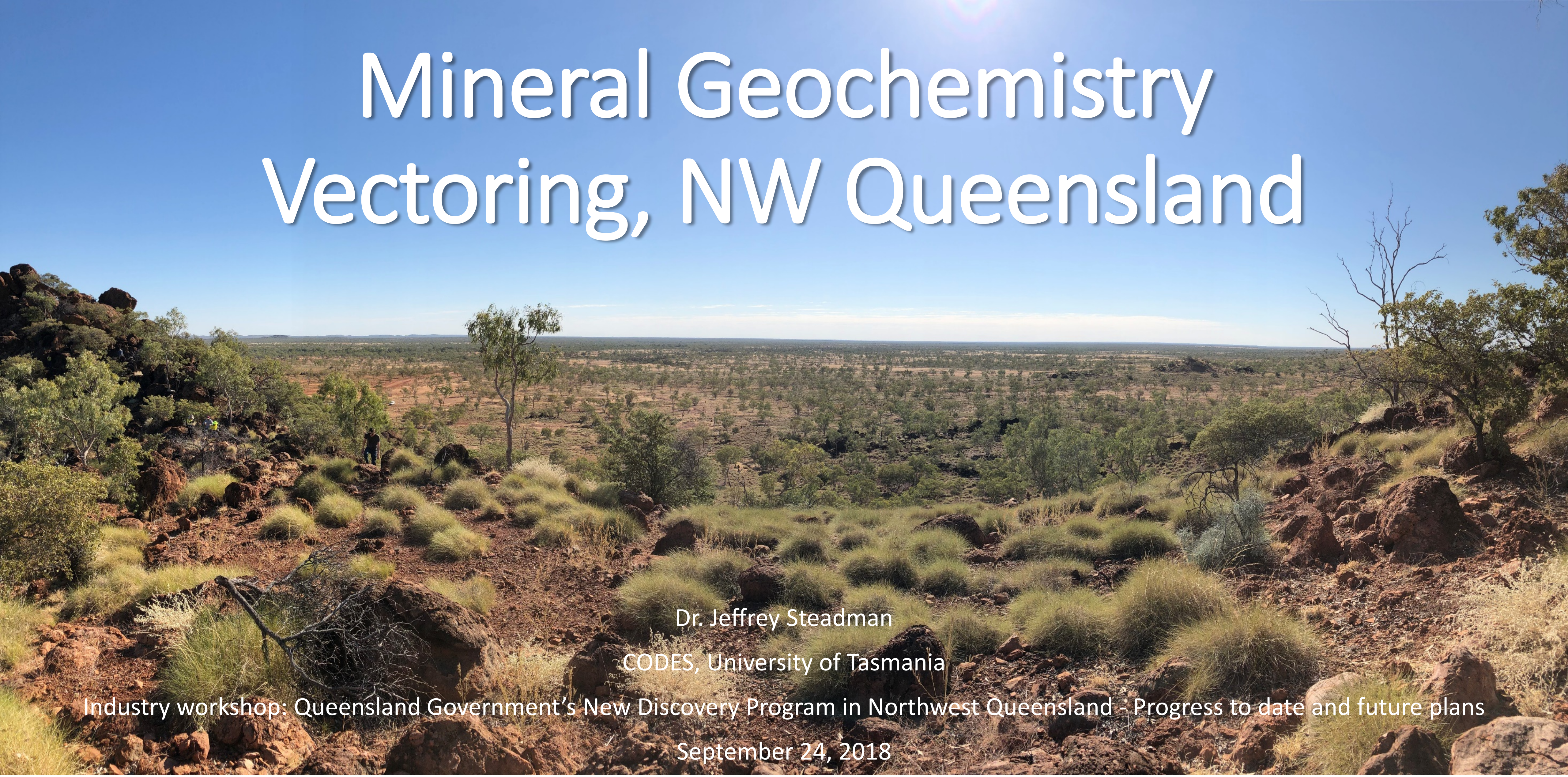


Mineral Geochemistry Vectoring, NW Queensland

Dr. Jeffrey Steadman

CODES, University of Tasmania

Industry workshop: Queensland Government's New Discovery Program in Northwest Queensland - Progress to date and future plans

September 24, 2018

CODES

UNIVERSITY of TASMANIA

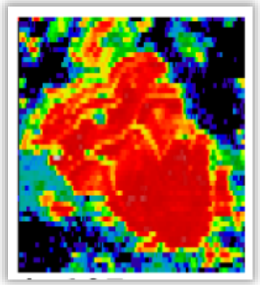
GEOLOGICAL SURVEY OF QUEENSLAND

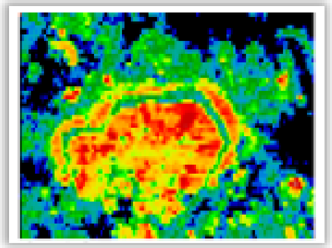
Queensland Government

Presentation outline

- Introduction to mineral chemistry
- Previous work
  - South Australia IOCG (py-hem)
  - Lady Loretta, QLD (py)
- Planned work for NW Queensland

Mineral geochemistry vectoring



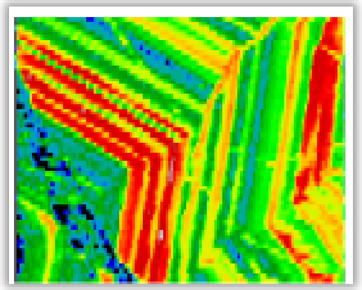


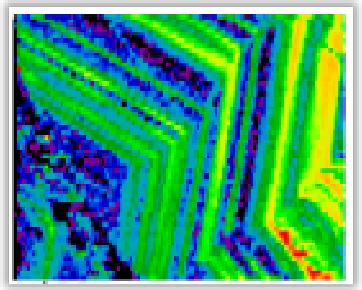
- Many gangue minerals found in hydrothermal alteration assemblages are sensitive to changes in fluid chemistry and temperature
  - Sulfides (e.g., pyrite and pyrrhotite)
  - Silicates (chlorite, epidote, quartz)
  - Oxides (hematite, magnetite)
  - Carbonates (dolomite, calcite)
- These characteristics enable us to obtain reliable paragenetic information about a deposit or prospect and can help improve exploration efforts

UNIVERSITY of TASMANIA

CODES

Why laser ablation?





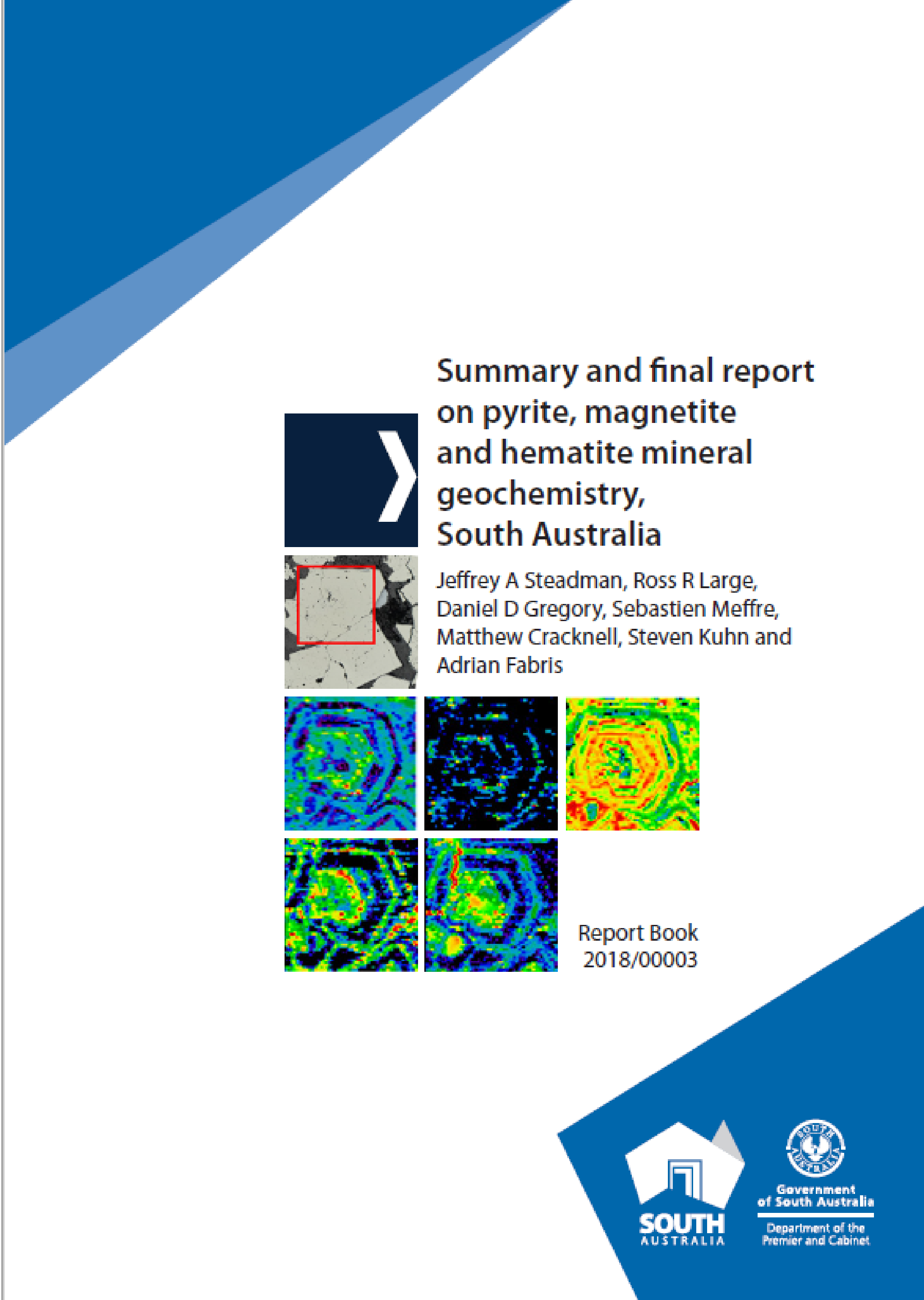
- Mineral trace element geochemistry is not a new discipline (~50 years)
- Early methods: Electron microprobe and solution ICPMS
  - Problems – high detection limits (microprobe) and no spatial context (solution ICPMS)
- Later developments: proton microprobe; SIMS and TIMS
  - Pros: low detection limits; spatial context preserved
  - Cons: Very expensive
- Laser ablation combined with ICPMS solved these problems
  - Particularly imaging

UNIVERSITY of TASMANIA

CODES

South Australia mineral geochemistry vectoring project

- Sponsored by the Geol Survey of South Australia
- Three years (2014-2017)
- Aims:
  - <u>Phase 1:</u> Database of pyrite-magnetite-hematite analyses from deposits across SA; ‘fingerprint’ styles of mineralization; trace element vector development
  - <u>Phase 2:</u> Characterization of pyrite (±magnetite, hematite) from Mineral Systems Drilling Program; evaluation against known systems
  - <u>Phase 3:</u> Characterization of pyrite and hematite (±magnetite) from Intercept Hill (Emmie Bluff); IOCG vectoring


Summary and final report on pyrite, magnetite and hematite mineral geochemistry, South Australia

Jeffrey A Steadman, Ross R Large, Daniel D Gregory, Sebastien Meffre, Matthew Cracknell, Steven Kuhn and Adrian Fabris

