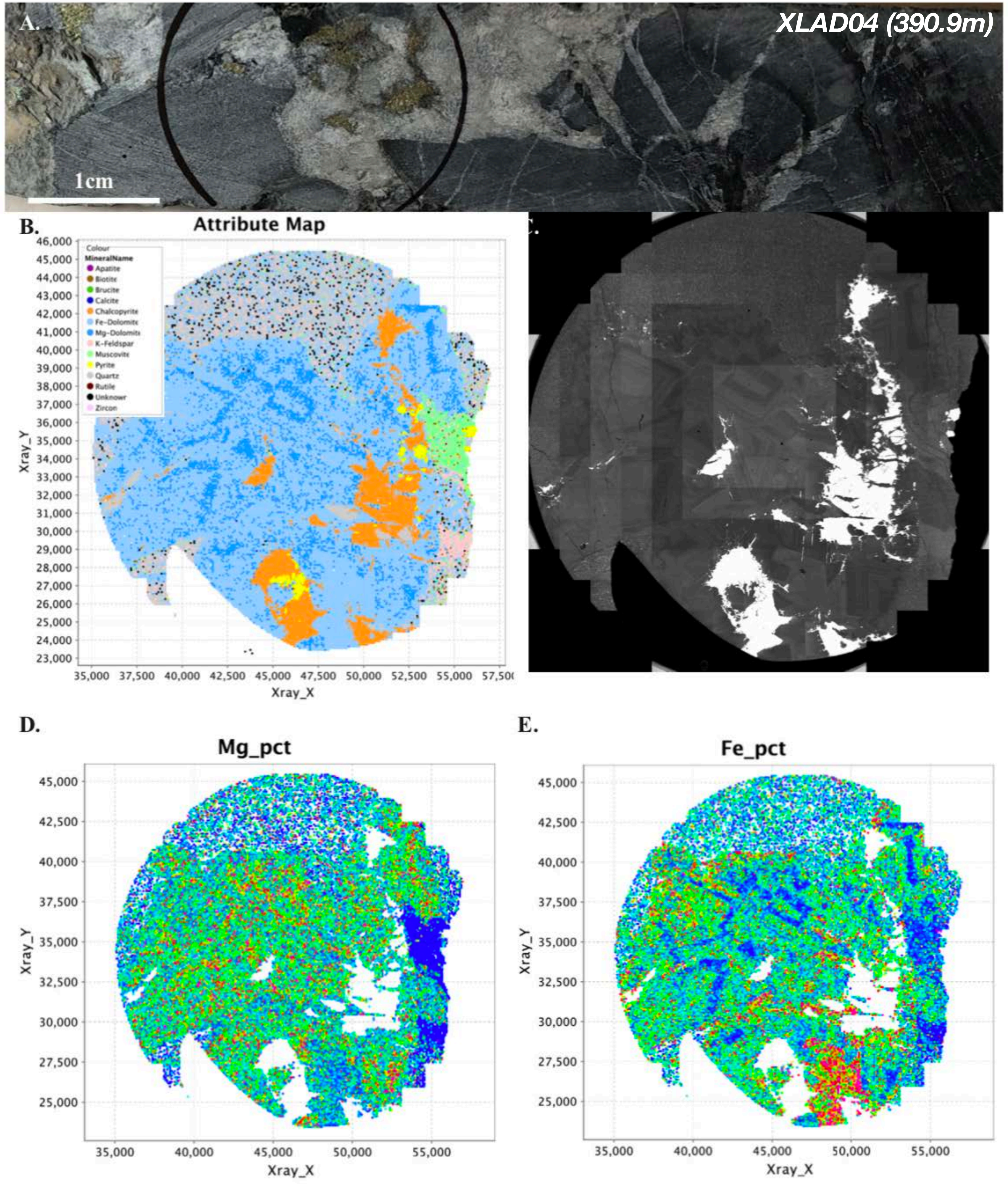


Lady Annie carbonate study

- <u>Aims:</u>
  - Document the paragenesis of carbonate veins
  - Investigate the chemistry of carbonate to fingerprint the Cu mineralisation
  - Use fingerprint signature(s) to test the footprint of the Lady Annie deposit

Methodology

- X-ray modal analysis (XMOD) to obtained mineralogy and back scattered electron (BSE) images
- Laser ablation of carbonate phases identified by XMOD and BSE images



