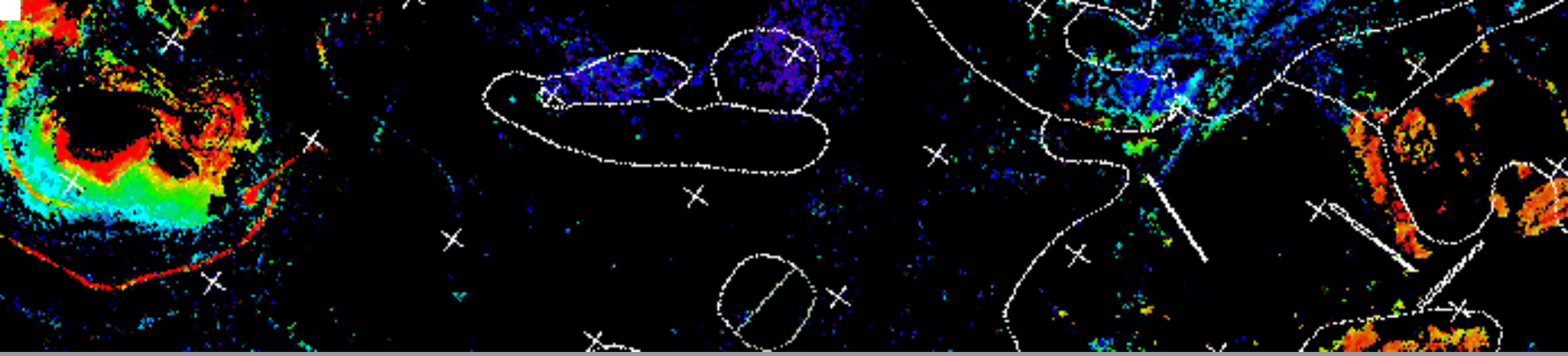


Mapping Regolith and Alteration Mineral Physicochemistries using Airborne Hyperspectral Data

Tom Cudahy[1], M. Caccetta[1], A, Cornelius[1,2], R. Hewson[1], M. Wells[1], M. Skwarnecki[3], S. Halley[4] and P. Hausknecht[5]

1 CSIRO Exploration & Mining, 26 Dick Perry Ave, Kensington, WA, 6151, Australia.

[2] CRC FOR Landscape Environments and Mineral Exploration, Kensington, WA, 6151.

[3] Geological Survey of Western Australia, East Perth, WA, 6004.

[4] Placer Dome Asia Pacific, West Perth, WA, 6005.

[5] HyVista Corporation, Kensington, WA, 6151.

CSIRO

Geological Survey of Western Australia

HyVista Corporation

Department of Industry and Resources

Placer Dome Asia Pacific

CRCLEME

Cooperative Research Centre for Landscape Environments and Mineral Exploration

Challenges/Perceptions

- **75% of Australia is covered by deep regolith**
- **All “exposed” areas have already been well explored (mapped)**
- **Next generation of mineral deposits are “buried”**
- **Remote sensing only measures the top few microns**
- **Implication : remote sensing has no value for mineral exploration in Australia**

BUT

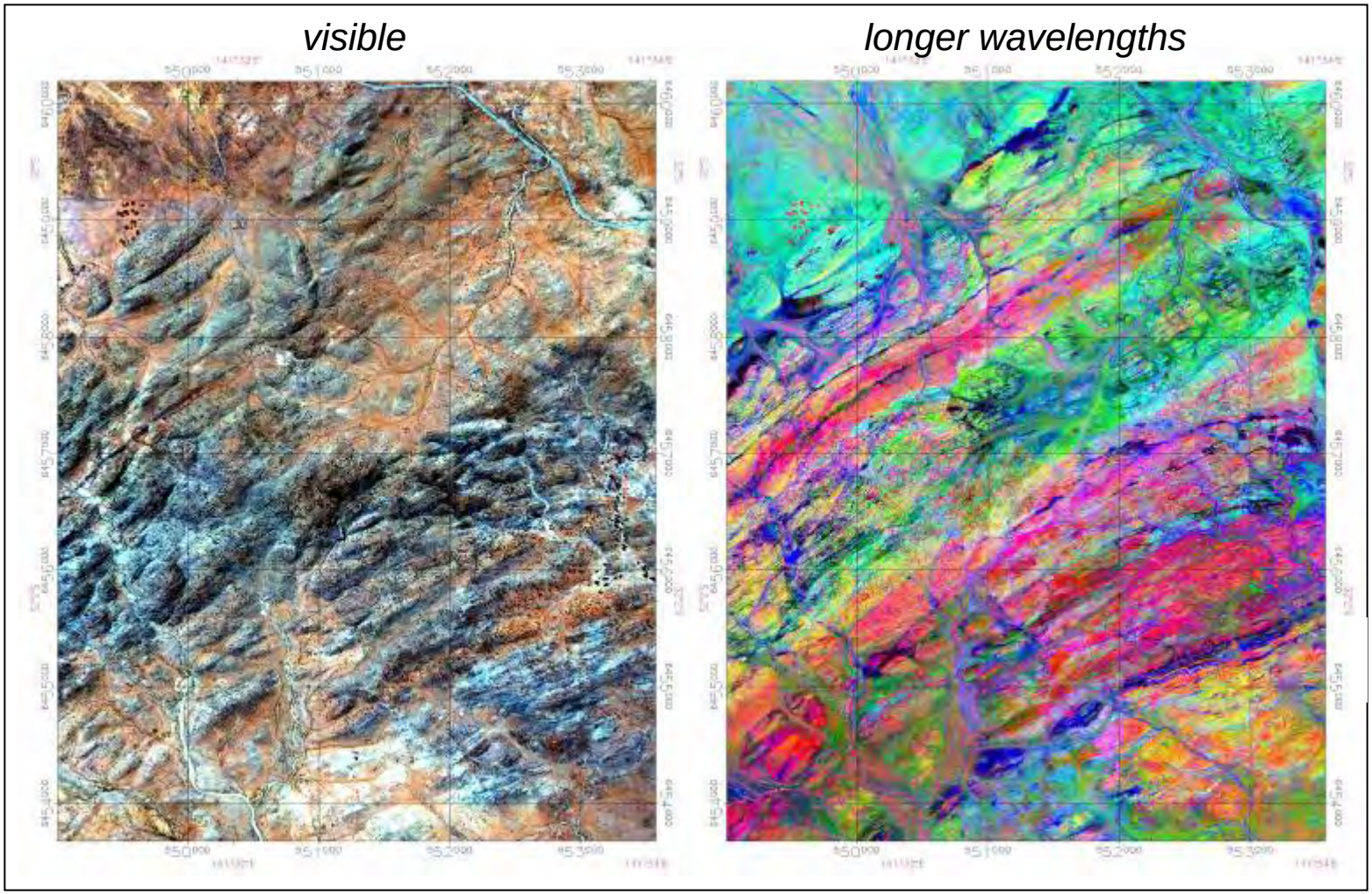
- **How well has the surface been mapped?**
  - Transported versus *in situ* materials
- **Would publicly available pre-competitive maps of alteration mineralogy be a useful product to help target mineralisation especially in “erosional” areas?**

What Can New Generation Remote Sensing Technologies Achieve Today?

Seeing beyond the visible

visible

longer wavelengths



What Can New Generation Remote Sensing Technologies Achieve Today?