Report Book 2018/00003

SOUTH AUSTRALIA

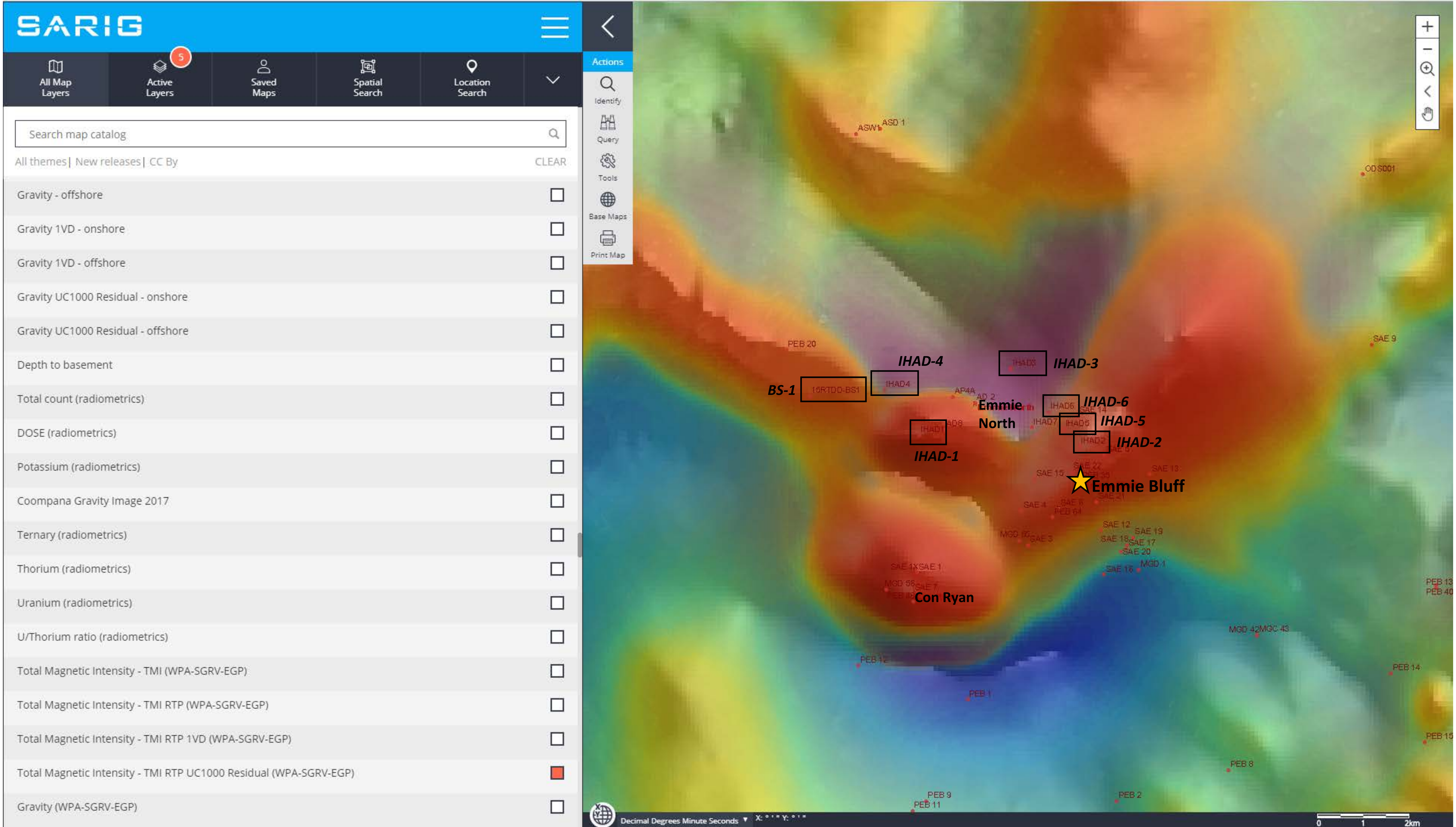
Government of South Australia

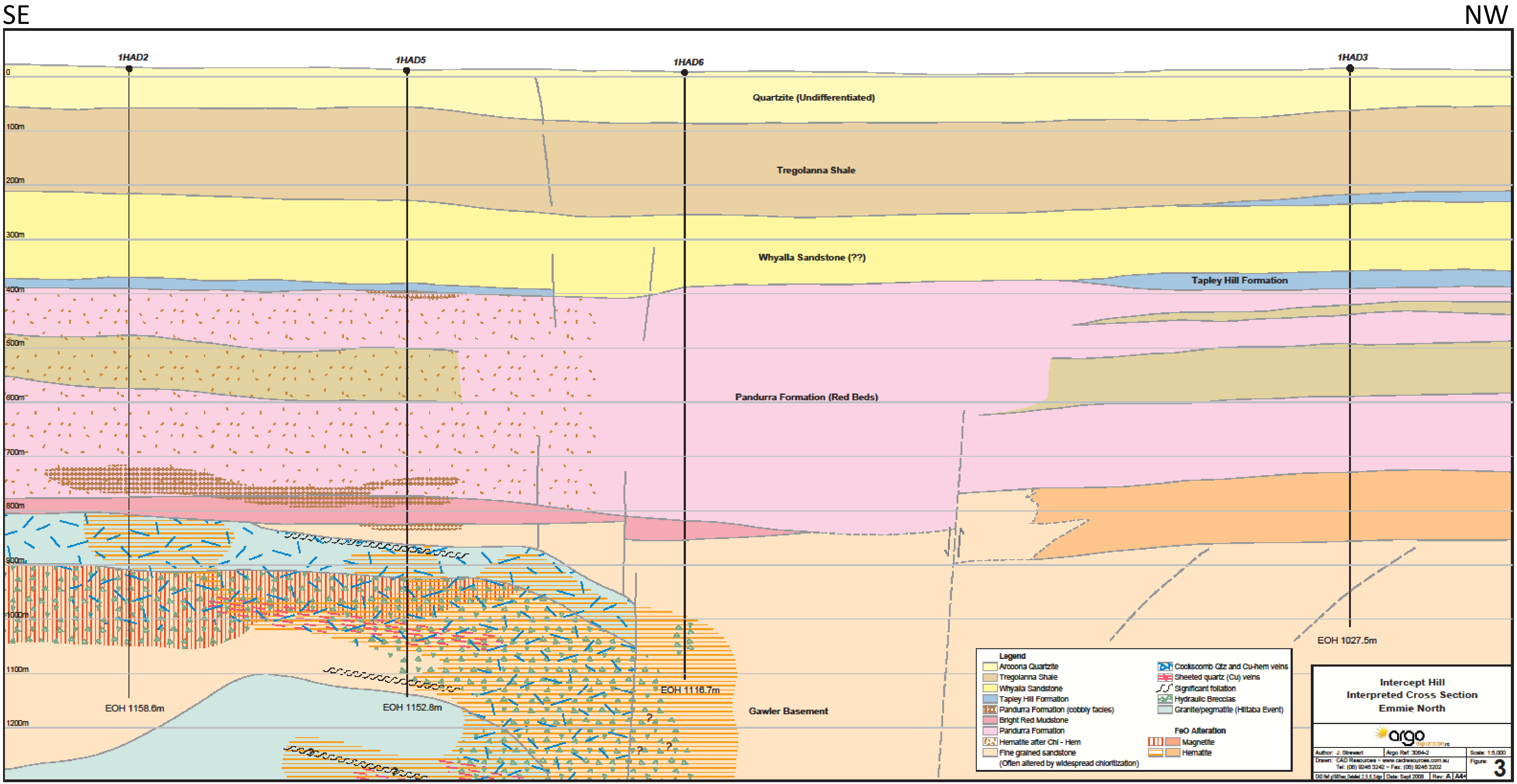
Department of the Premier and Cabinet

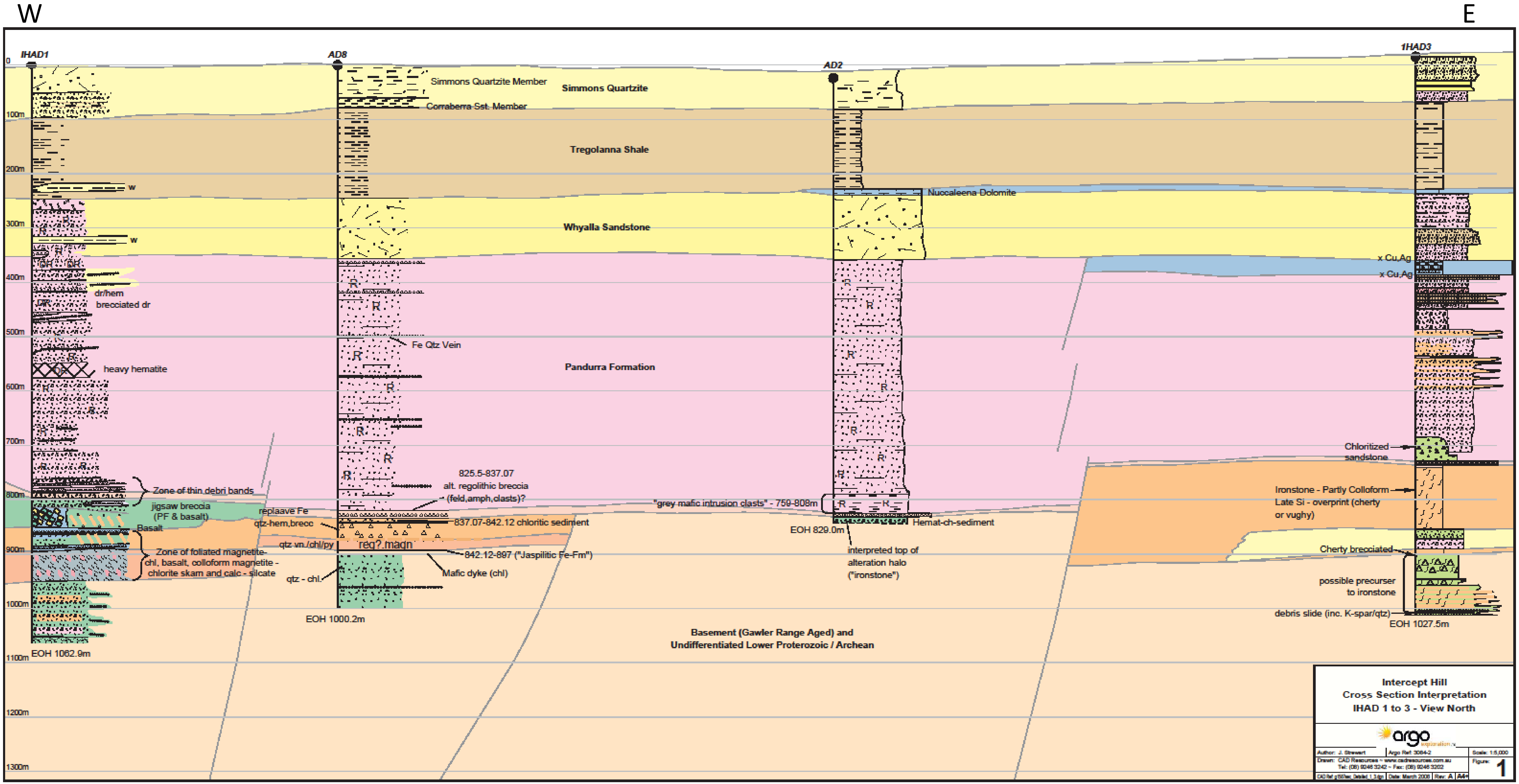
UNIVERSITY of TASMANIA

Phase 3: Intercept Hill/Emmie Bluff

- Six holes drilled by Argo at Intercept Hill (~90 km S of Olympic Dam) were sampled in April 2017
  - IHAD-1, -2, -3, -4, -5, and -6
- Additional set of samples from BS-1, ~8 km west of Intercept Hill/Emmie Bluff
- Dual pyrite and hematite imaging focus
- Great results

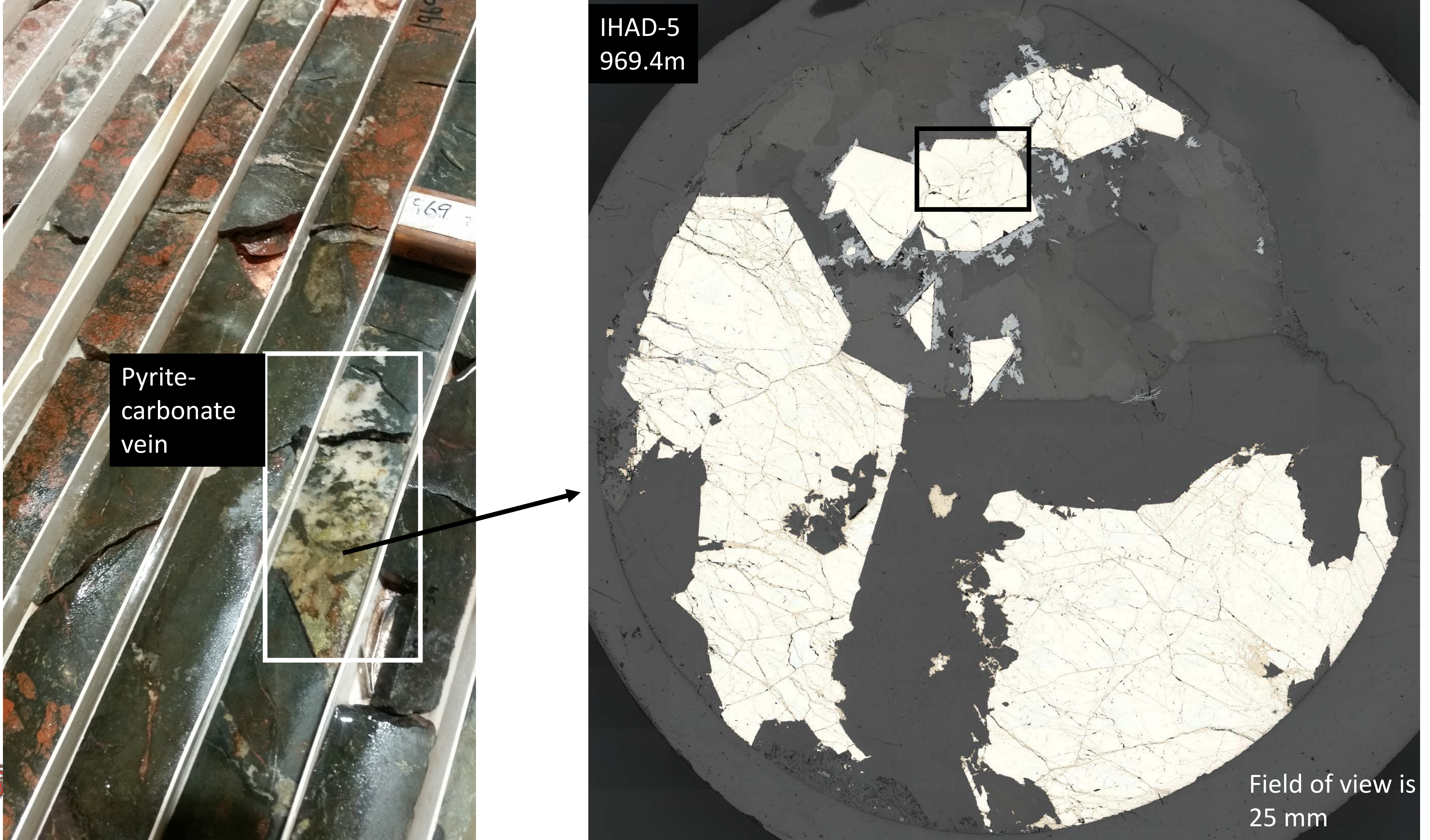

SARIG
5
All Map Layers
Active Layers
Saved Maps
Spatial Search
Location Search
Search map catalog
All themes | New releases | CC By
CLEAR
Gravity - offshore
Gravity 1VD - onshore
Gravity 1VD - offshore
Gravity UC1000 Residual - onshore
Gravity UC1000 Residual - offshore
Depth to basement
Total count (radiometrics)
DOSE (radiometrics)
Potassium (radiometrics)
Coompana Gravity Image 2017
Ternary (radiometrics)
Thorium (radiometrics)
Uranium (radiometrics)
U/Thorium ratio (radiometrics)
Total Magnetic Intensity - TMI (WPA-SGRV-EGP)
Total Magnetic Intensity - TMI RTP (WPA-SGRV-EGP)
Total Magnetic Intensity - TMI RTP 1VD (WPA-SGRV-EGP)
Total Magnetic Intensity - TMI RTP UC1000 Residual (WPA-SGRV-EGP)
Gravity (WPA-SGRV-EGP)
Actions
Identify
Query
Tools
Base Maps
Print Map
IHAD-4
IHAD-3
BS-1
IHAD-6
Emmie North
IHAD-5
IHAD-2
IHAD-1
Emmie Bluff
Con Ryan
Decimal Degrees Minute Seconds
0
1
2km


SE
NW
1HAD2
1HAD5
1HAD6
1HAD3
0
100m
200m
300m
400m
500m
600m
700m
800m
900m
1000m
1100m
1200m
Quartzite (Undifferentiated)
Tregolanna Shale
Whyalla Sandstone (??)
Tapley Hill Formation
Pandurra Formation (Red Beds)
Gawler Basement
EOH 1158.6m
EOH 1152.8m
EOH 1116.7m
EOH 1027.5m
Legend
Arcoona Quartzite
Tregolanna Shale
Whyalla Sandstone
Tapley Hill Formation
Pandurra Formation (cobbly facies)
Bright Red Mudstone
Pandurra Formation
Hematite after Chl - Hem
Fine grained sandstone
(Often altered by widespread chloritization)
Cockscomb Qtz and Cu-hem veins
Sheeted quartz (Cu) veins
Significant foliation
Hydraulic Breccias
Granite/pegmatite (Hiltaba Event)
FeO Alteration
Magnetite
Hematite
Intercept Hill
Interpreted Cross Section
Emmie North
Author: J. Stewart
Argo Ref: 3084-2
Scale: 1:5,000
Drawn: CAD Resources ~ www.cadresources.com.au
Tel: (08) 9246 3242 ~ Fax: (08) 9246 3202
Figure: 3
Date: Sept 2008
Rev: A
A4+