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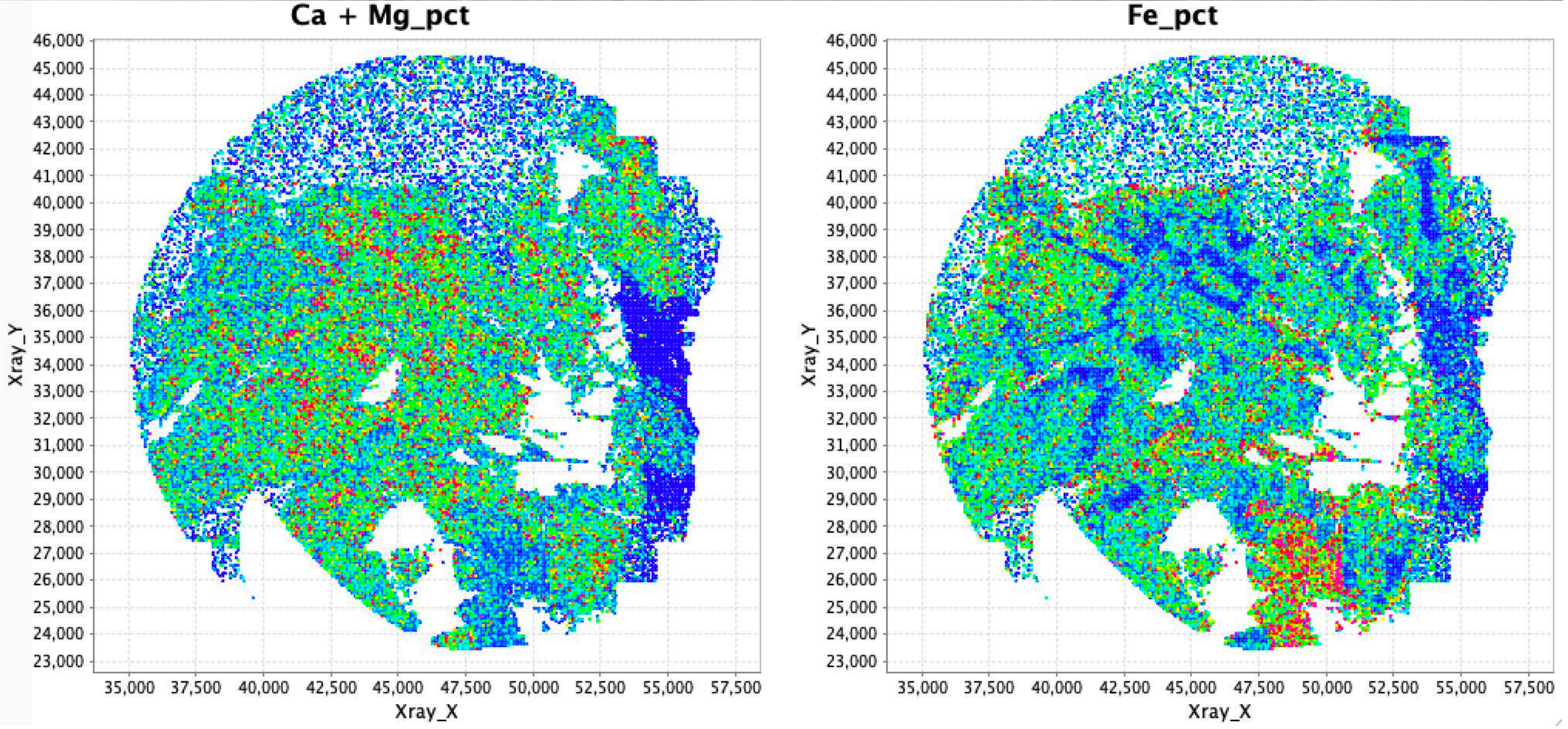
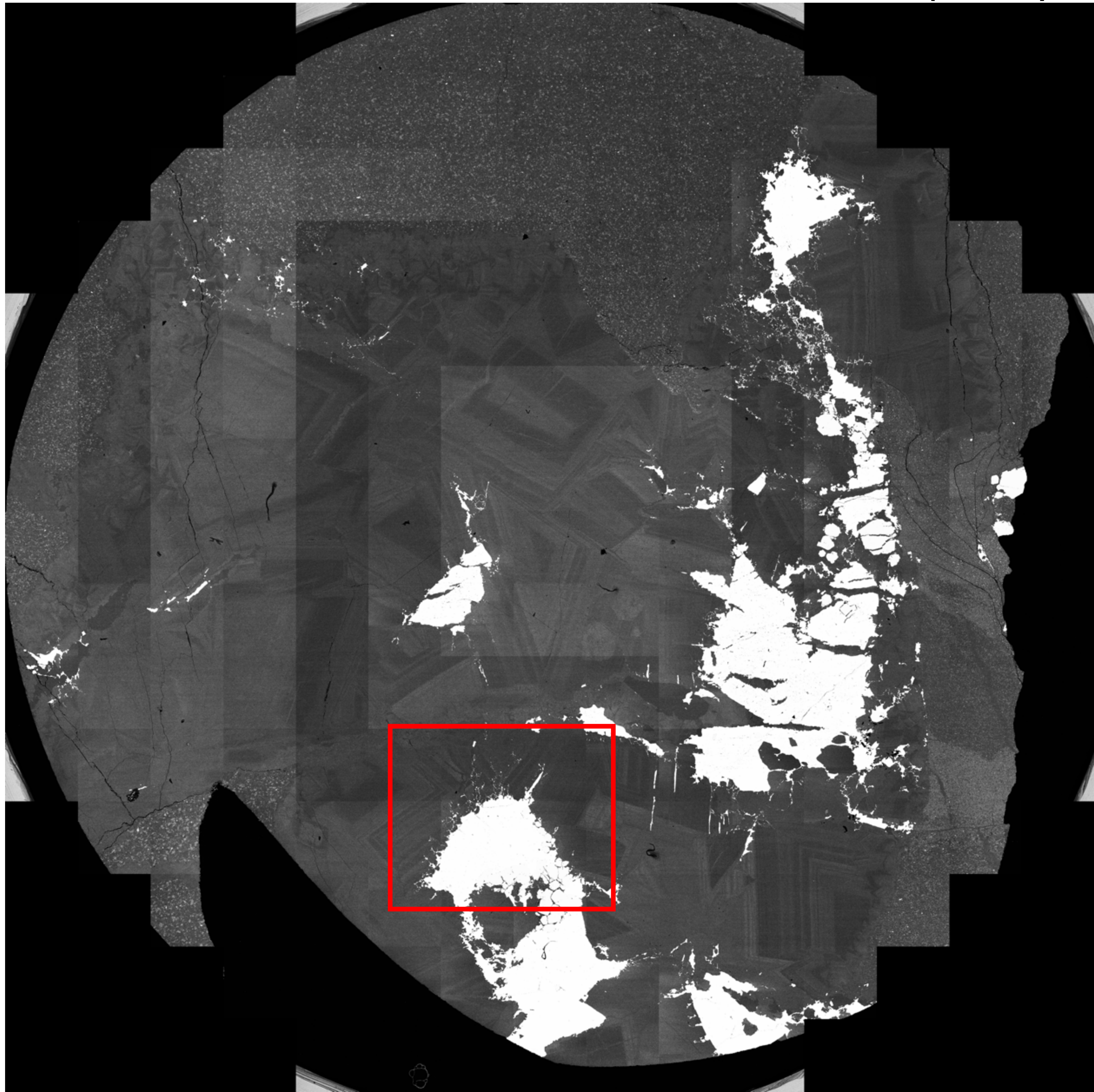
Results