Seeing beyond the visible

Mapping of mineralogy from every pixel on the ground

- See between the trees:

What Can New Generation Remote Sensing Technologies Achieve Today?

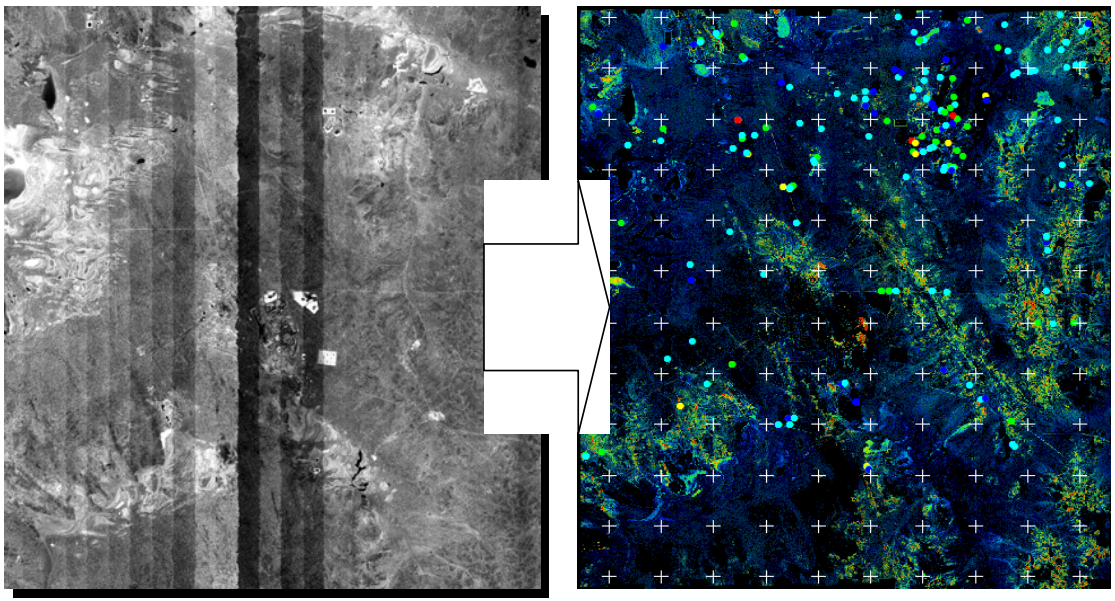
Seeing beyond the visible

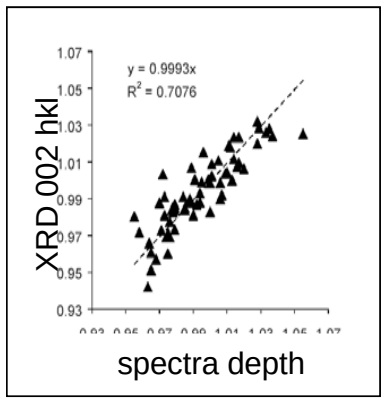
Mapping of mineralogy from every pixel on the ground

- See between the trees:

Accurate, seamless maps of mineral abundances and mineral chemistries

- Laboratory-grade spectroscopy remotely





kaolin abundance

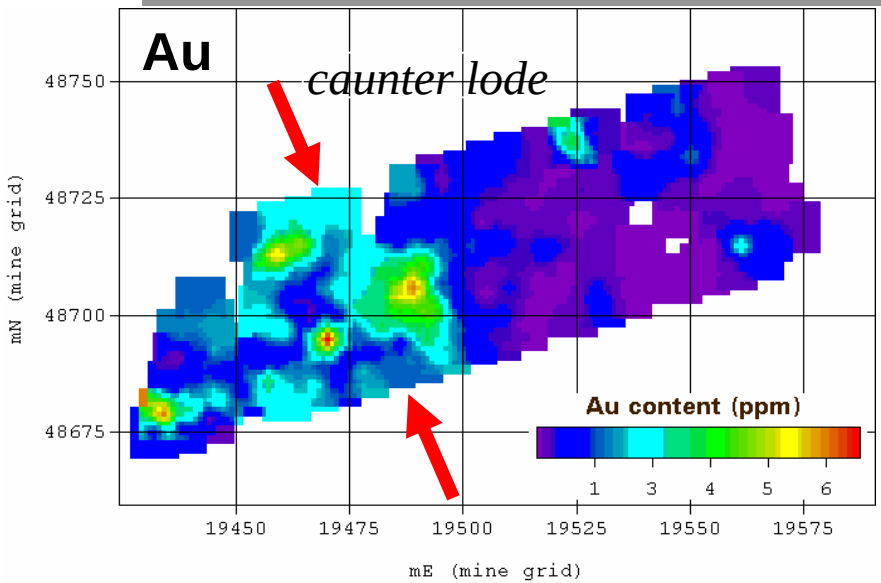
15% 80%

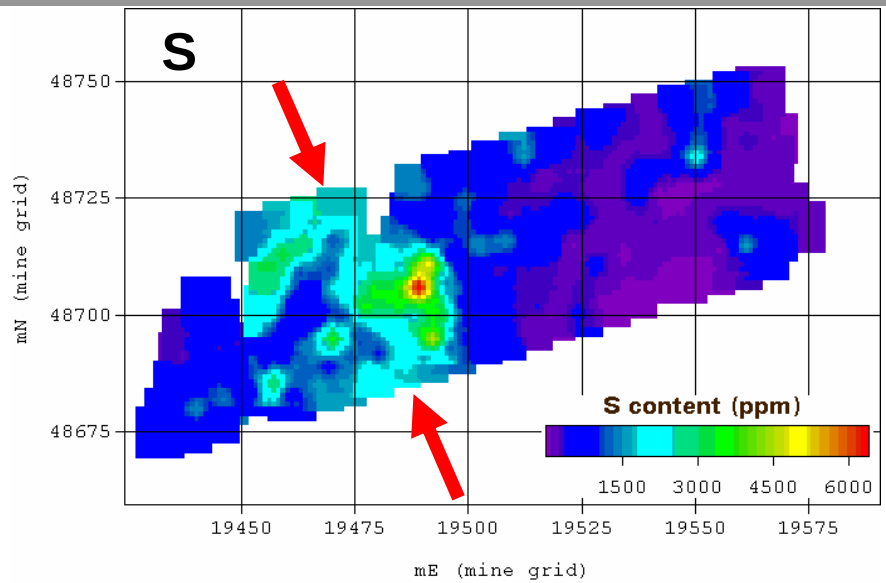
Geological Models Unlock/Reveal the Exploration Potential