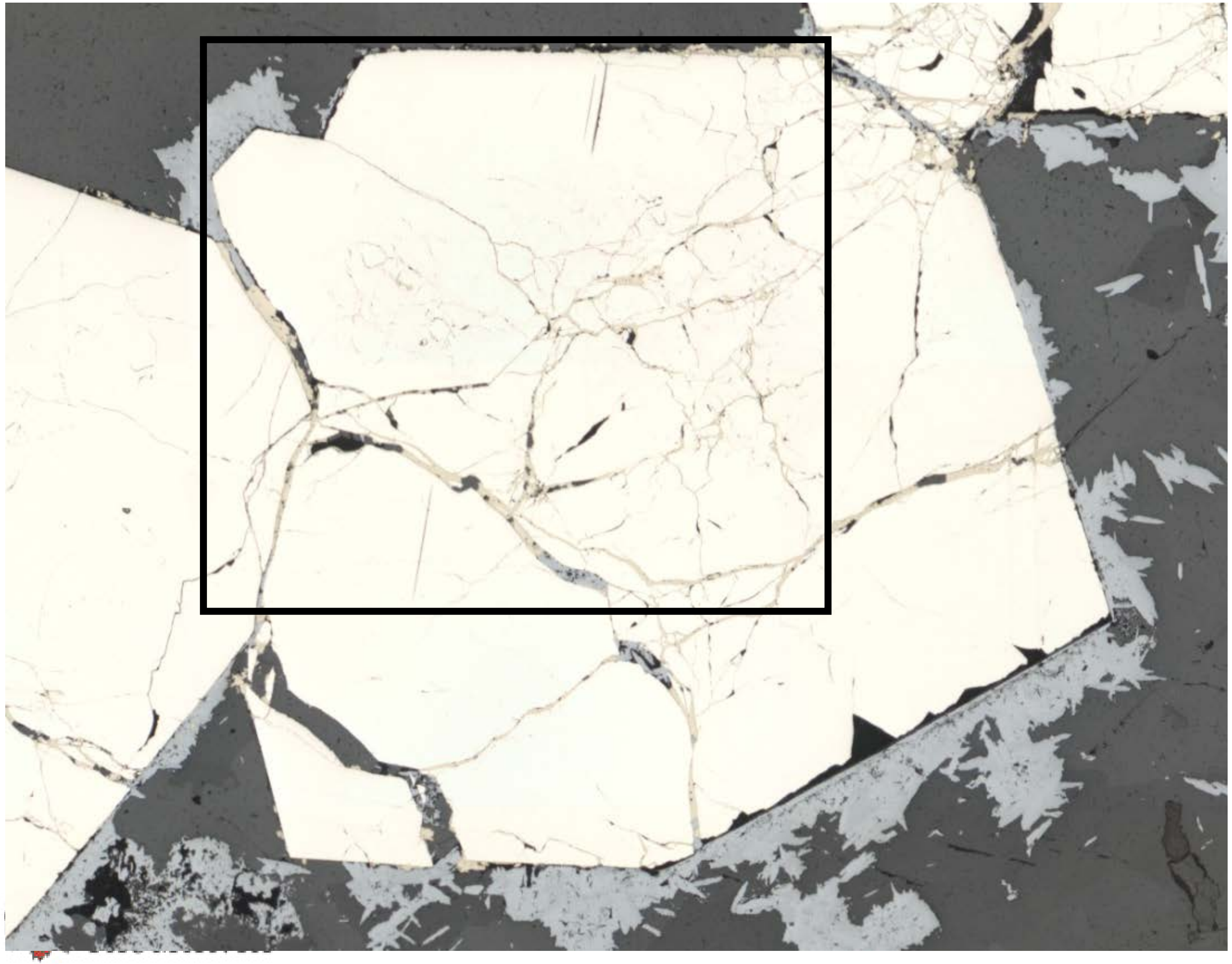


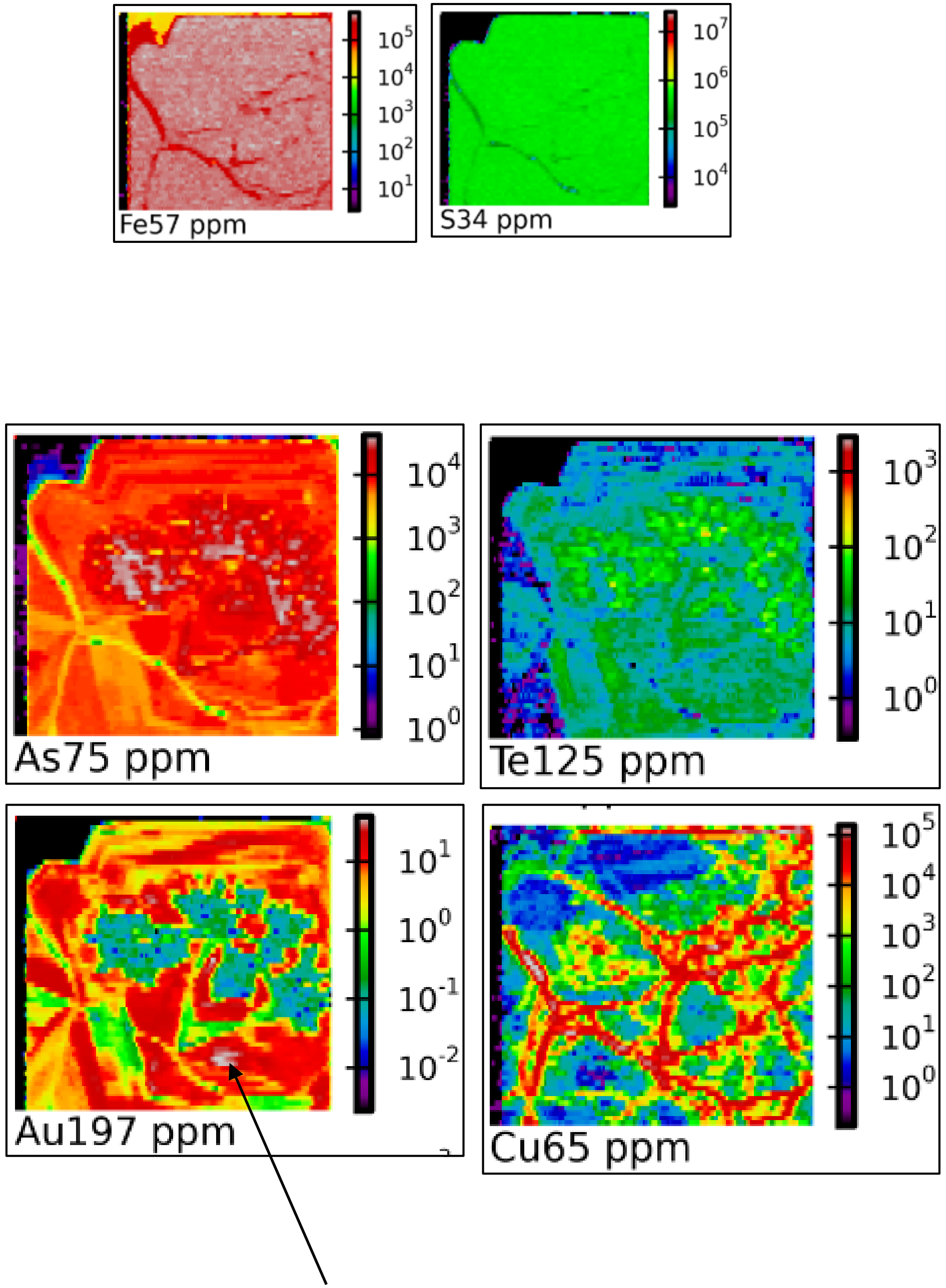
W
E
IHAD1
AD8
AD2
1HAD3
0
100m
200m
300m
400m
500m
600m
700m
800m
900m
1000m
1100m
1200m
1300m
Simmons Quartzite Member
Corraberra Sst. Member
Simmons Quartzite
Tregolanna Shale
Nuccaleena Dolomite
Whyalla Sandstone
Pandurra Formation
w
w
dr/hem
brecciated dr
heavy hematite
Fe Qtz Vein
x Cu,Ag
x Cu,Ag
Chloritized sandstone
Zone of thin debri bands
jigsaw breccia (PF & basalt)
Basalt
replaave Fe
qtz-hem,brecc
qtz vn./chl/py
reg?.magn
Zone of foliated magnetite-chl, basalt, colloform magnetite - chlorite skarn and calc - silcate
qtz - chl.
825.5-837.07 alt. regolithic breccia (feld,amph,clasts)?
837.07-842.12 chloritic sediment
842.12-897 ("Jaspilitic Fe-Fm")
Mafic dyke (chl)
"grey mafic intrusion clasts" - 759-808m
Hemat-ch-sediment
EOH 829.0m
interpreted top of alteration halo ("ironstone")
Ironstone - Partly Colloform Late Si - overprint (cherty or vughy)
Cherty brecciated
possible precurser to ironstone
debris slide (inc. K-spar/qtz)
EOH 1027.5m
EOH 1000.2m
EOH 1062.9m
Basement (Gawler Range Aged) and Undifferentiated Lower Proterozoic / Archean
Intercept Hill
Cross Section Interpretation
IHAD 1 to 3 - View North
Author: J. Stewart
Argo Ref: 3084-2
Scale: 1:5,000
Figure: 1
Date: March 2008
Rev: A