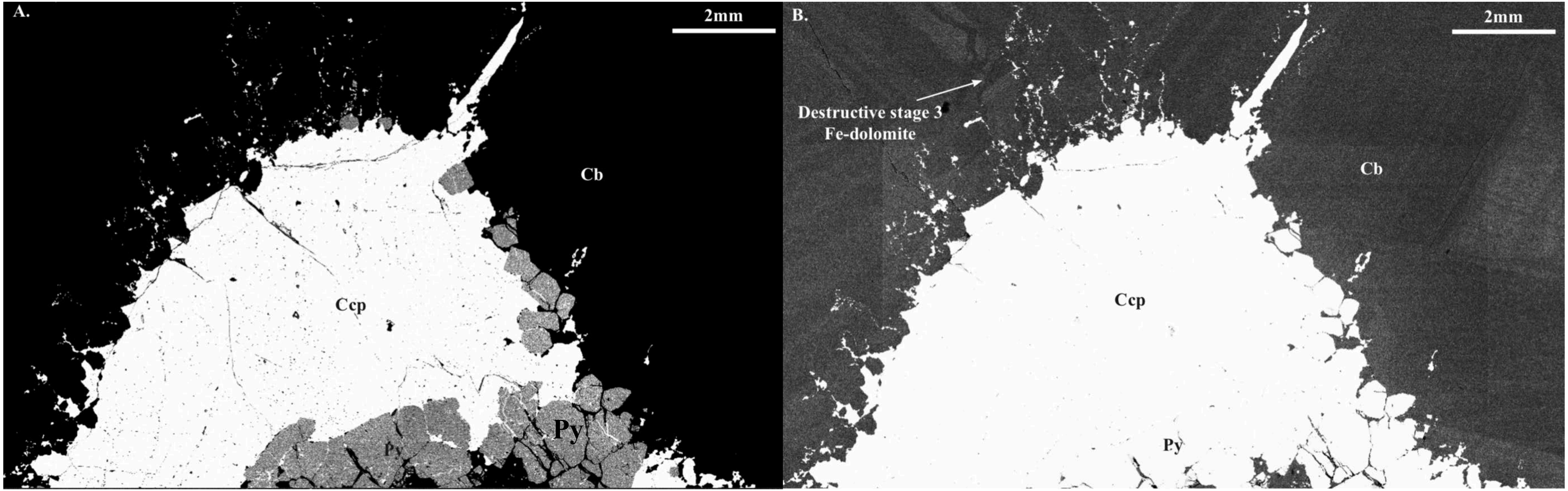


XLAD04 (390.9m)



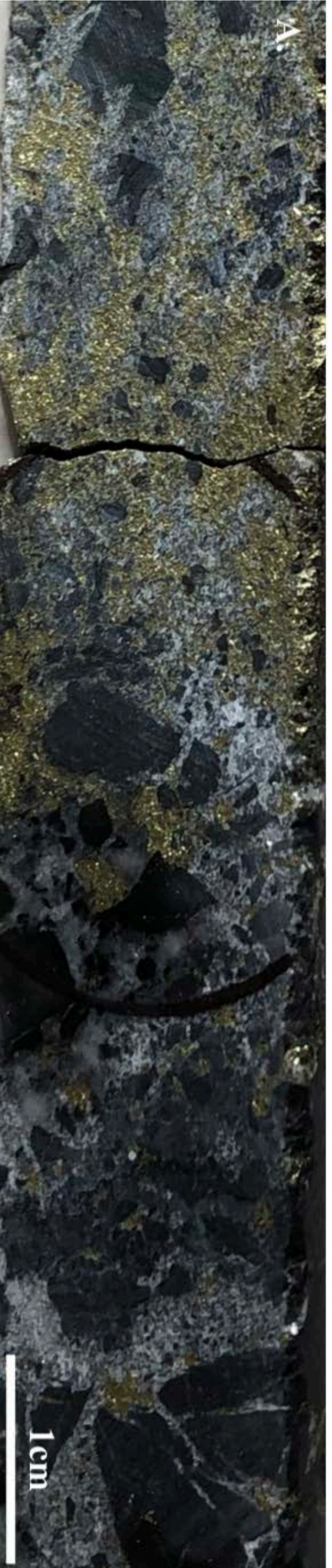
- Pre-mineralisation carbonate associated with oscillatory zoning between Ca-Mg and Fe-dolomite