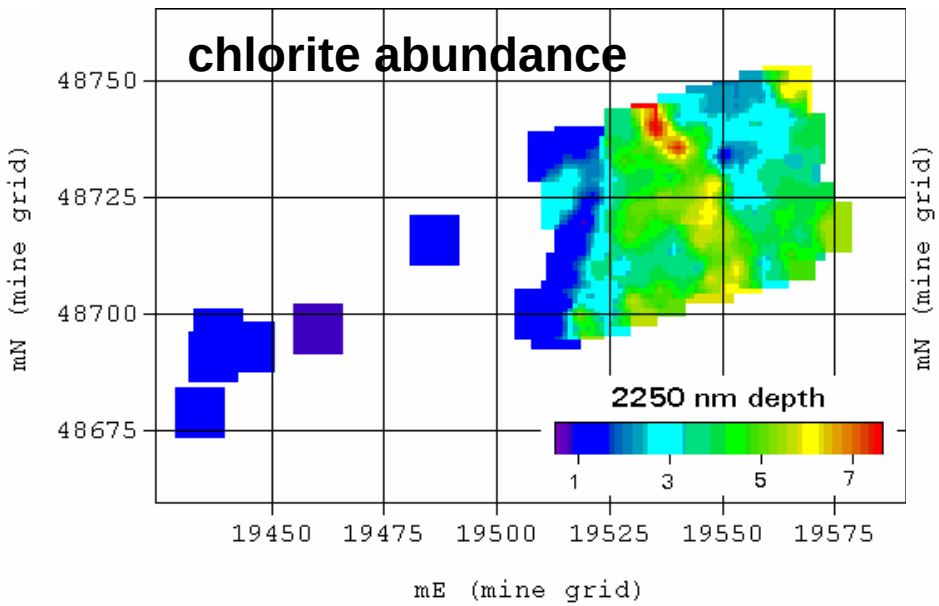
From KCGM, 1996

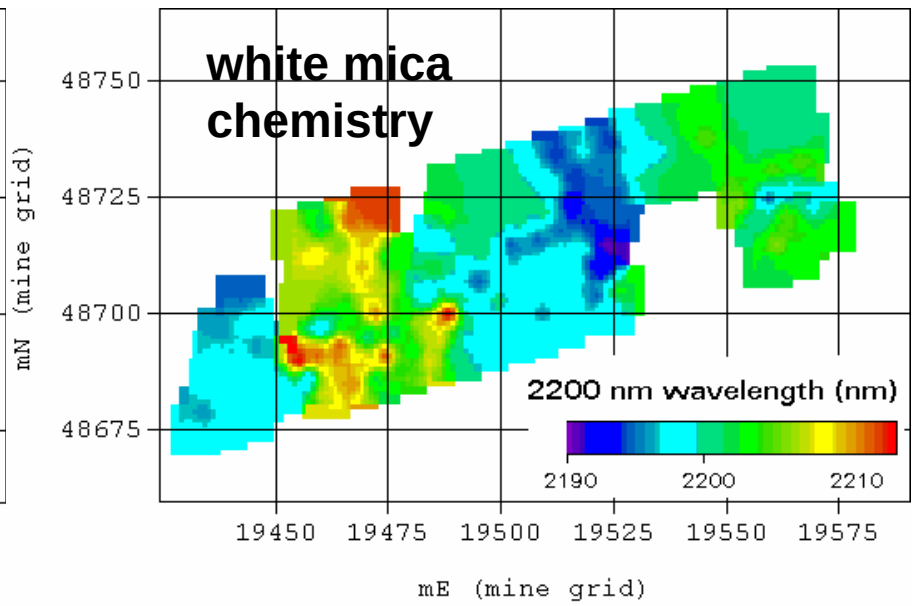
Zone	Subzone	Description	Diagnostic Minerals	Gold (ppm)
Chlorite		Green-grey colour; primary igneous textures; large spatial extent (~1 km).	chlorite, ±calcite; ±paragonite	<0.1
Carbonate		White, pink, beige colour; primary textures less common; medium spatial extent (<100 m)	Ankerite/siderite; muscovite	~0.2
Pyrite/lode	**Types1-4** (see below for details)	Heterogeneous colour (inc. grey-bronze colour imparted by fine grained pyrite); no igneous textures; gouge and breccia common; <10m wide		
	Type 1		Ankerite (60%)	0.1-3
	Type 2	.	Muscovite, tellurides, ankerite	1-10 000
	Type 2a		Vanadium-bearing minerals	1-100 000
	Type 3		Quartz (80%)	0.1-3

Archaean Au alteration – Fimiston “Birthday South” Bench









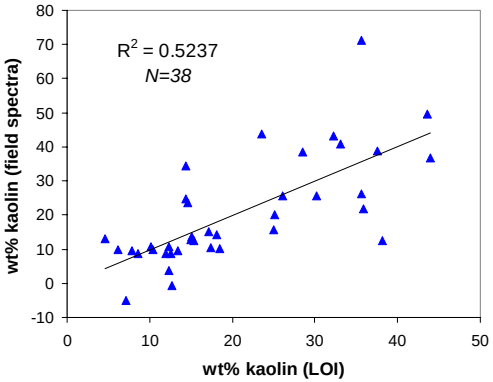
MERIWA M370 Demonstration Project

The overall project objective was to develop, validate, and deliver a series of maps of regolith and alteration mineral abundances and mineral physicochemistries for the 1:100 000 scale map sheet centered over Kalgoorlie-Boulder.

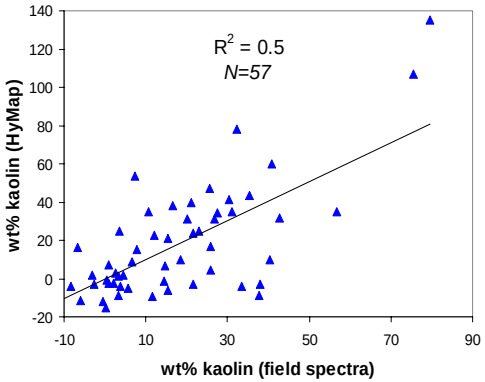
Kalgoorlie-Kanowna 1:100 000 scale mapsheet