IHAD-1
IHAD-2
IHAD-2
IHAD-2
IHAD-5


Pyrite-carbonate vein
IHAD-5
969.4m
Field of view is 25 mm

IHAD5-969.4m

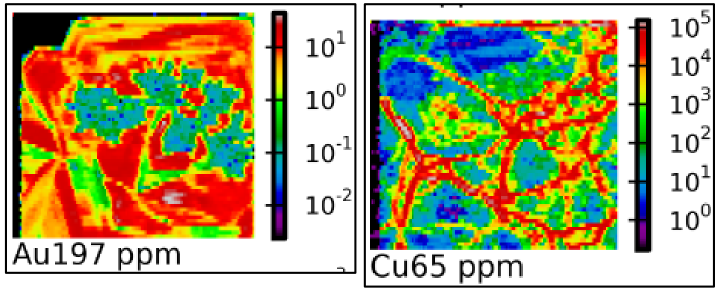


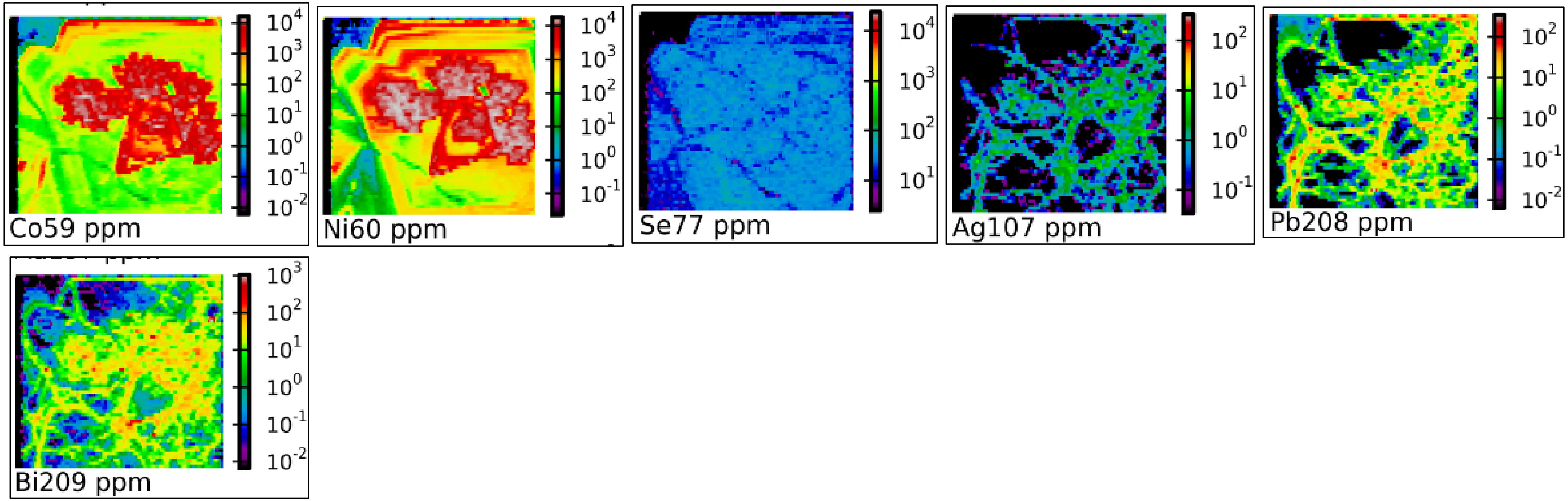


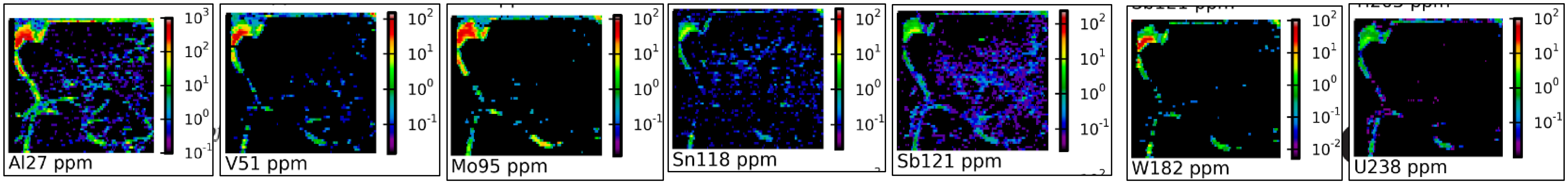
> 40 ppm Au

CODES

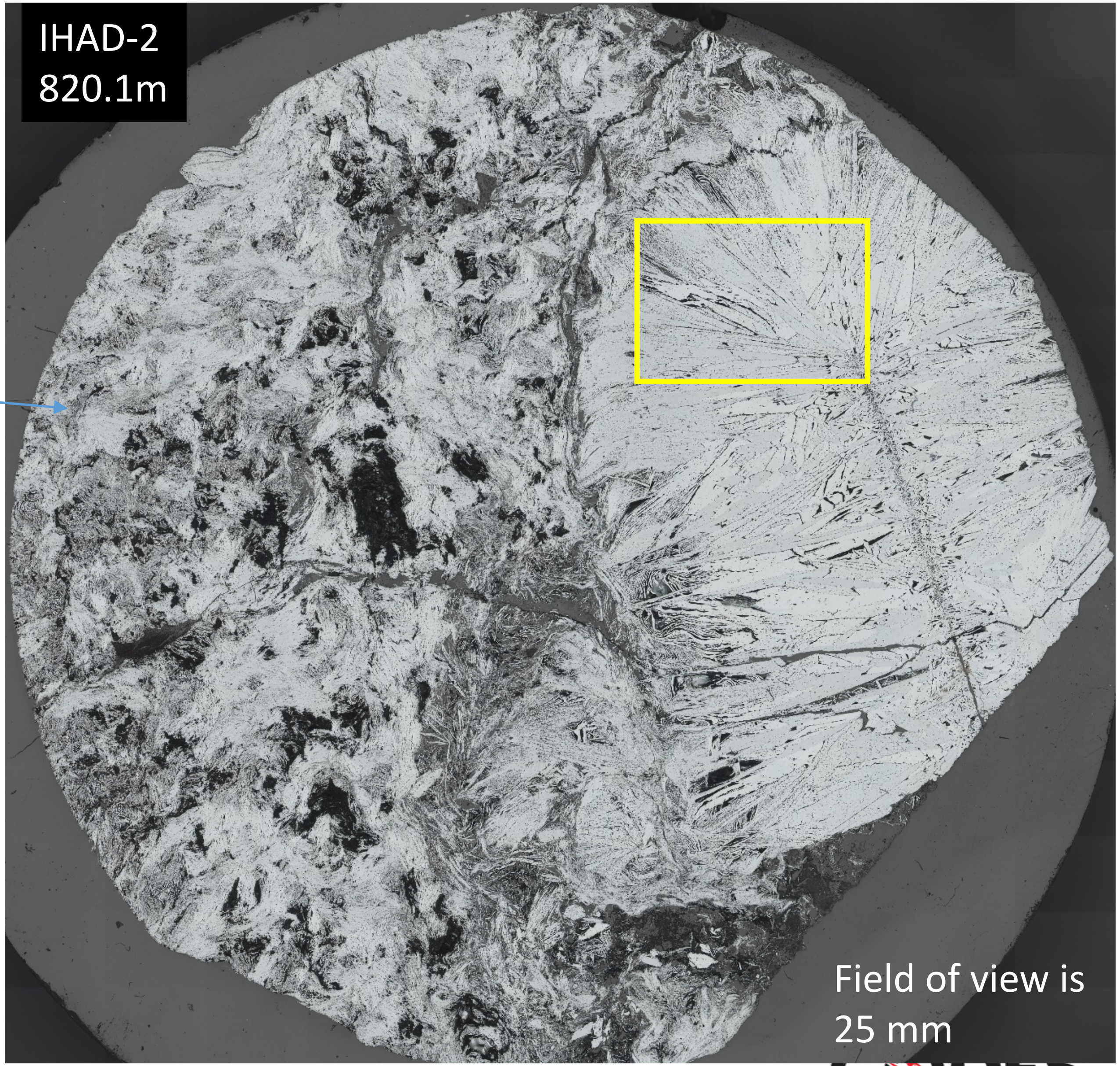
IHAD5-969.4m


Au197 ppm
Cu65 ppm

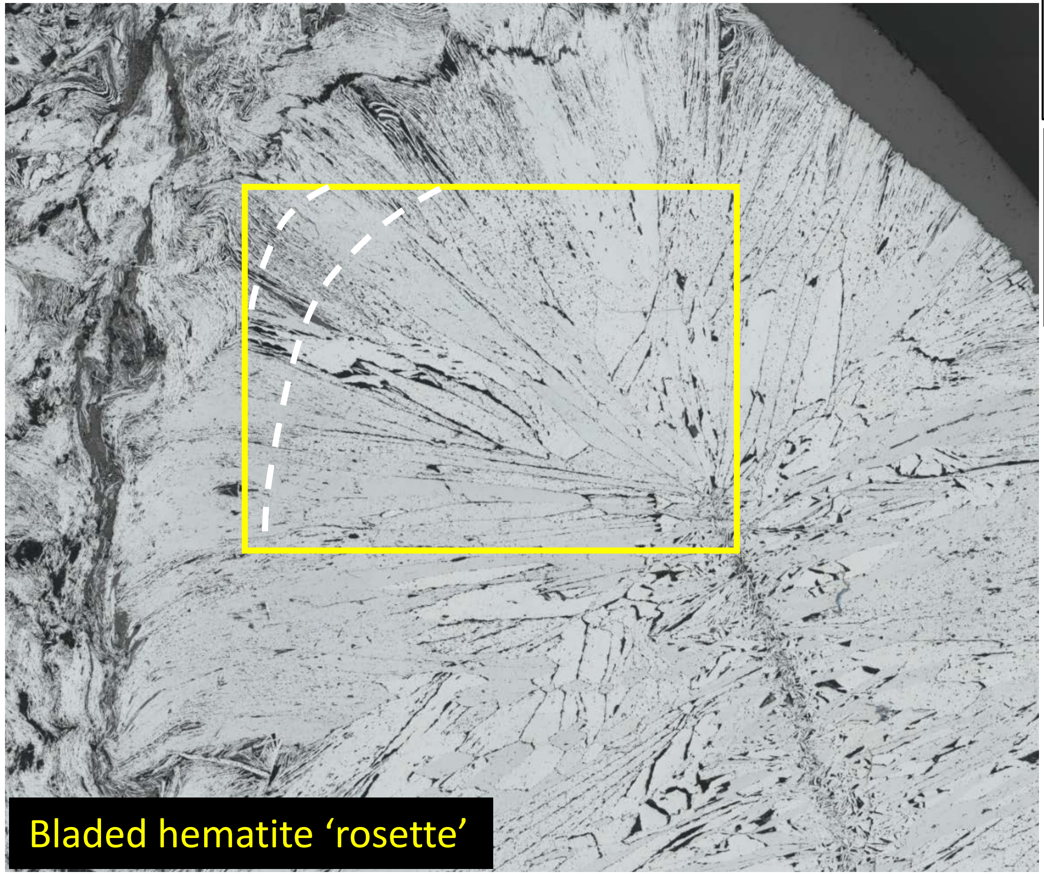

Co59 ppm
Ni60 ppm
Se77 ppm
Ag107 ppm
Pb208 ppm
Bi209 ppm

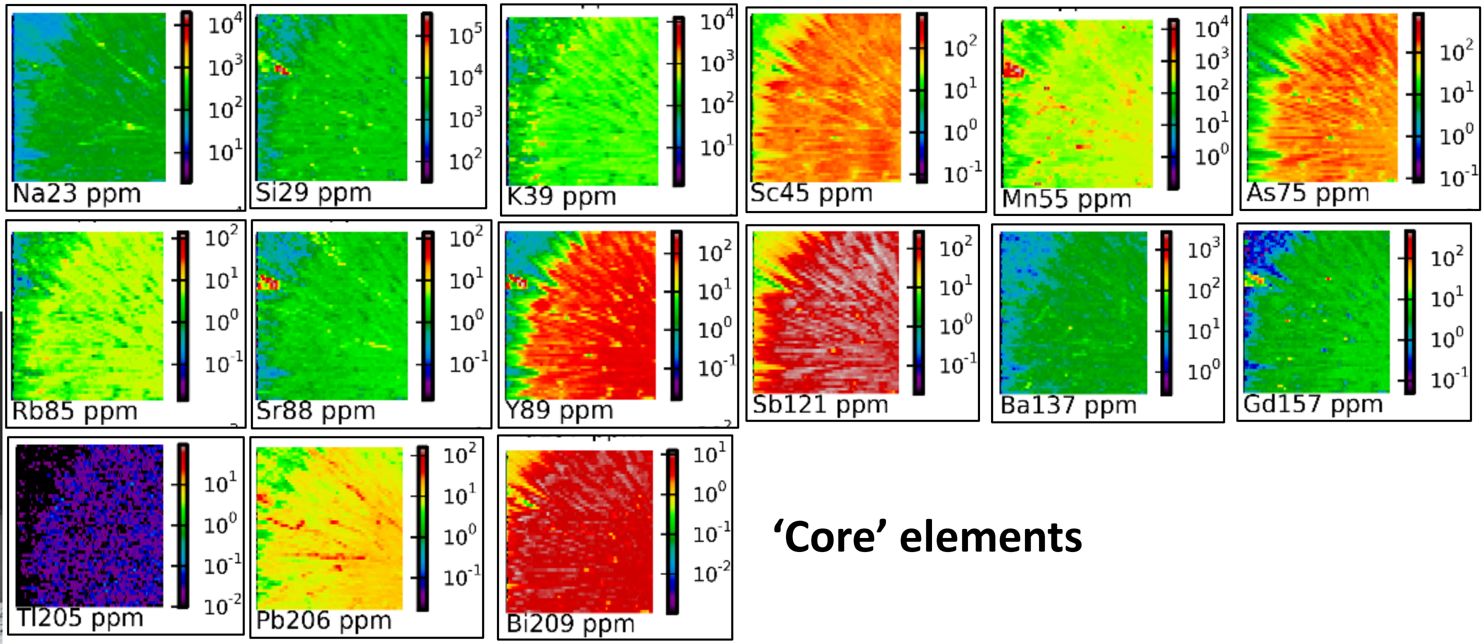

Al27 ppm
V51 ppm
Mo95 ppm
Sn118 ppm
Sb121 ppm
W182 ppm
U238 ppm


Granitic breccia w/hem

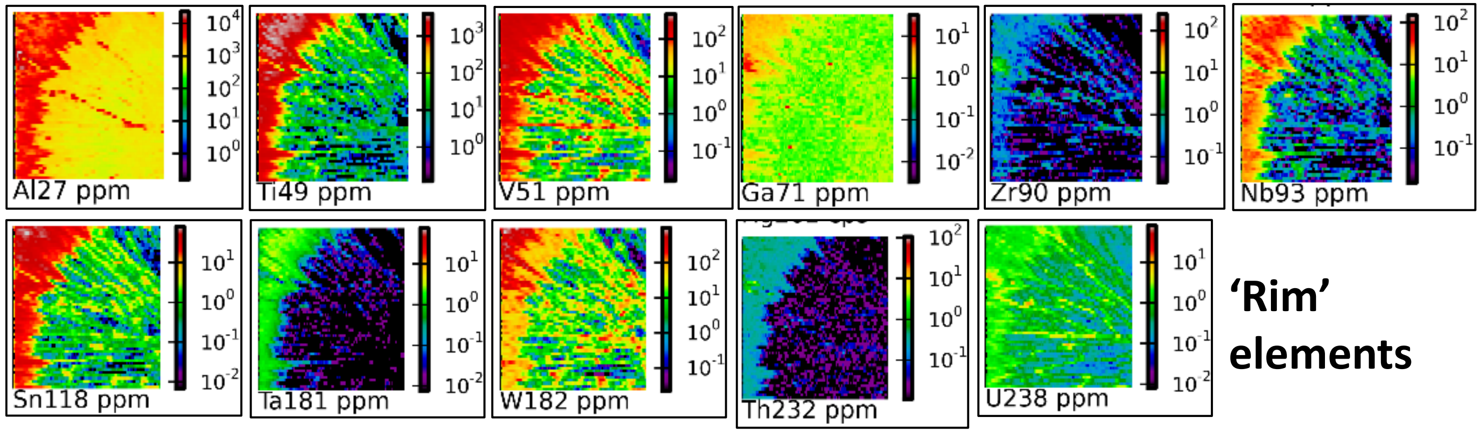

IHAD-2
820.1m
Field of view is
25 mm

IHAD2-820.1m

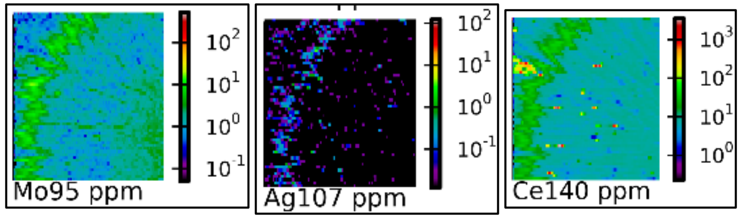




‘Core’ elements



‘Rim’ elements



Core-rim boundary

UNIVERSITY of TASMANIA

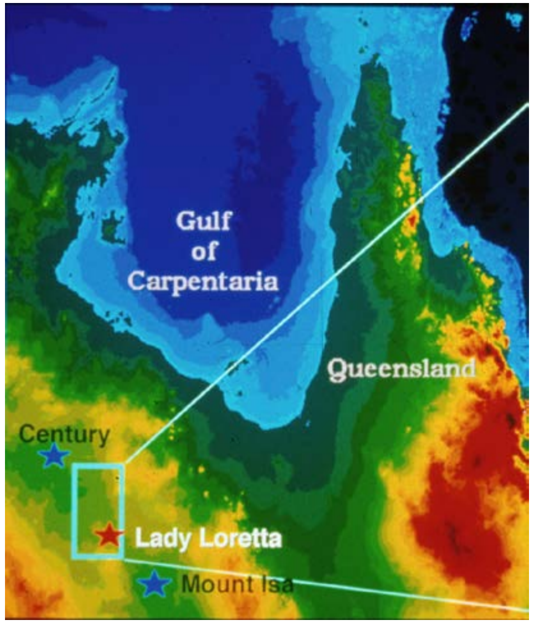
CODES

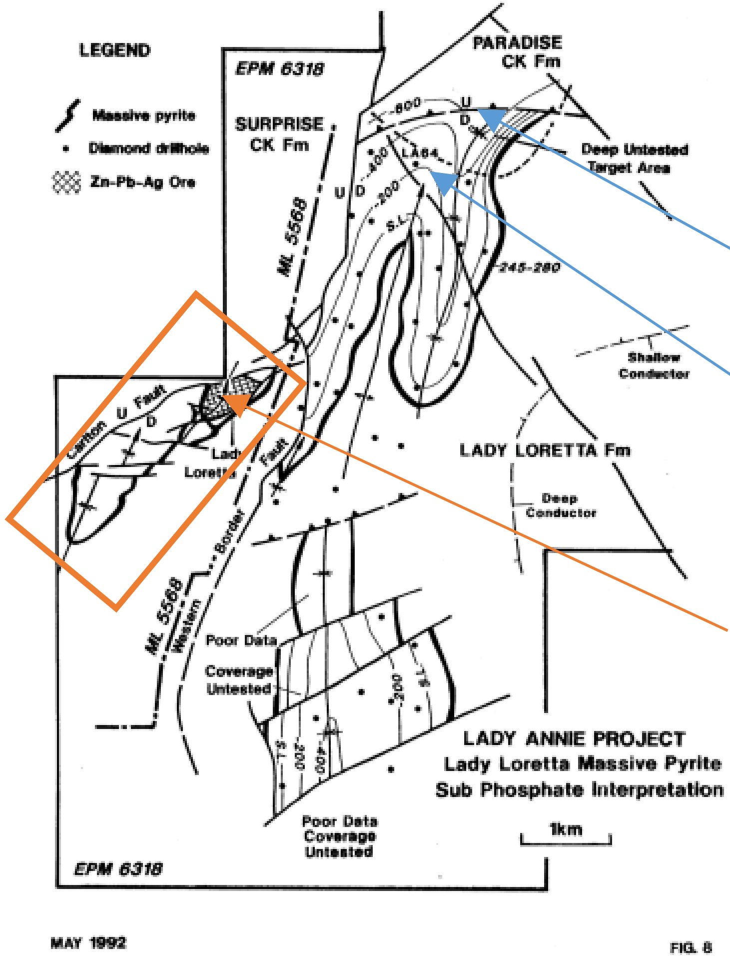
Vectoring at Lady Loretta using LA-ICP-MS pyrite trace element geochemistry