Results

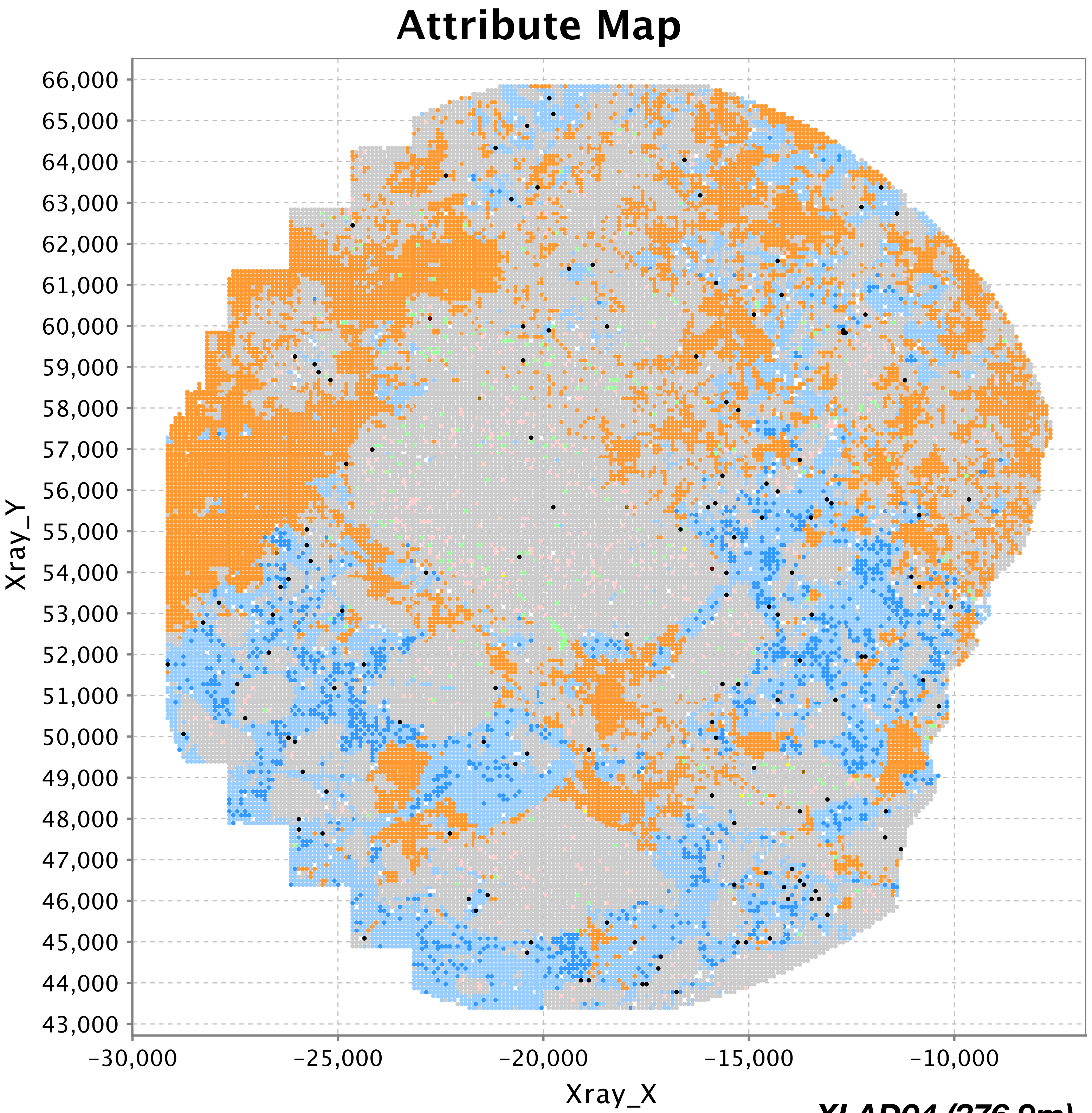


XLAD04 (390.9m)

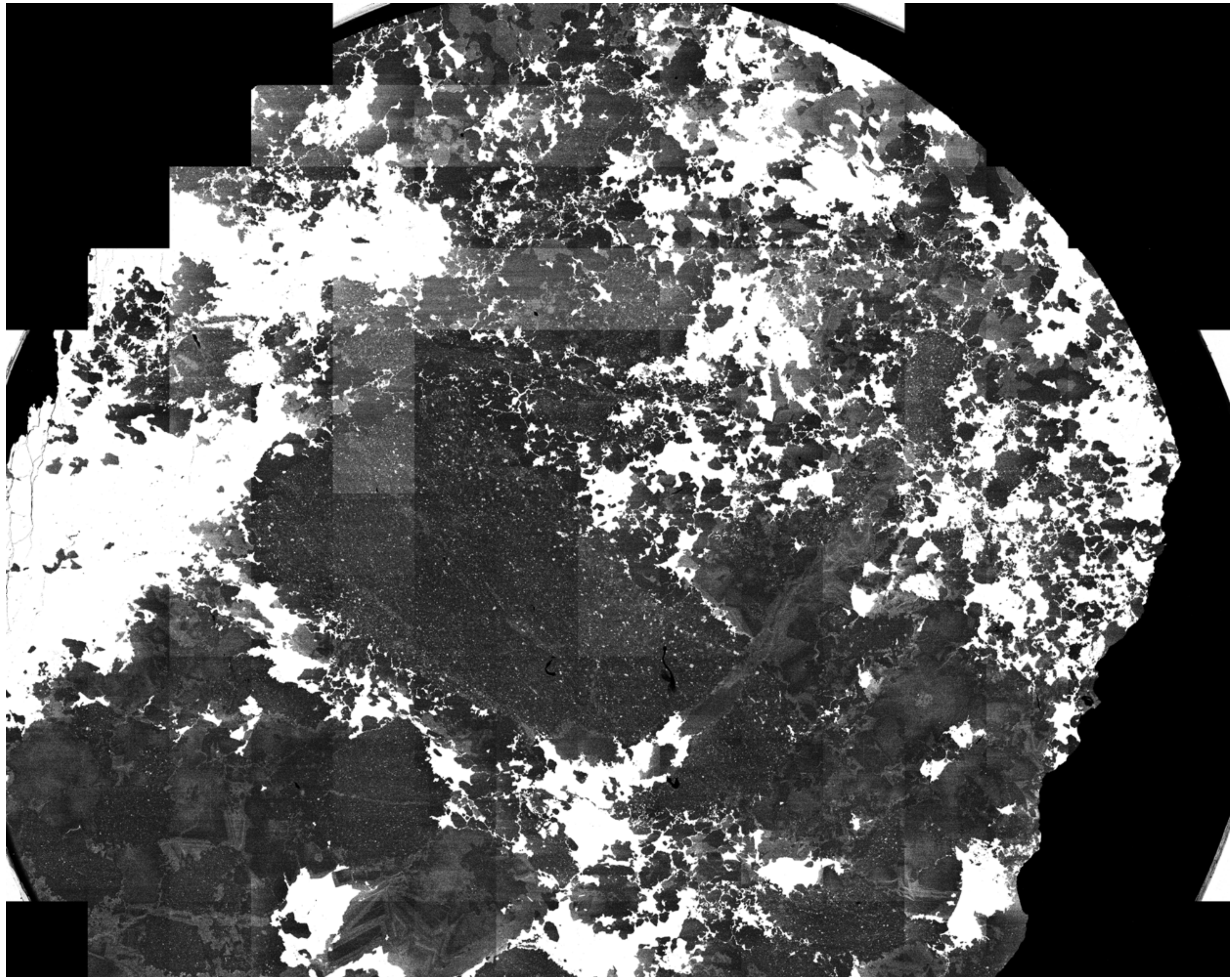
- So far: Carbonate 1 (Ca-Mg) +2 (Fe) → Py → CCp + Carbonate 3