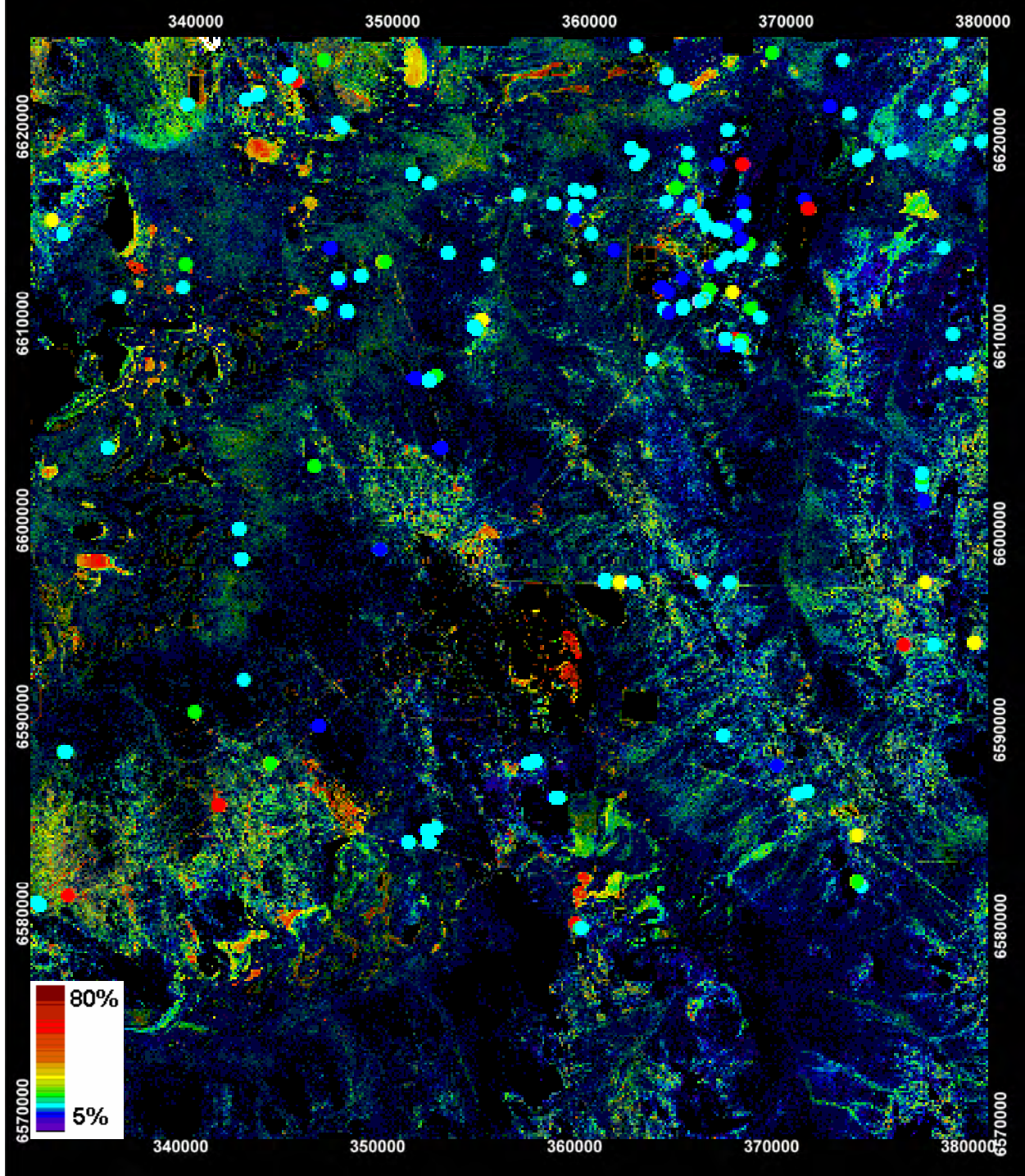
Kaolin Abundance

XRF/XRD vs ASD



field vs airborne

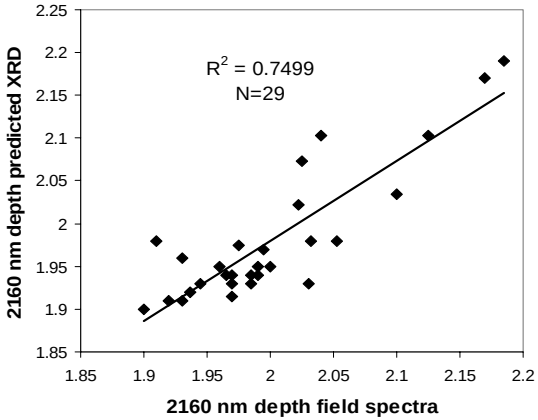




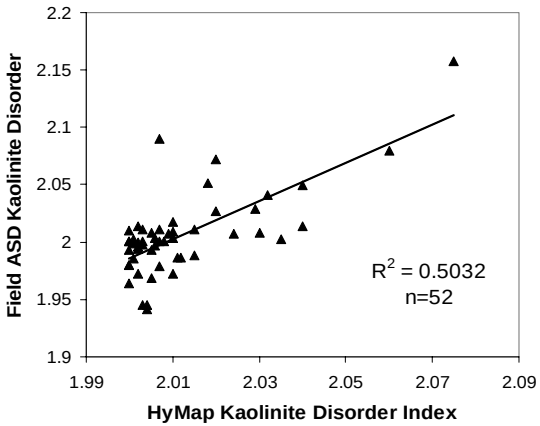
Kalgoorlie-Kanowna 1:100 000 scale mapsheet