UNIVERSITY of TASMANIA

CODES

Sample location – Lady Loretta





5 km

DDH LA67 (three samples)

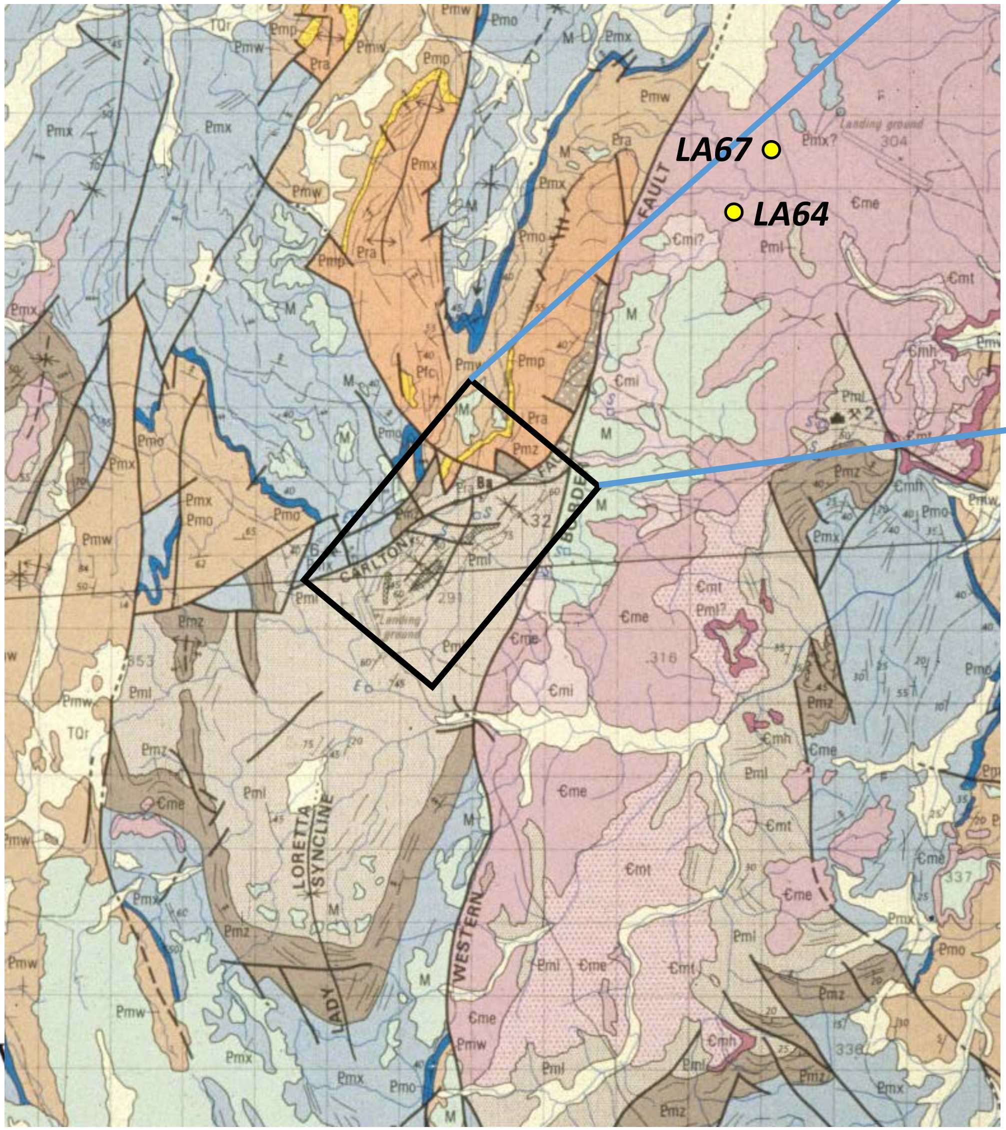
DDH LA64 (one sample)

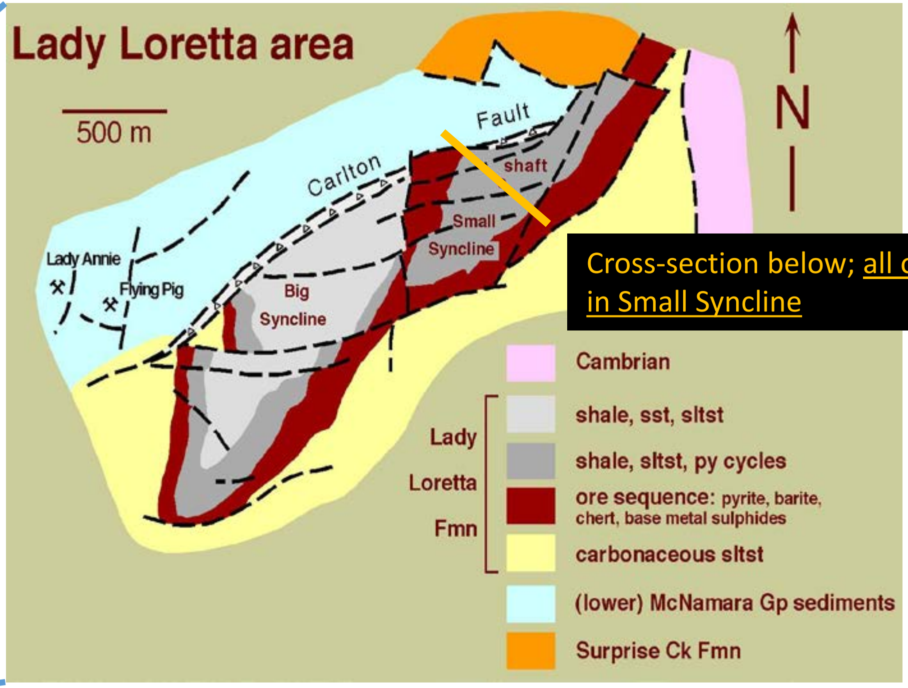
Lady Loretta mine
(27 samples)