Results

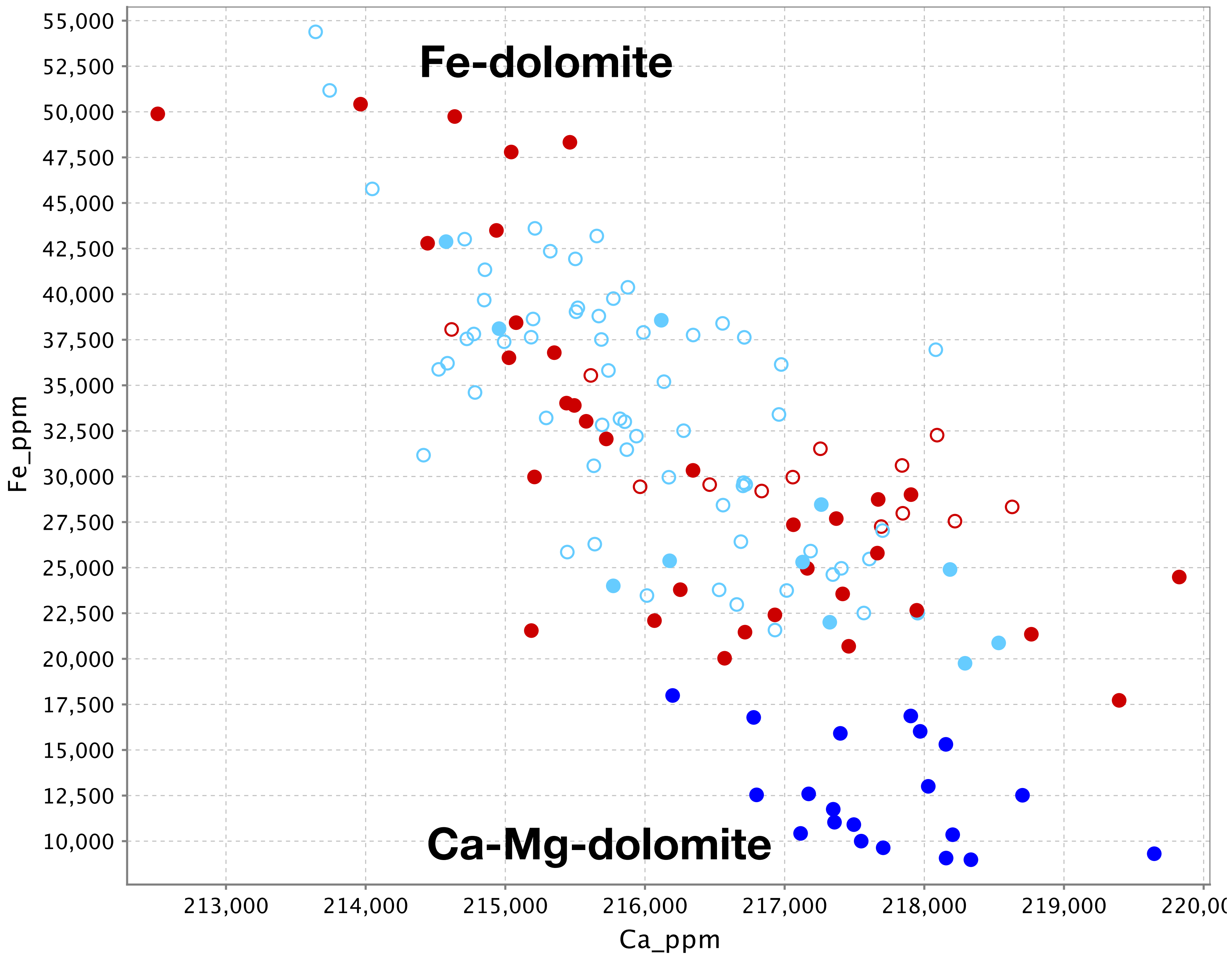


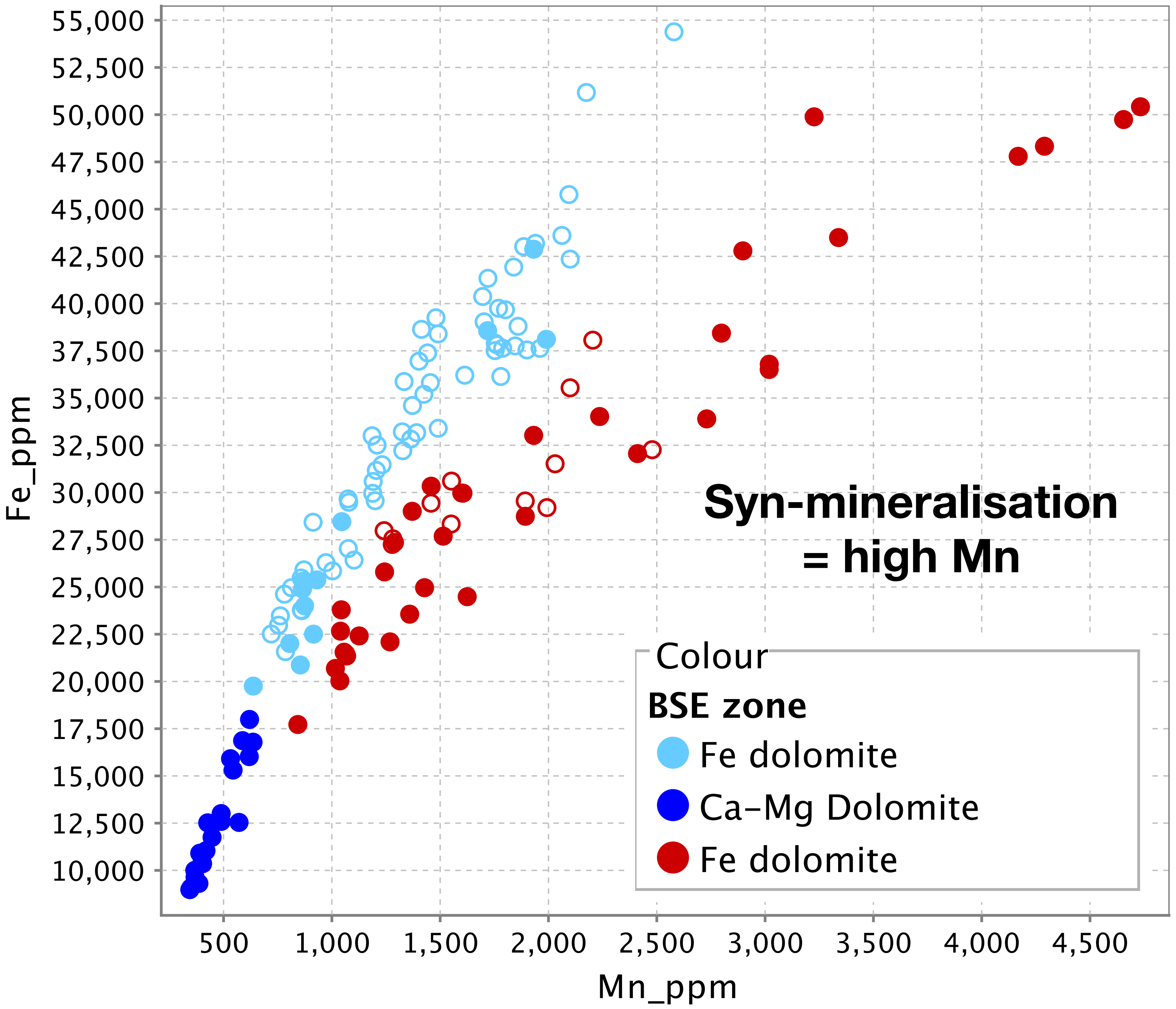
XLAD04 (376.9m)



- Silicification seems early compared to pre-mineralisation carbonate