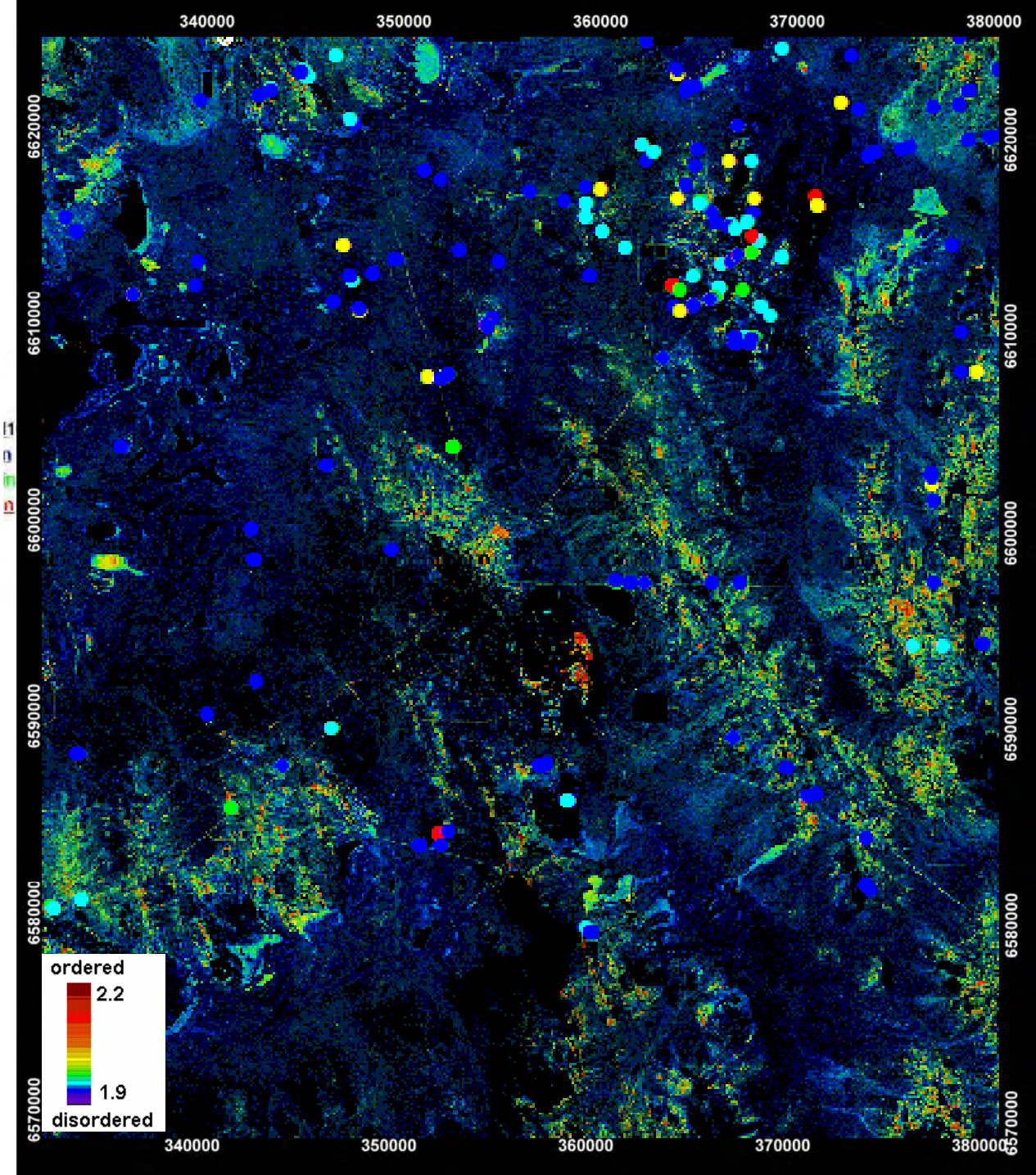
Kaolin Disorder

XRD vs ASD



field vs airborne

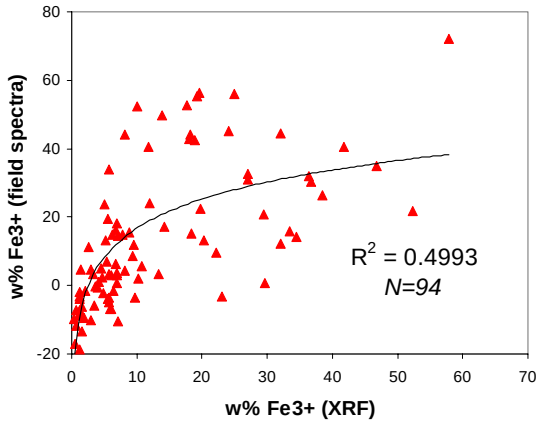




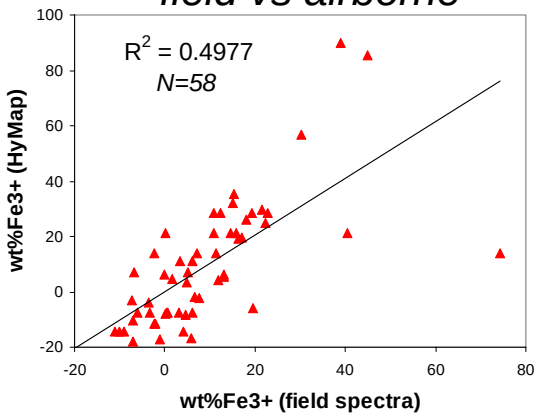
Kalgoorlie-Kanowna 1:100 000 scale mapsheet