UNIVERSITY of TASMANIA

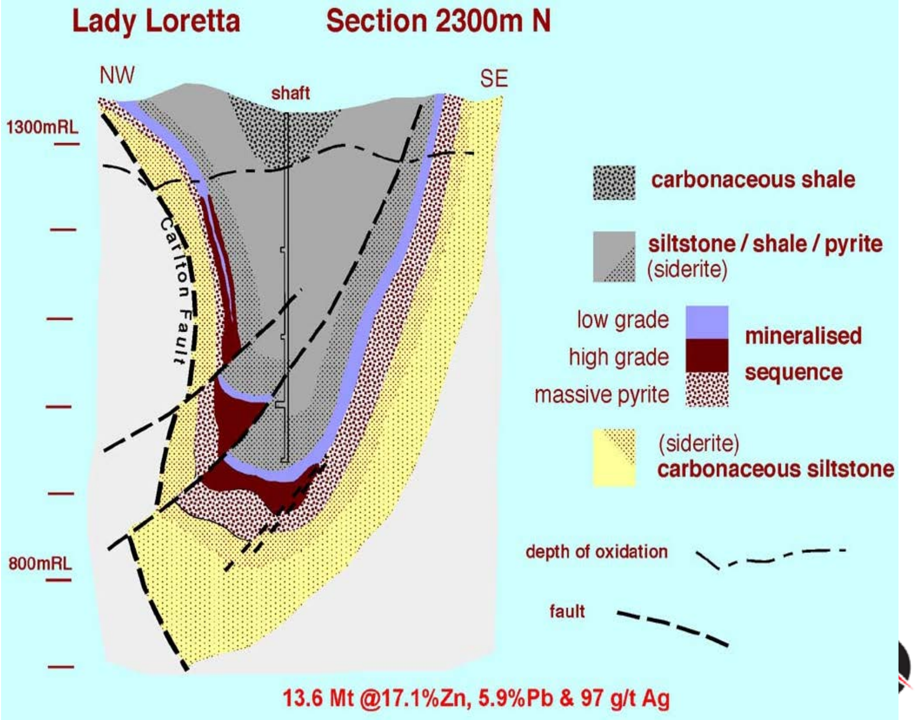
CODES

Lady Loretta geology

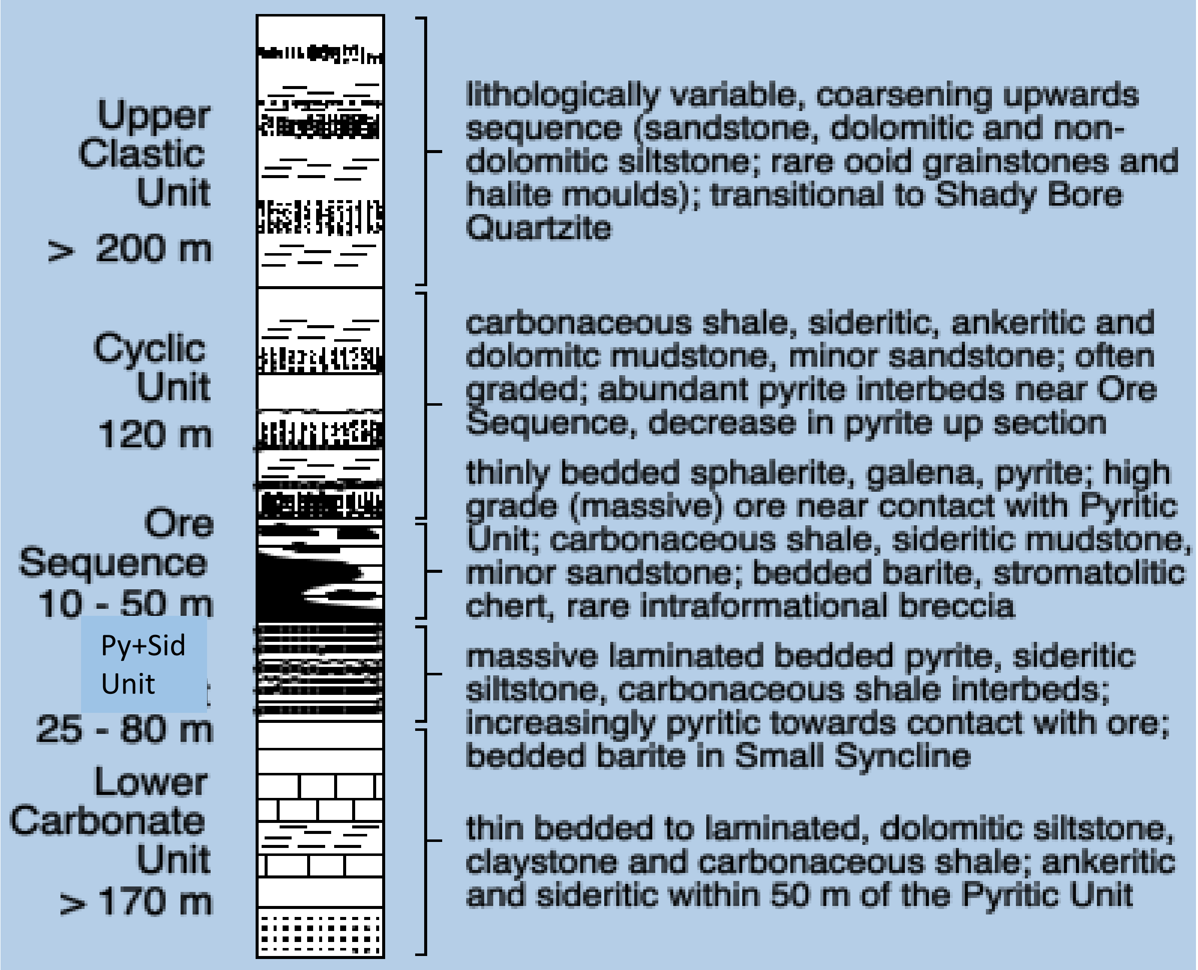


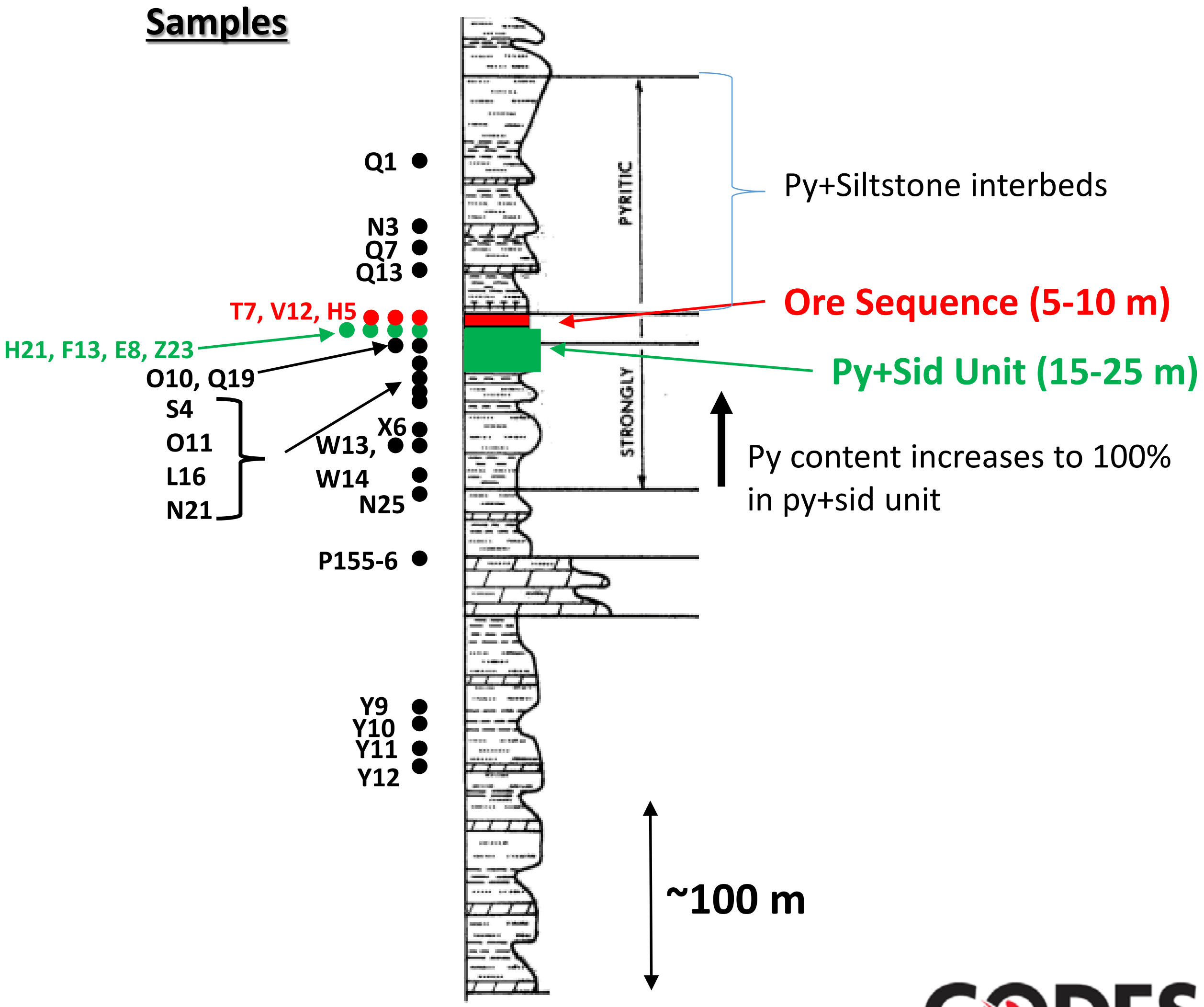


Cross-section below; <u>all ore in Small Syncline</u>



Lady Loretta geology – local stratigraphy and samples





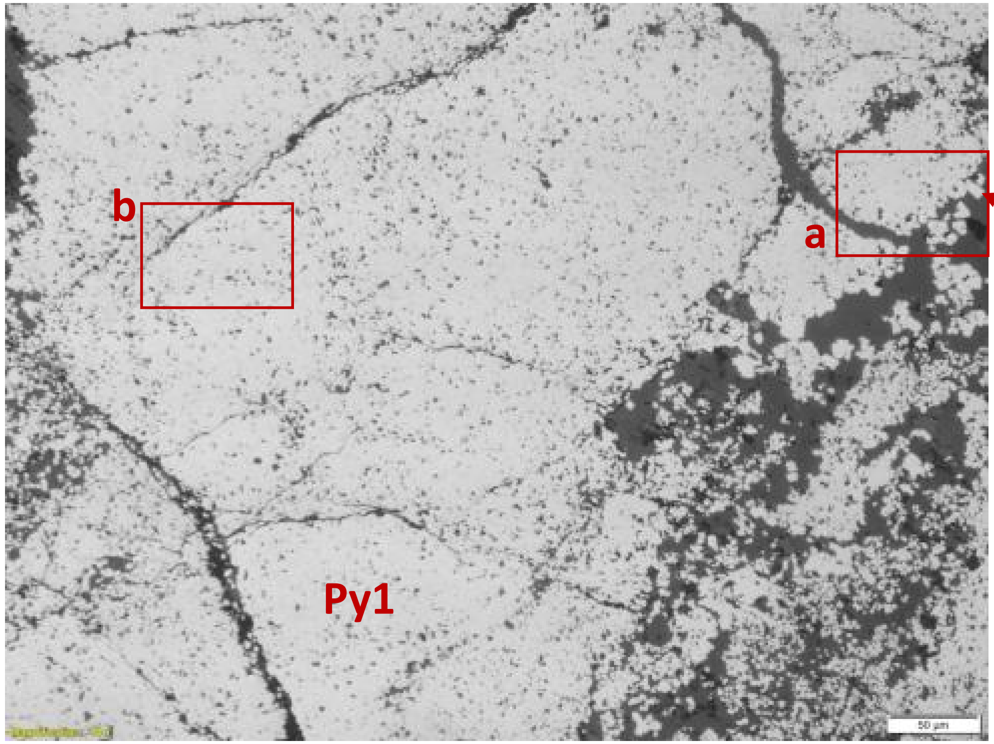
UNIVERSITY of TASMANIA

CODES

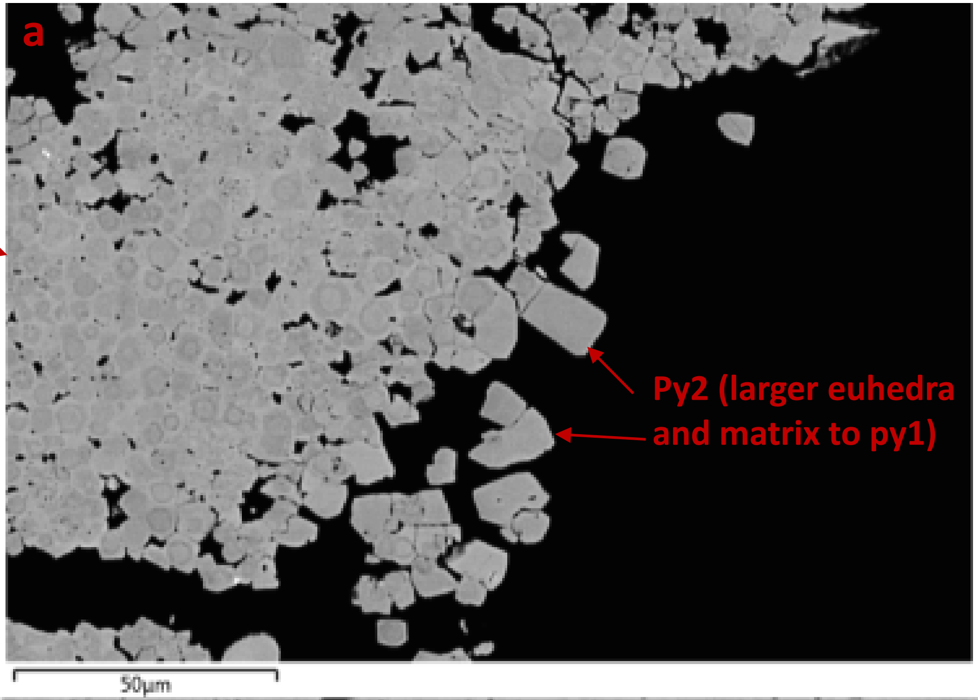
Work completed

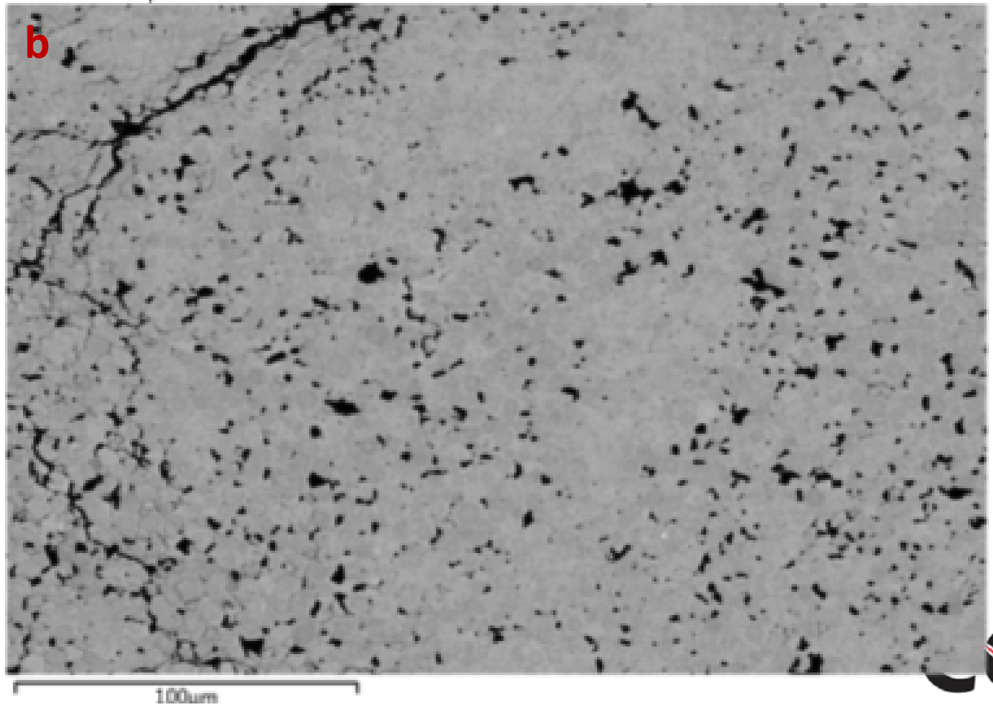
- 15 of 29 samples were analysed by optical and scanning electron microscope (SEM) prior to LA-ICP-MS analyses
  - Purpose: identify the general textural characteristics and mineralogy of sample suite (i.e., petrographic characterization)
- All 29 samples were then analysed using LA-ICP-MS at CODES, University of Tasmania
  - Spot analyses only (15-25 spots per sample; 5 matrix spots per sample)
  - 655 pyrite spots
  - 145 matrix spots
  - Purpose of matrix spots is to de-convolute pyrite signal from matrix 'background'; most pyrite in these samples is very fine grained and intimately intergrown with the rock matrix

Pyrite 1a & 2



Sample Y9, optical microscope (5x objective); SEM photographs on the right

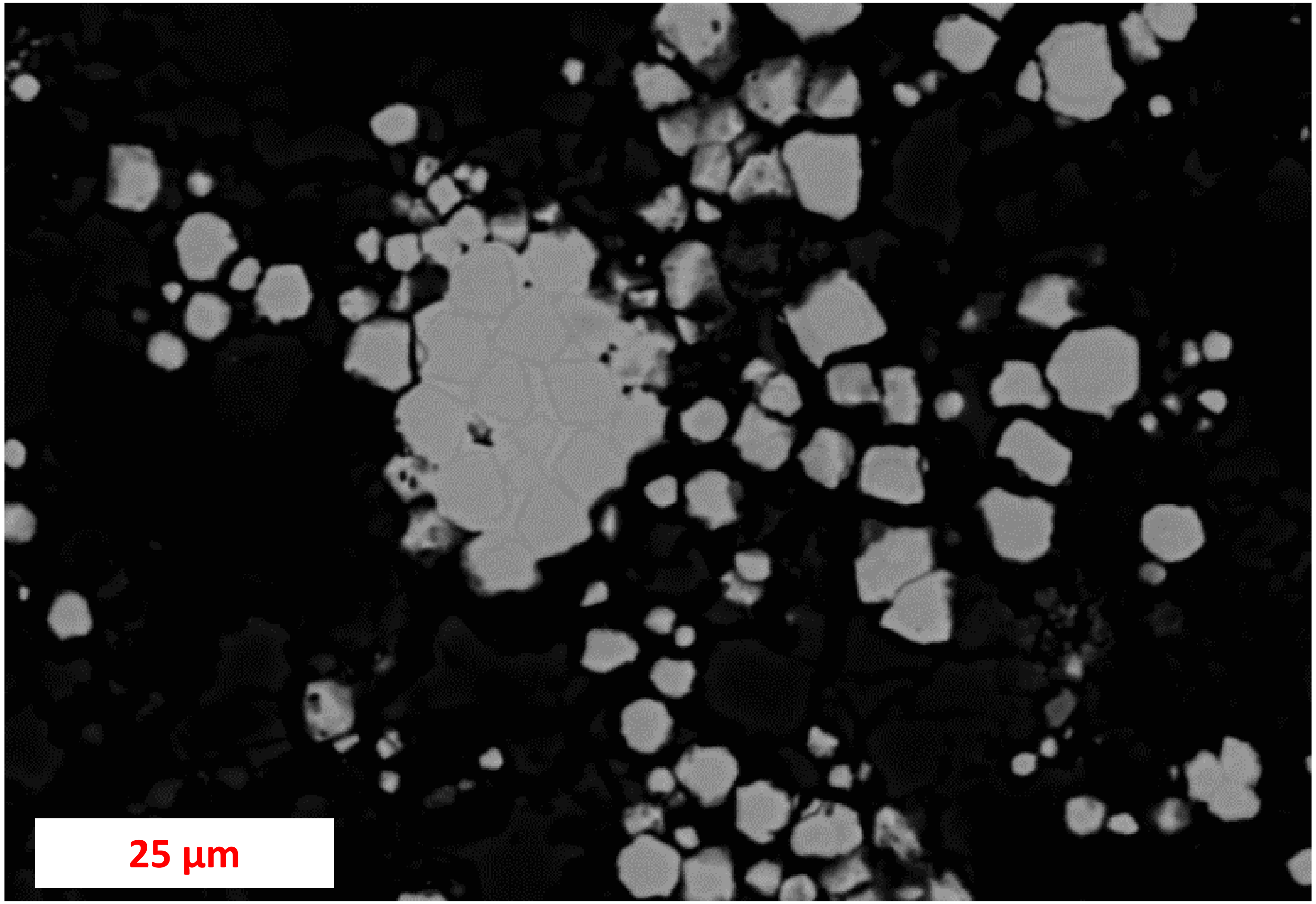




UNIVERSITY of TASMANIA

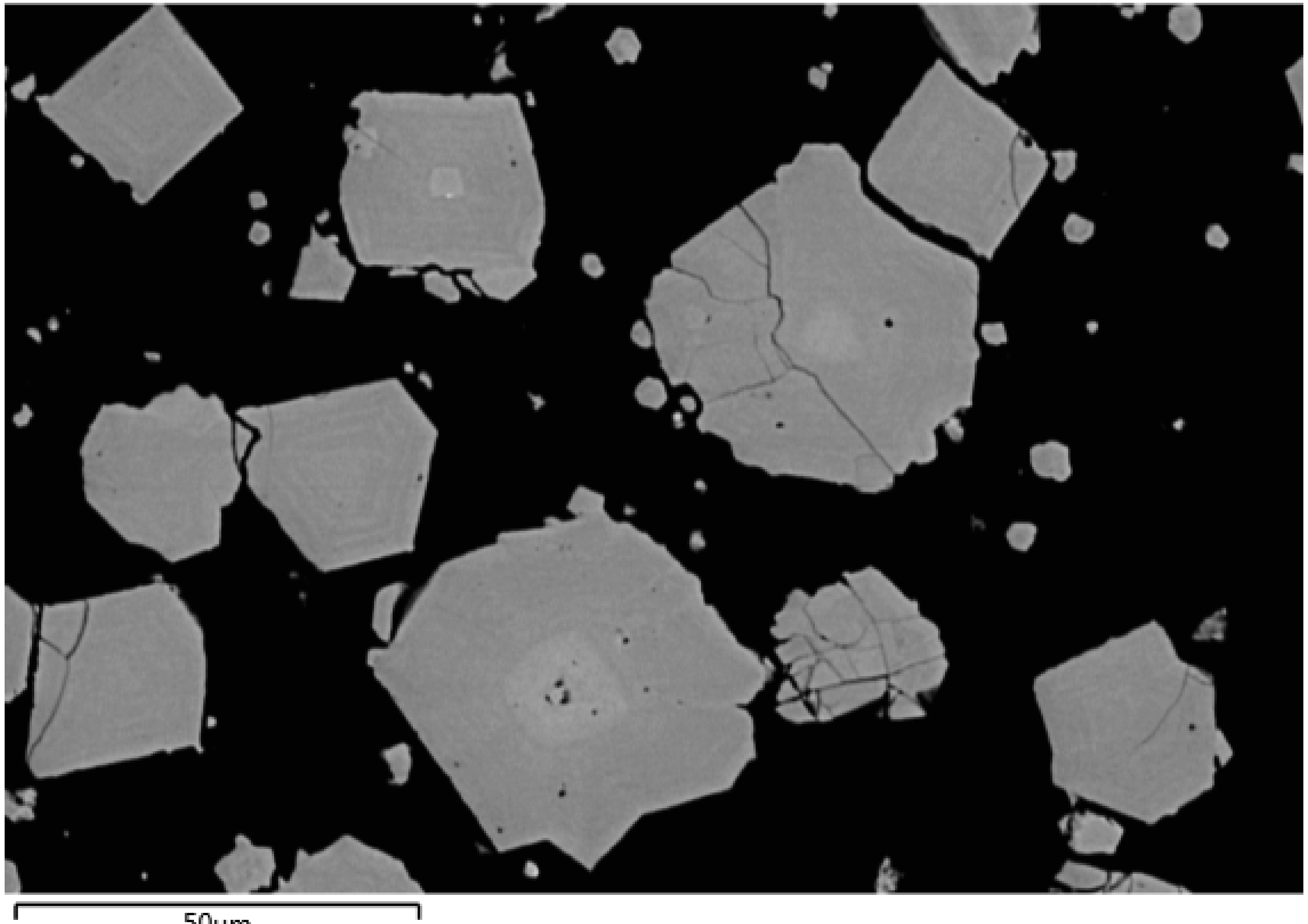
CODES

Pyrite 1a textural variations – framboids?