Carbonate chemistry





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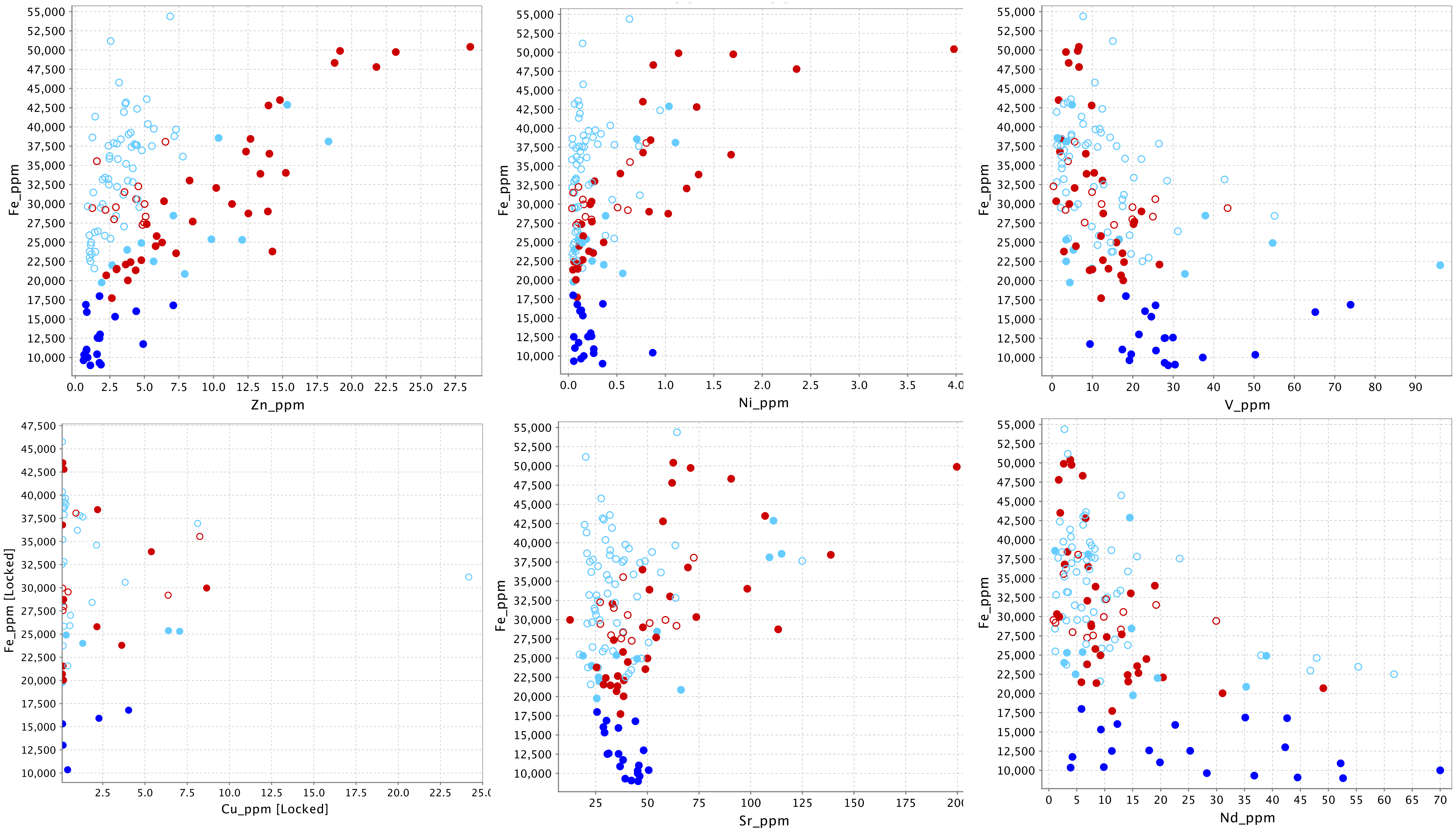
Carbonate chemistry