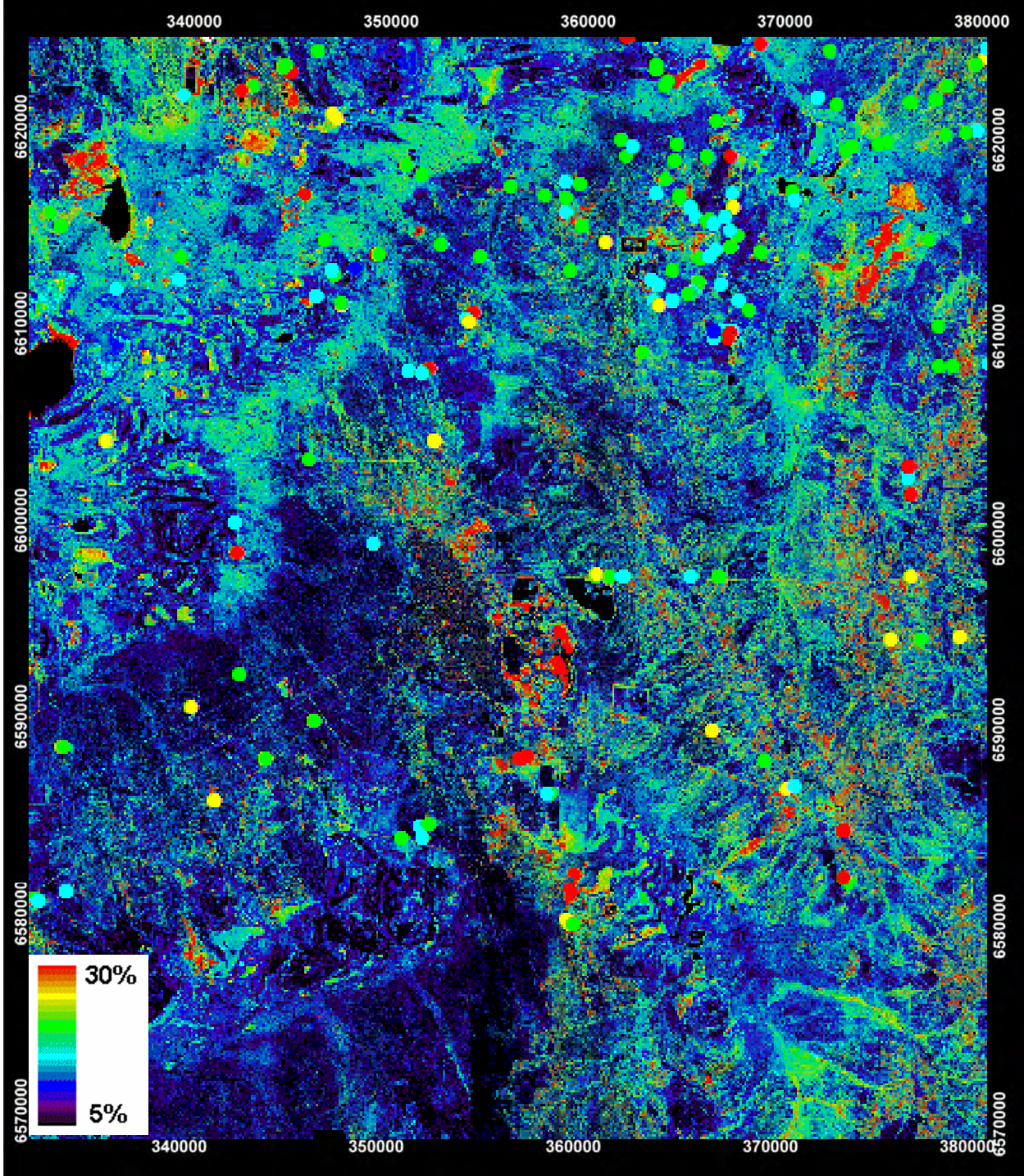
Ferric Oxide Abundance

XRF vs ASD

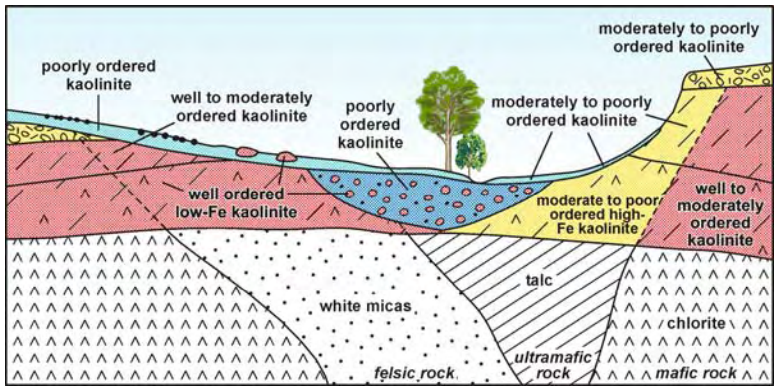


field vs airborne

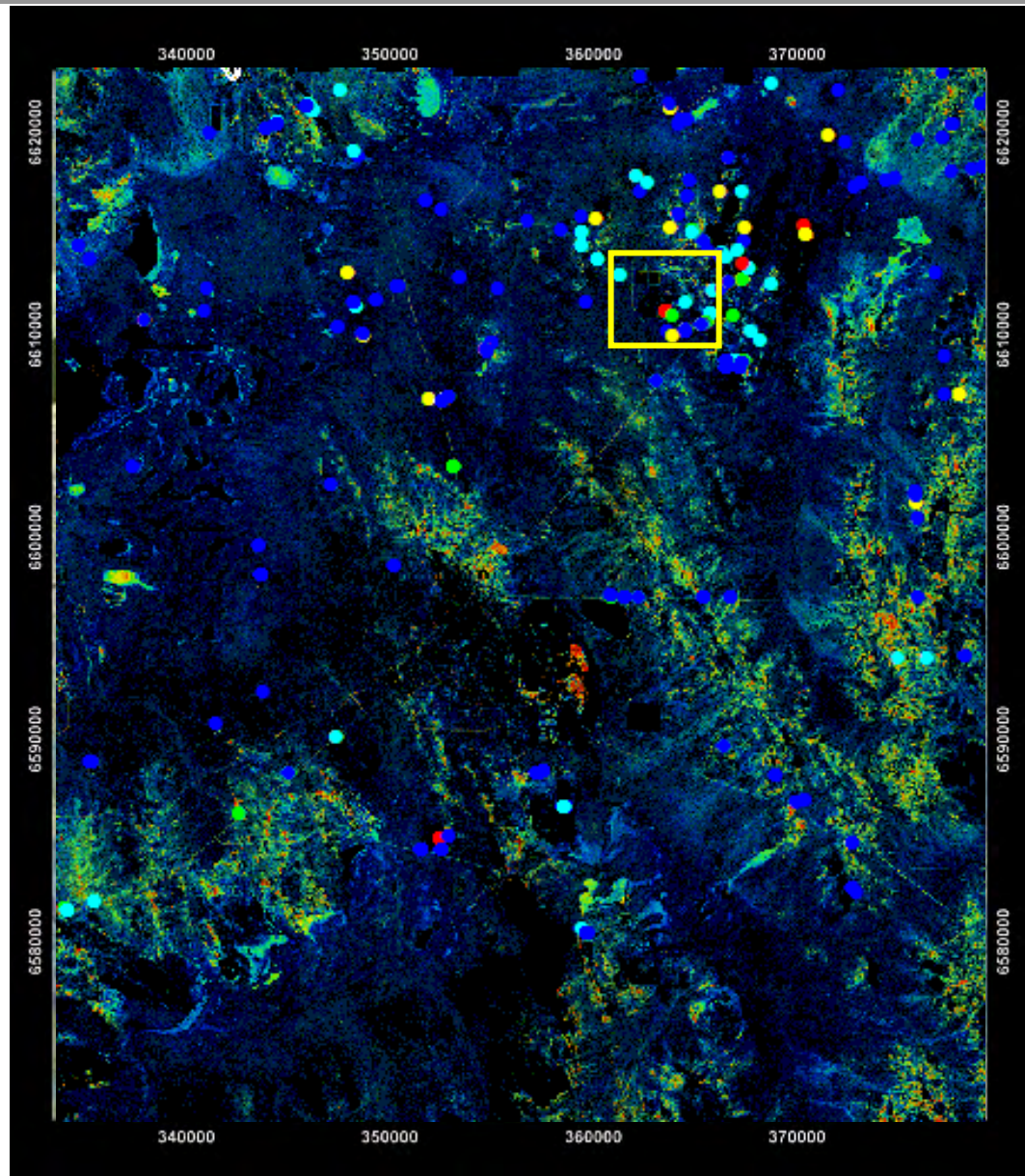




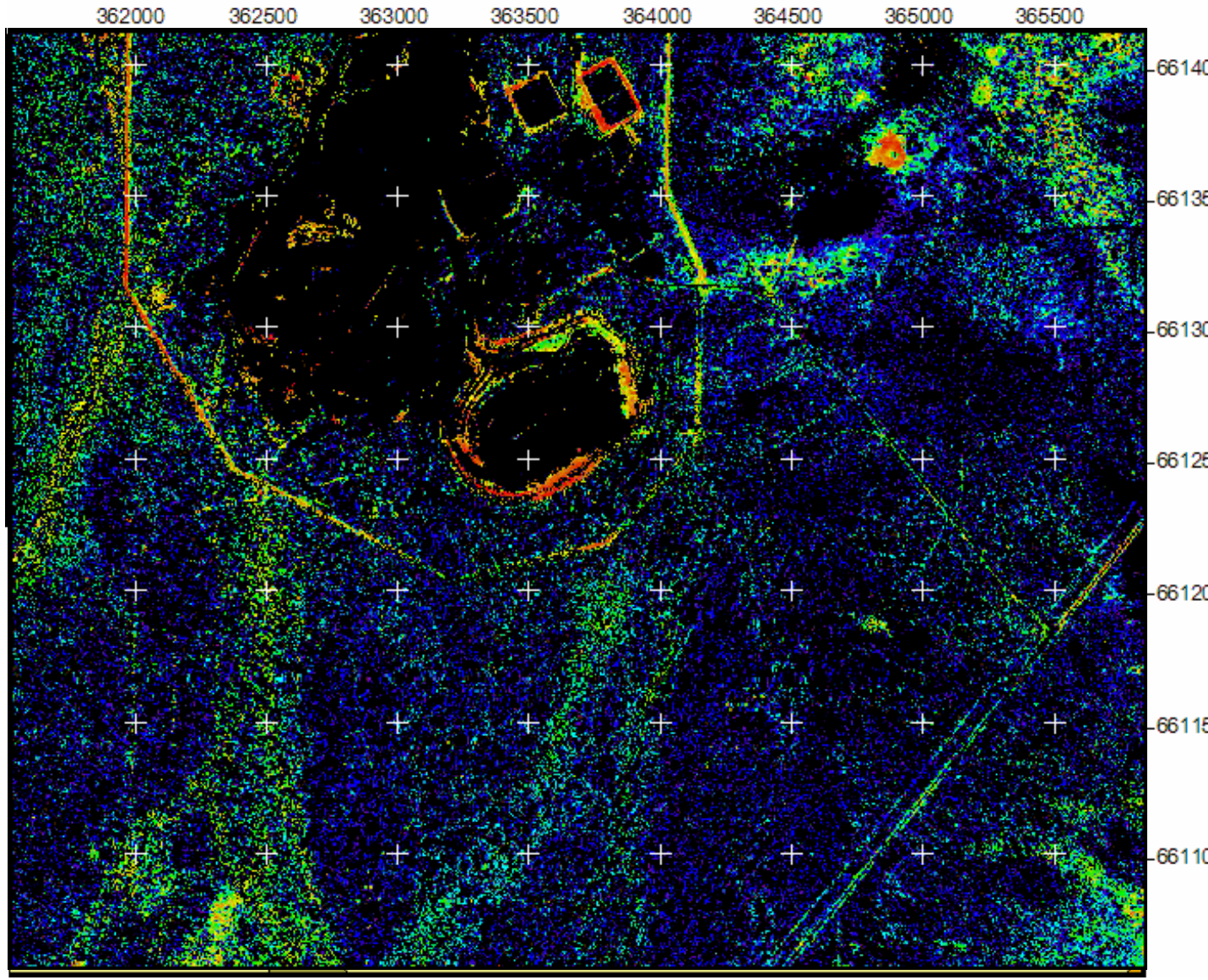
How do you use mineral information for regolith mapping?



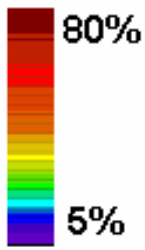
transported versus in situ using kaolin disorder?