- Detail of previous SEM photomicrograph
- Again, note pyrite 1 grains cemented by a later pyrite generation (pyrite 2)

Pyrite 1b texture

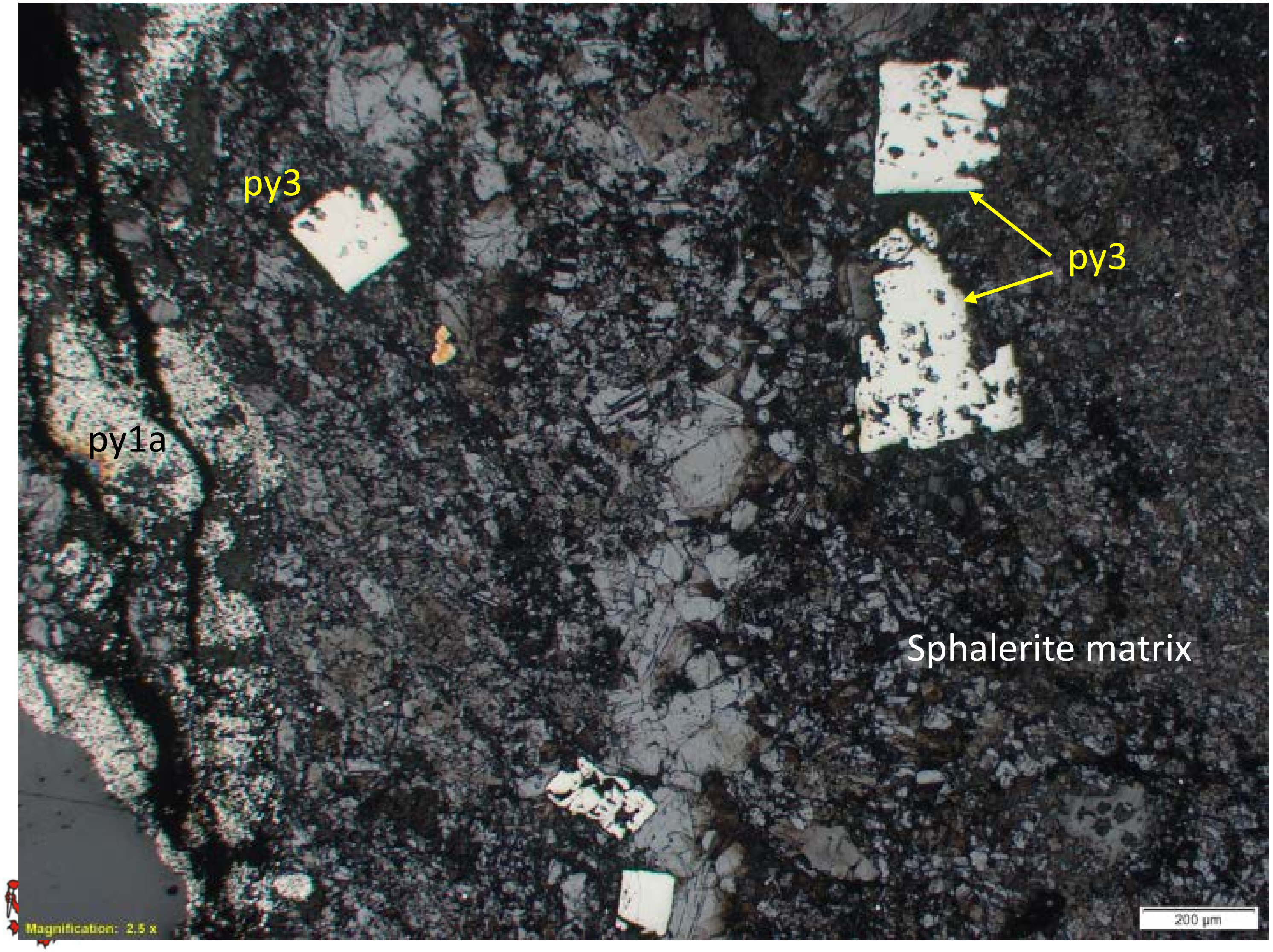


50µm

Sample Q13

- SEM photomicrograph of py1b euhedra
- Note intricate internal zonation
- Suggests repeated growth events

Pyrite 3 textural context

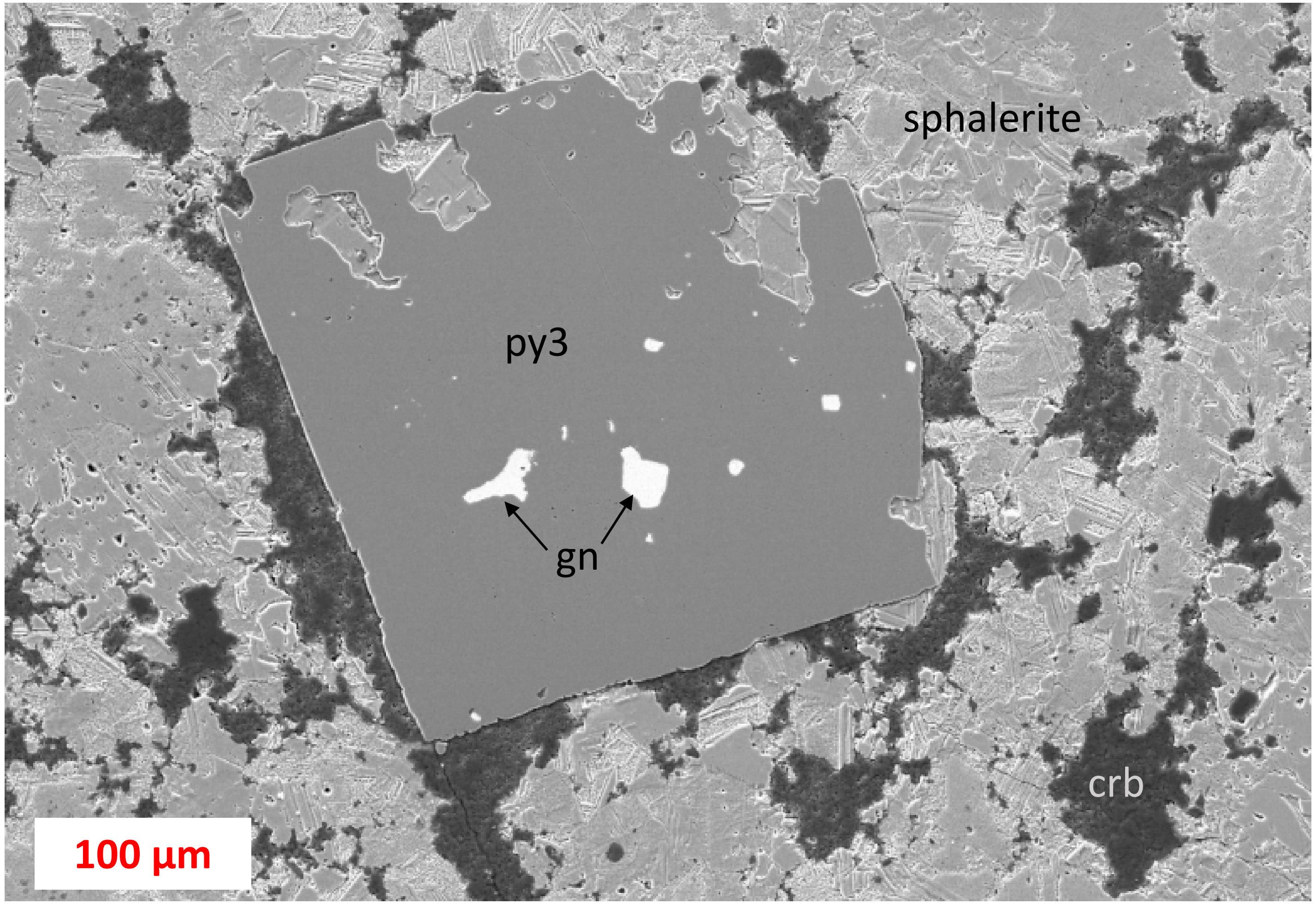


- Near-ore samples contain large, inclusion-bearing py3 euhedra
- Pyrite 1a also present in these samples (see left side of photomicrograph)

Sample H21
(Pyritic Unit)

CODES

Pyrite 3 textural context

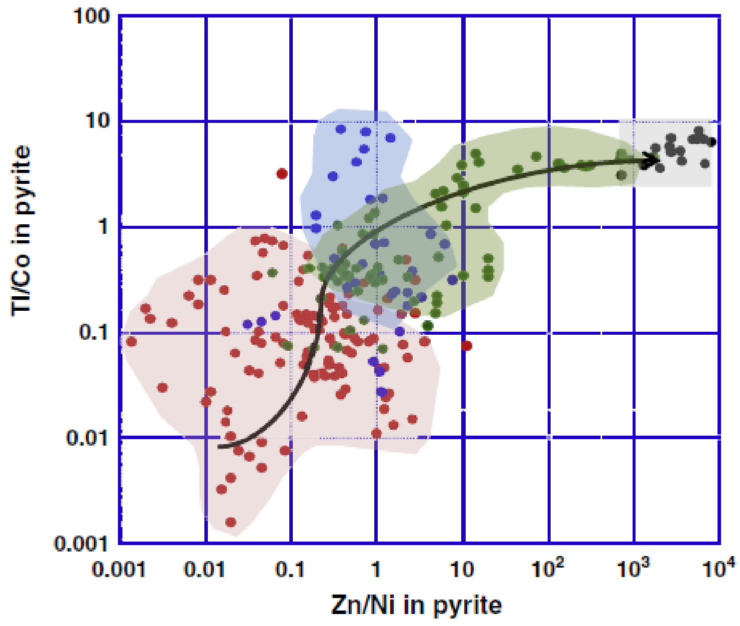


- Detail of py3 euhedra
- Note inclusions of ore minerals (sphalerite; galena)
- Also note the lack of internal zonation (compare to py1b)

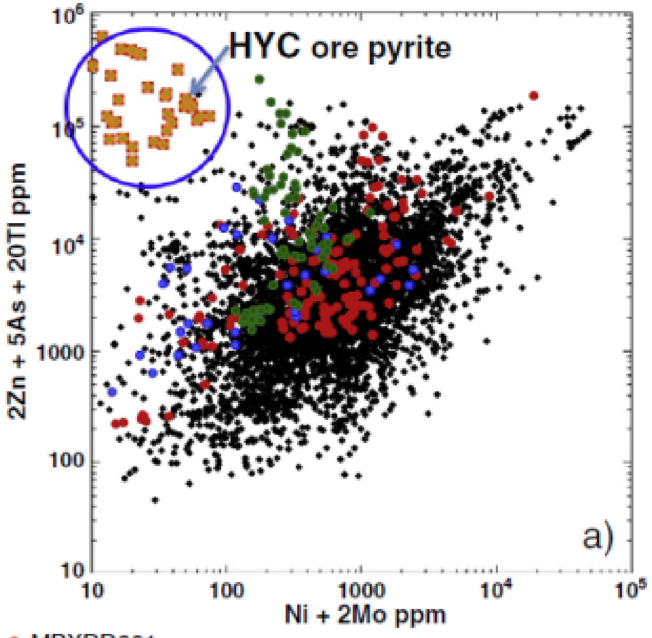
Results – LA-ICP-MS pyrite trace element geochemistry

Previous work

- Mukherjee and Large (2017, OGR) studied pyrite trace element chemistry from within and proximal to the McArthur River (HYC) SEDEX Zn-Pb deposit (e.g., Leila Yard 1; Myrtle 4), as well as pyrite from distal areas (MBXDD001)
- They identified several key element ratios which provide distance-to-orebody constraints for HYC (see figures at right)



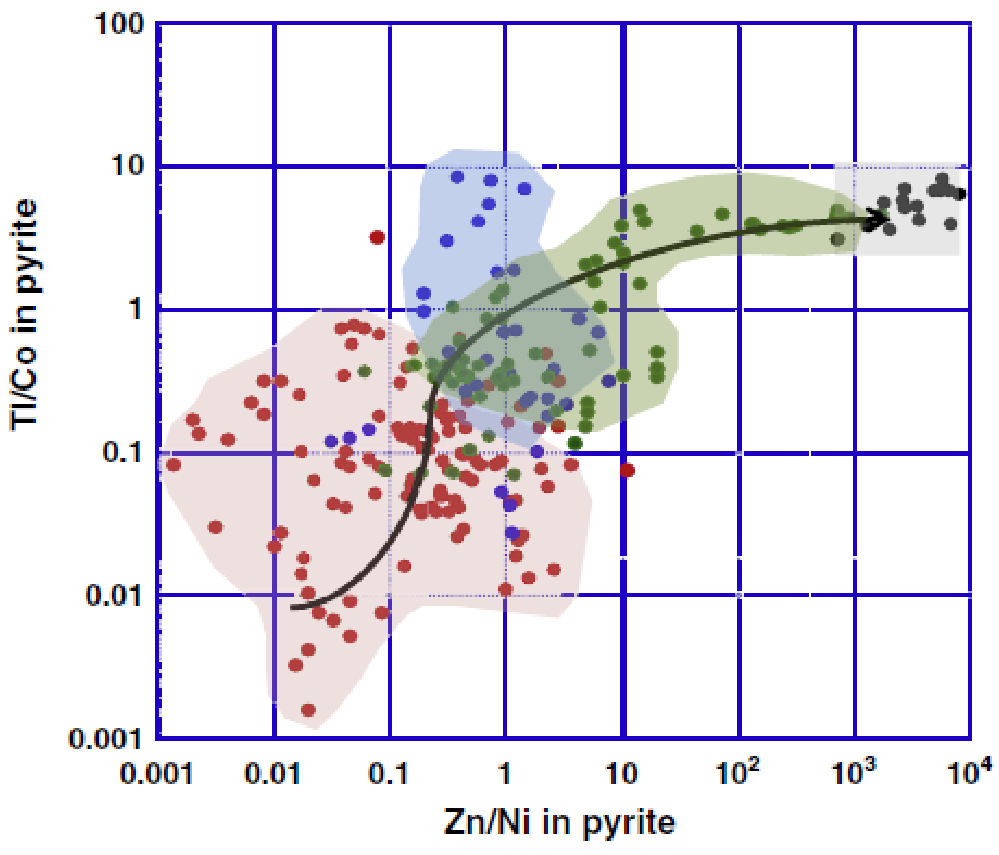
MBXDD001
Leila Yard 1
Myrtle 4
HYC ore pyrite