- Syn-mineralisation carbonates are associated with high Zn, Ni, Sr and low V and REE

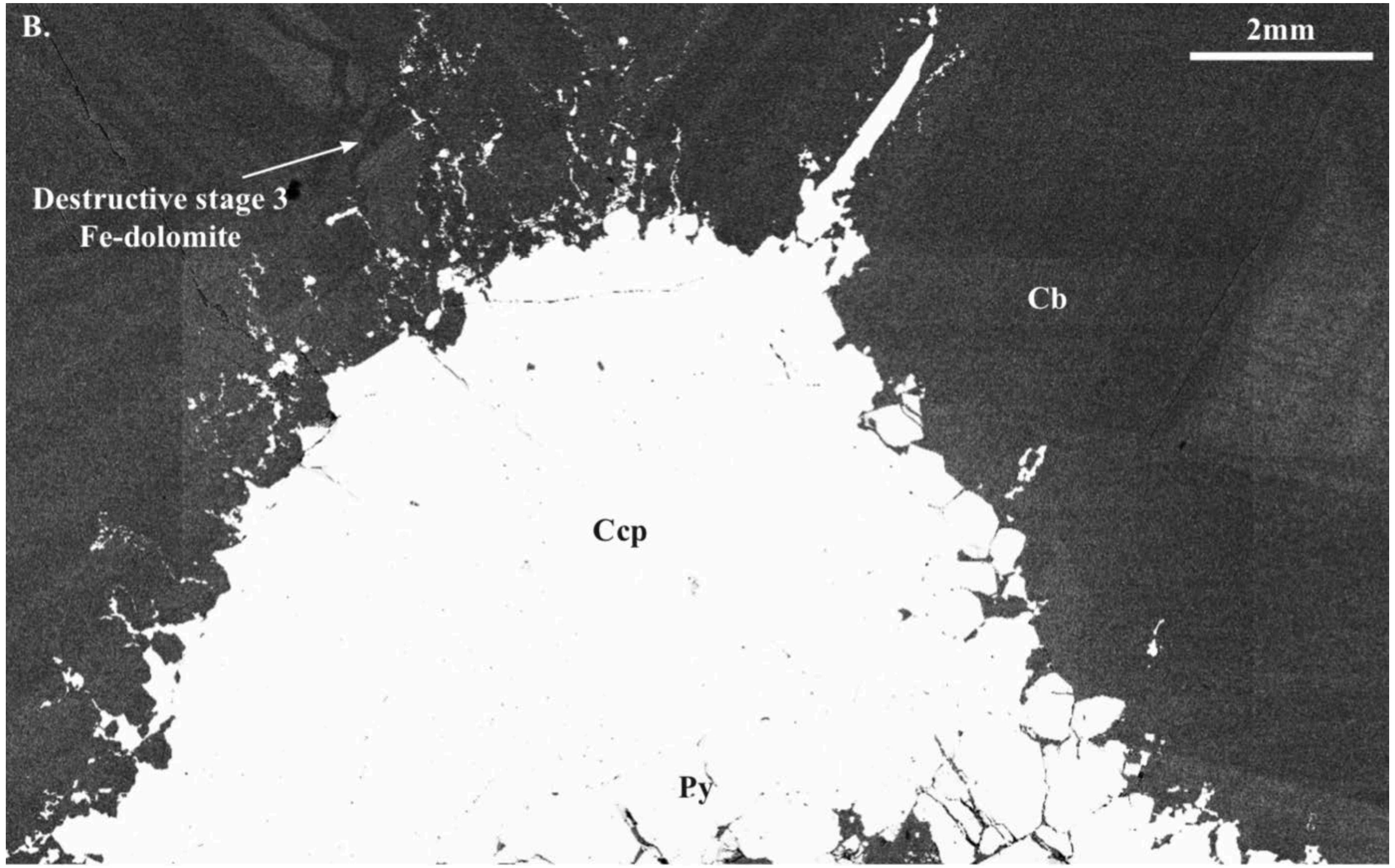


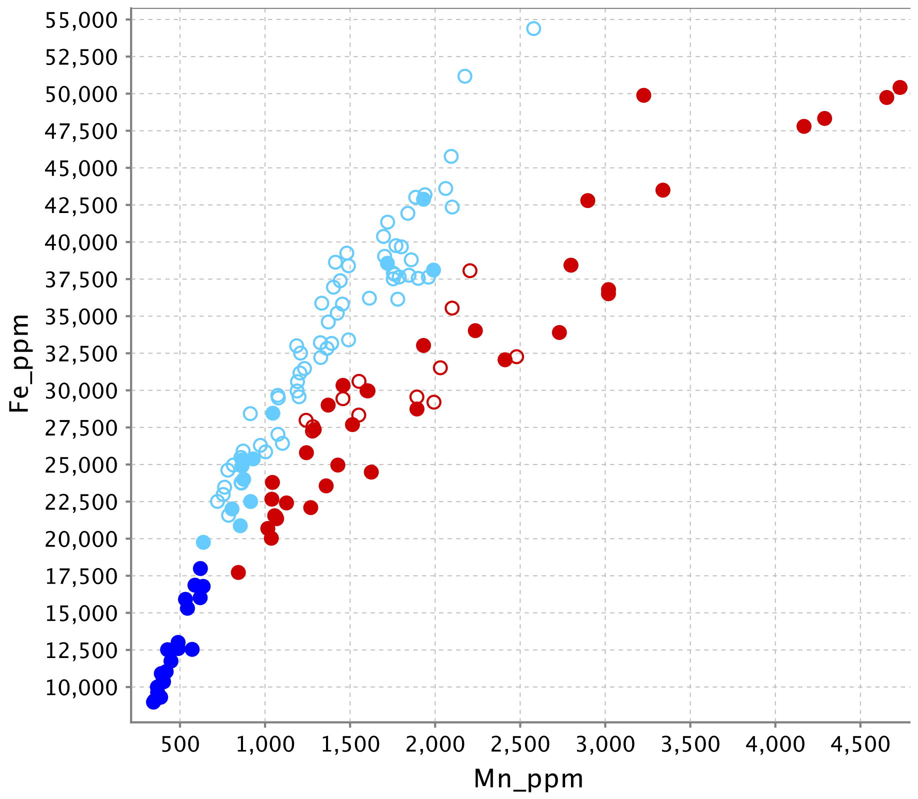
Lady Annie summary

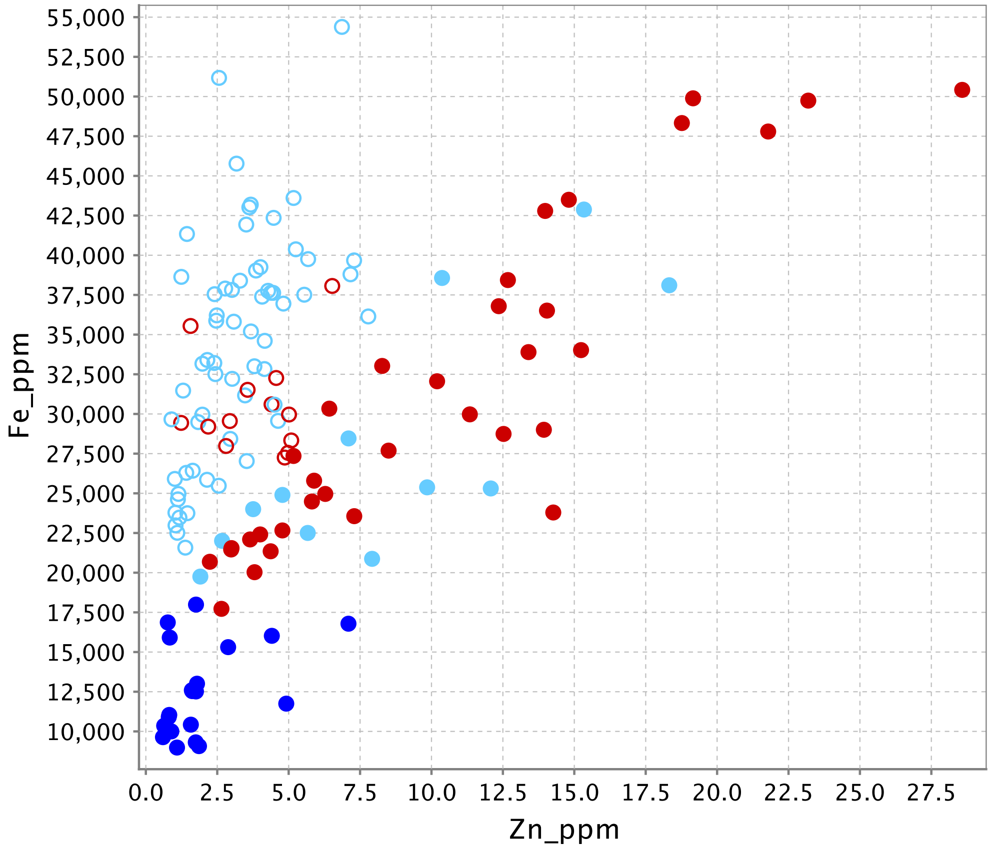
- Mineralisation is late and associated with Fe-dolomite

  - Enriched in Mn, Zn, Ni and Sr

- Early carbonate have oscillatory zoning between Ca-Mg dolomite and Fe-dolomite







Outcomes and Implications

- E1 and Ernest Henry magnetite appear to be relatively unique, and perhaps indicating higher T° fluids involved?

  - Potential to use magnetite to discriminate these types of systems amongst the diverse IOCG alteration

- Pyrite chemistry can be used to identify high T° pyrite using Co-Ni ratio (>1)

- Carbonate phase associated with the Cu mineralisation at Lady Annie has a specific chemical signature that can be tracked

Future work

- We are now moving to evaluate how far these signatures might extend (footprint) at Ernest Henry, SWAN, Starra and Lady Annie
- Max Hohl, a new PhD student started early September on a project focused on the Starra deposits and aiming at determining "fingerprint" and "footprint" associated with them