Kanowna Belle

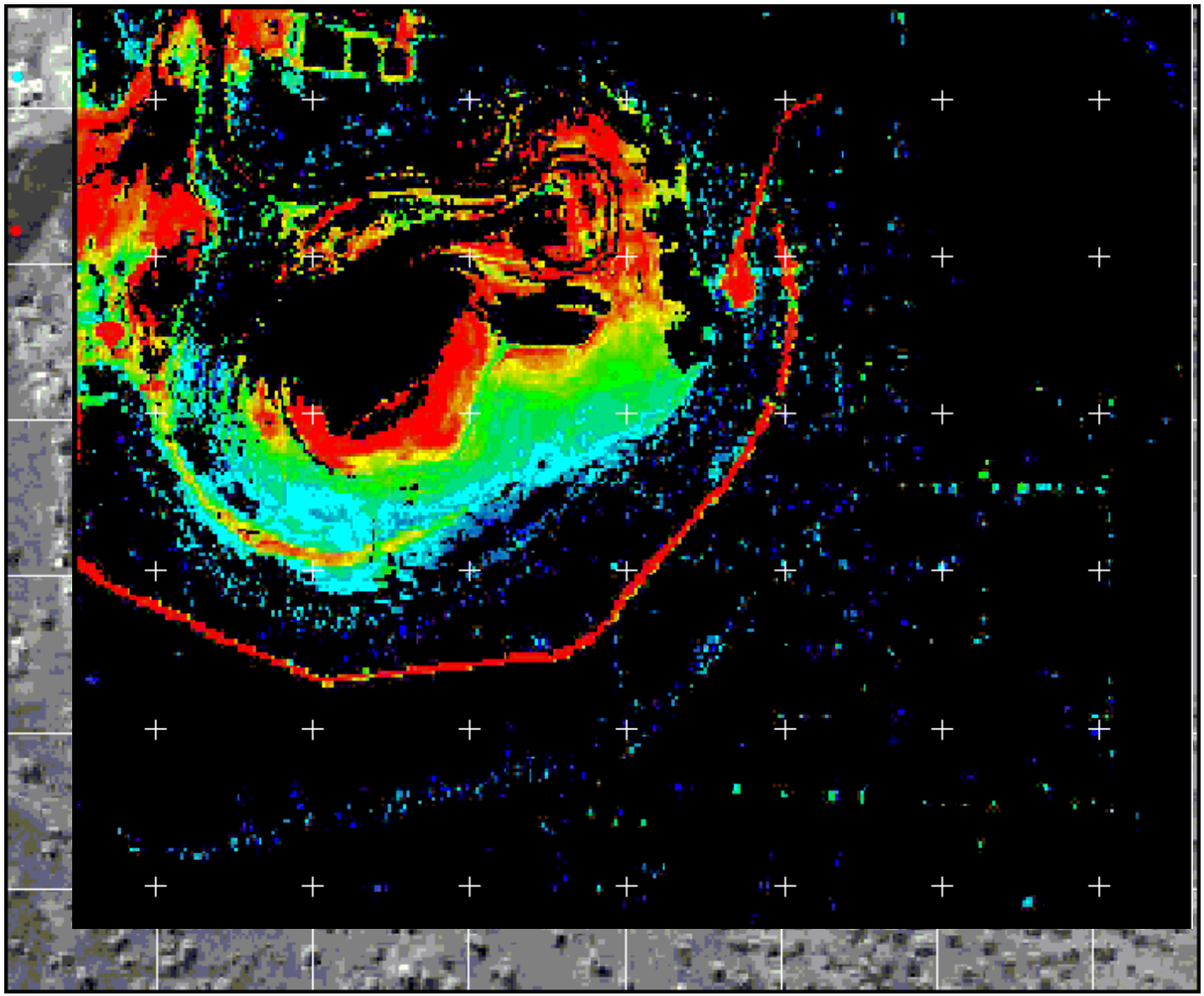


kaolin abundance



Kanowna Belle

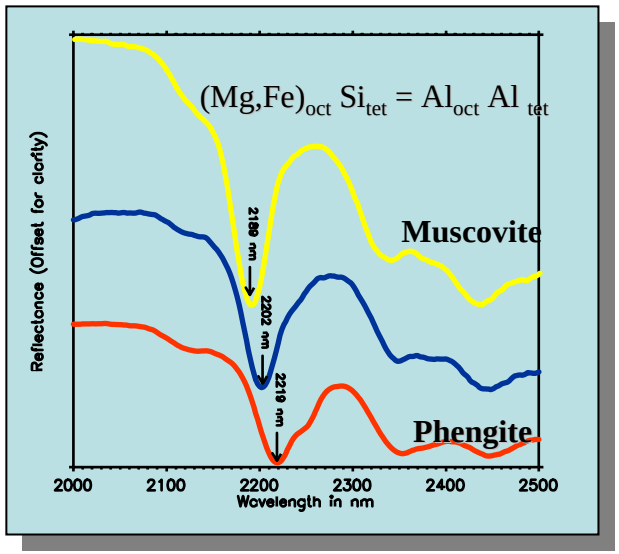
Kanowna Belle - Alteration Mapping (inc. drill spoil?)

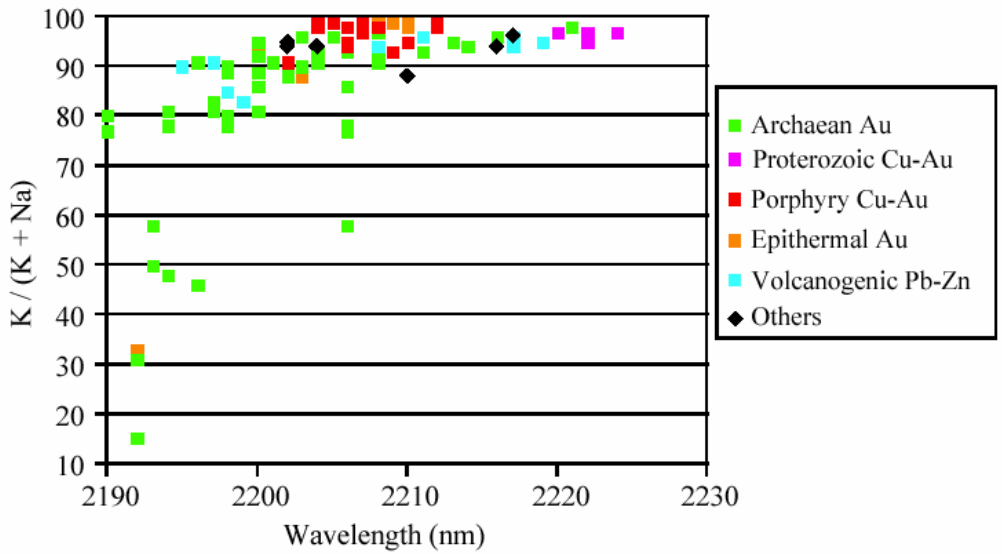


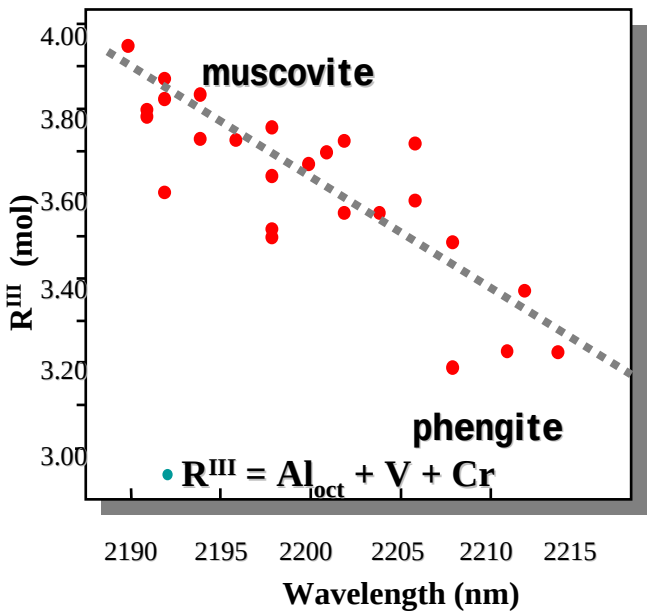
Hydric Fluid Model – *Walshe and others*