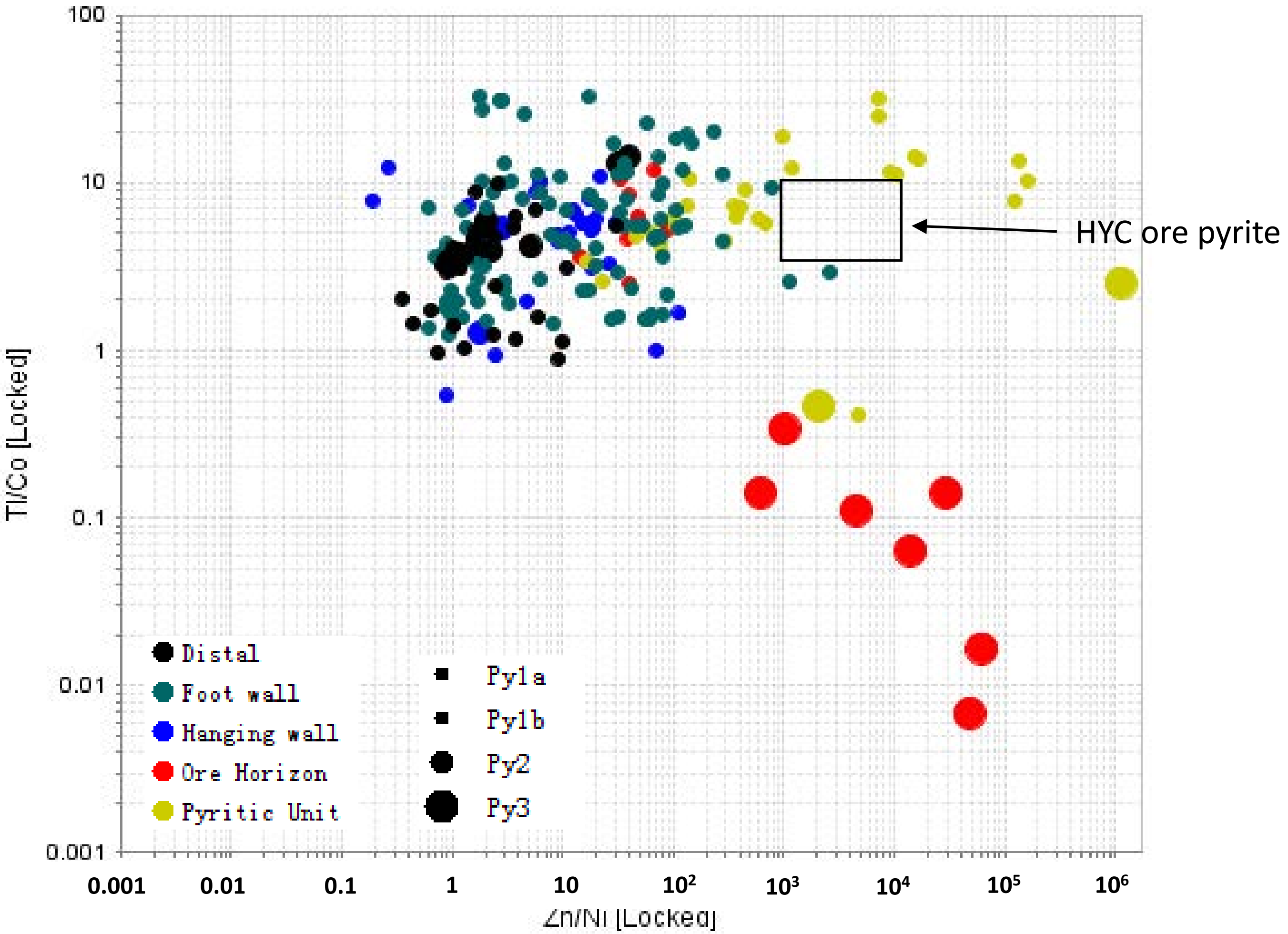


MBXDD001
Leila Yard 1
Myrtle-4
Background sedimentary pyrite analyses (Large et al., 2014)
HYC (McArthur River deposit) ore pyrite

UNIVERSITY of TASMANIA

Lady Loretta data – comparison with HYC





Mukherjee and Large, 2017, OGR

- MBXDD001
- Leila Yard 1
- Myrtle 4
- HYC ore pyrite

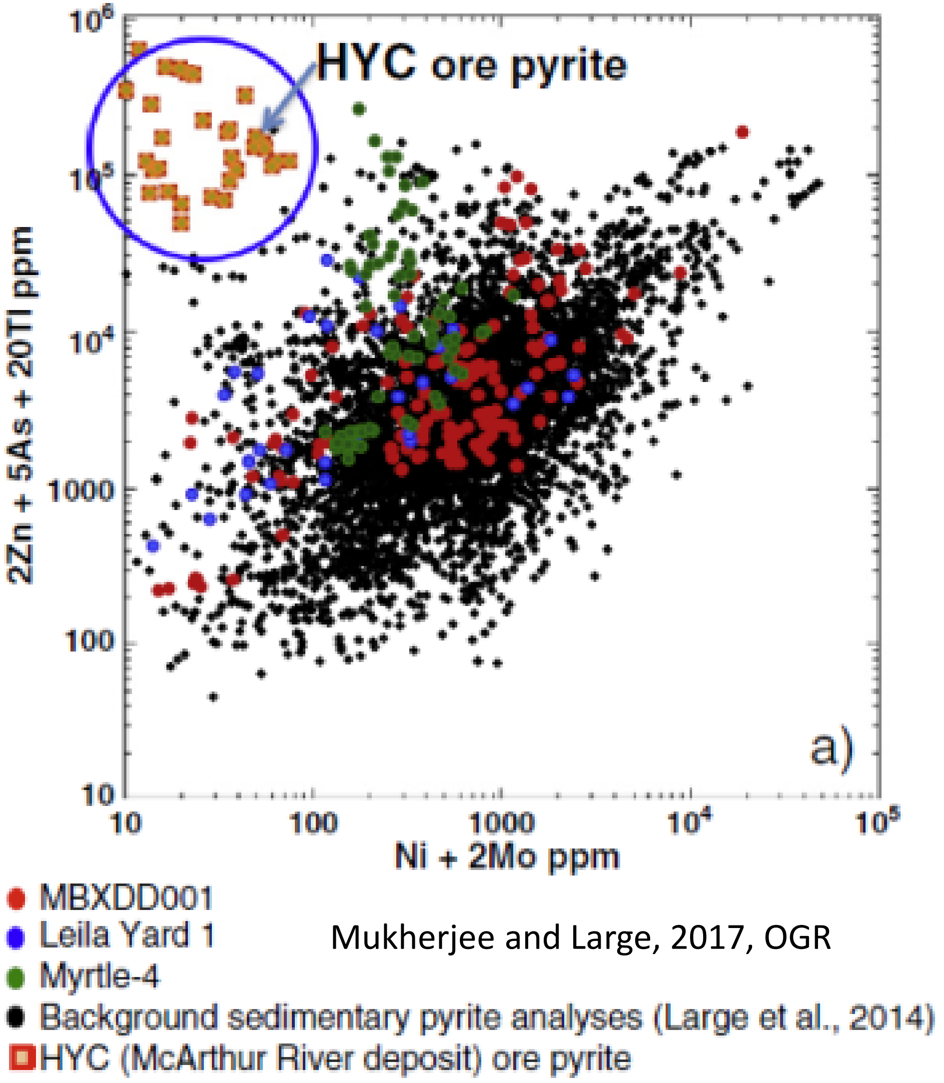
TASMANIA

CODES

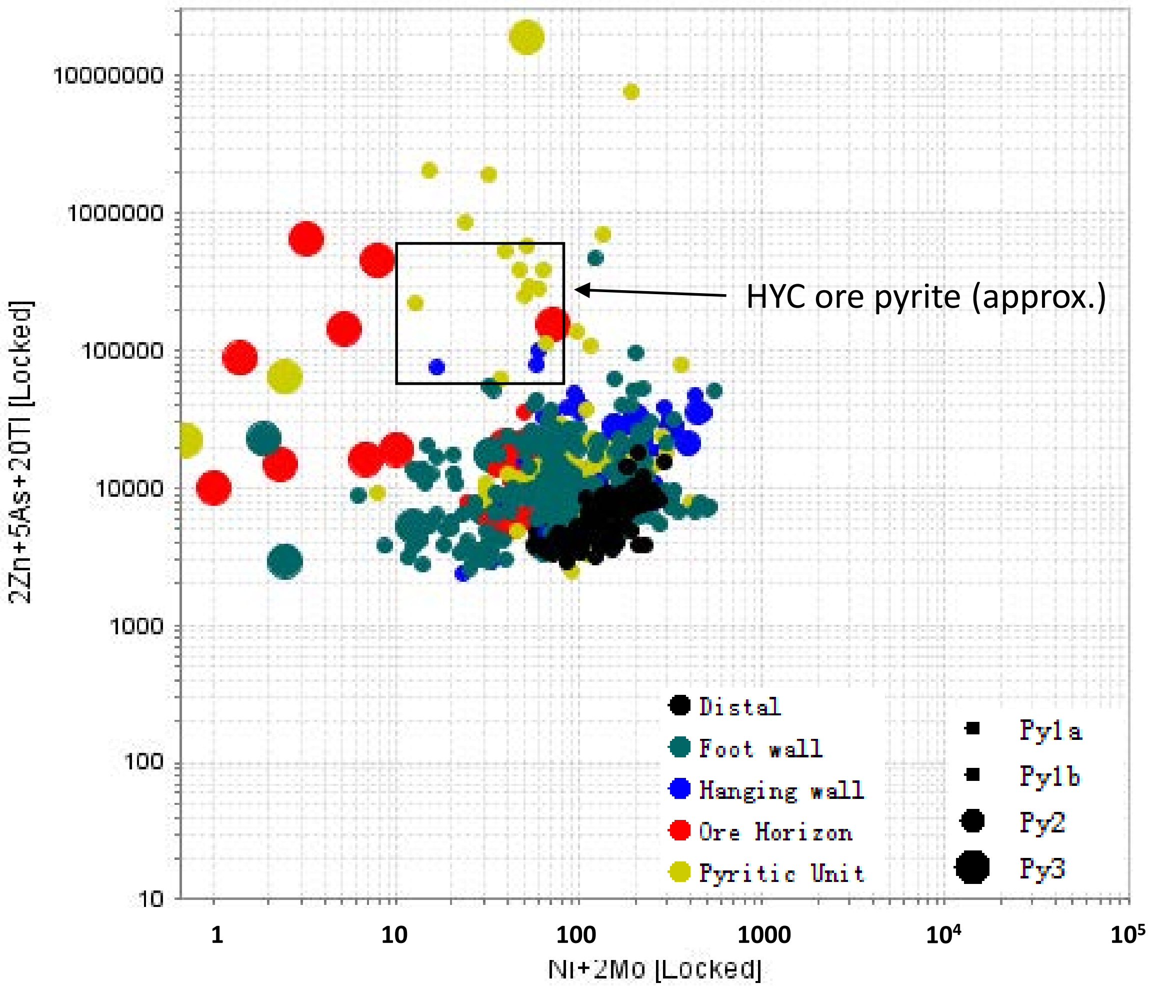
Tl/Co vs. Zn/Ni: discussion

- Coincident enrichments in Tl/Co and Zn/Ni ratios are thought to be indicative of ore zone and/or proximal SEDEX-style pyrite
  - HYC ore zone pyrite has Tl/Co between 5-10; Zn/Ni between 10^3-10^4
  - Pyrite from Lady Loretta has comparable values, with a few data points exceeding Zn/Ni = 10^4 at Tl/Co ratios of ~10
- The negative Tl/Co vs. Zn/Ni trend in ore zone pyrite from Lady Loretta is due to the fact that all ore zone analyses were conducted on Py3 rather than Py1a-b or Py2, as for the rest of the sample suite
  - Further analyses on Py1a in ore zone samples are planned
- Also, bear in mind that in the HYC study of Mukherjee and Large (2017), the distal samples from MBXDD001 were ~30 km away from HYC, whereas our 'distal' Lady Loretta samples from LA64 and LA67 are a maximum of 5 km from the ore zone

Lady Loretta data – comparison with HYC, cont.



Mukherjee and Large, 2017, OGR



Zn-As-Tl vs. Ni-Mo: discussion

- As with the previous diagrams, pyrite from the Lady Loretta ore zone plots close to the field defined by HYC ore pyrite from Mukherjee and Large (2017)
  - HYC ore pyrite: decrease in Ni and Mo toward ore zone; increase in Zn-As-Tl
  - Similar pattern at Lady Loretta; note high slope negative trend in Py1a from the Pyritic Unit, which sits immediately below the ore zone
- Again, the degree of separation between the Lady Loretta distal samples and ore zone samples on this diagram is not as great as for the HYC samples, likely due to differing scales between the two studies (30 km vs. 5 km)

Lady Loretta conclusions

- LA-ICP-MS trace element analyses of pyrite-bearing samples from within and around the Lady Loretta SEDEX Zn-Pb deposit reveal consistent enrichment/depletion trends in certain key elements, which are correlated with distance from the ore zone
  - E.g., Zn increases toward the ore zone; Ni and Mo decrease toward the ore zone
- This pattern is comparable to that defined for McArthur River (HYC) by Mukherjee and Large (2017)
- Pyrite textures and paragenesis at Lady Loretta are similar to other SEDEX-style systems of various ages around the world (e.g., Black Butte, USA = ~1470 Ma)

Future Work – NW Queensland

- Follow-up work on pyrite at Lady Loretta is warranted, but we will hold off on this for the time being
- Ernest Henry is next in line for this project
  - New EH drill core has recently arrived at GSQ's core facility in town
  - The first phase of work at Ernest Henry will focus on pyrite and magnetite (poss. PhD project for magnetite?)
  - Will consider second phase after first phase evaluation