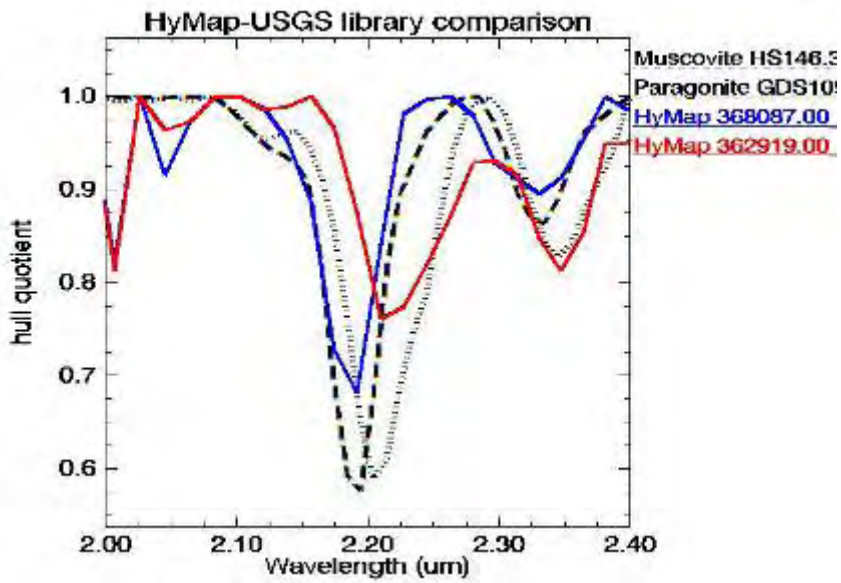
- **deep (mantle?) anhydrous, reduced, H_2 - CH_4 - H_2S - N_2 with components of Na, Cl and F?**
- **transports a wide range of elements of metallogenic interest (e.g. Ti, V, Cr, Co, Mo, W, U, Th, Au, PGEs)**
- **highly unstable in water saturated environments of the mid and upper crust and will degrade rapidly**
- **highly acidic fluids, yielding large scale footprints of minerals as kaolinite, pyrophyllite, chloritoid, paragonite**
- **if acid-absorbing species are available, it is possible to produce sodic alkaline brines that will give rise to quite contrasting alteration assemblages containing albite, phengite, biotite, amphiboles.**
- **Exploration Message : *"map the REDOX gradients"***
- **Mineral Mapping Key(s) : e.g. *"map white mica chemistry"***

Spectral Measurement of White Mica Chemistry





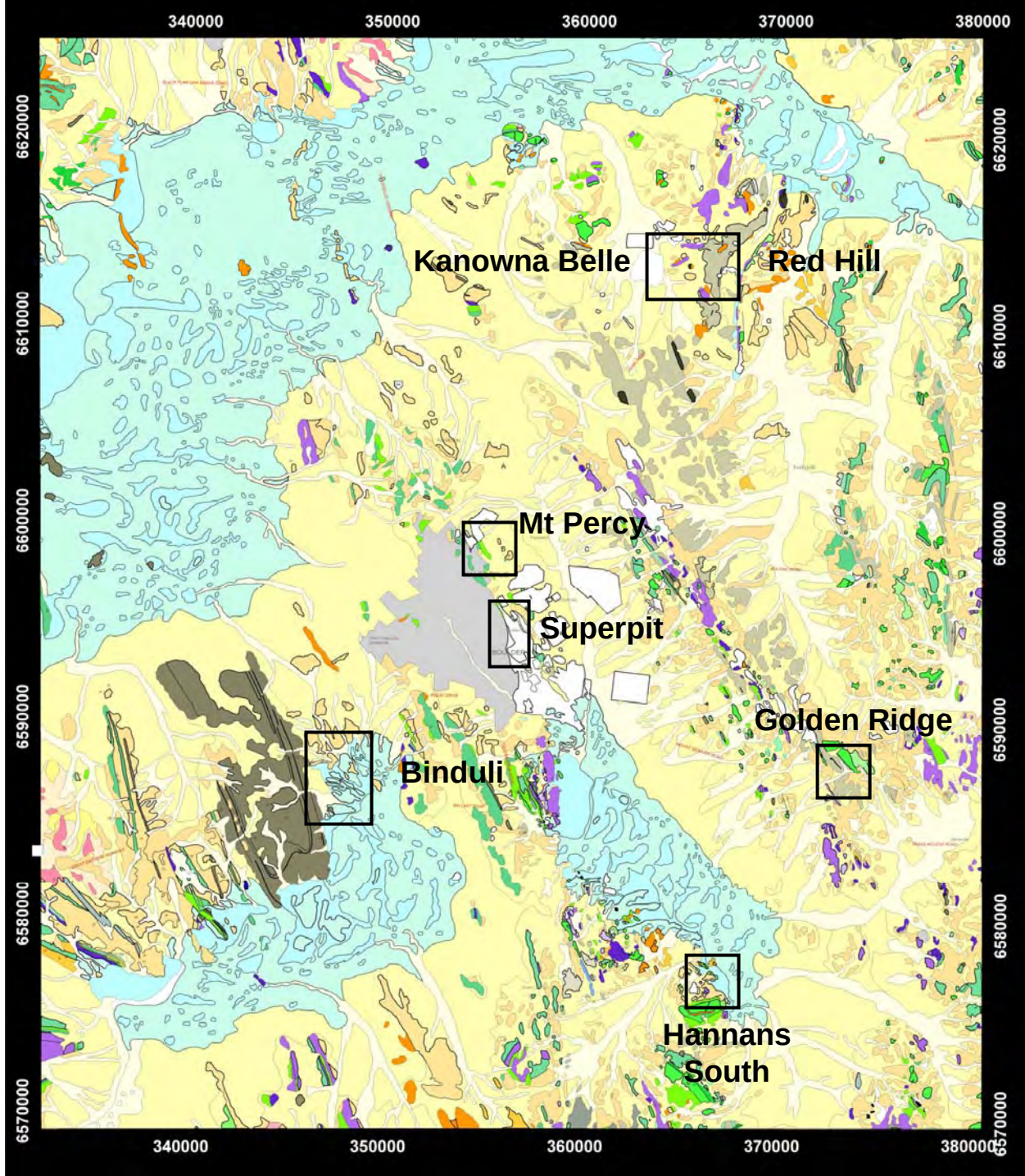


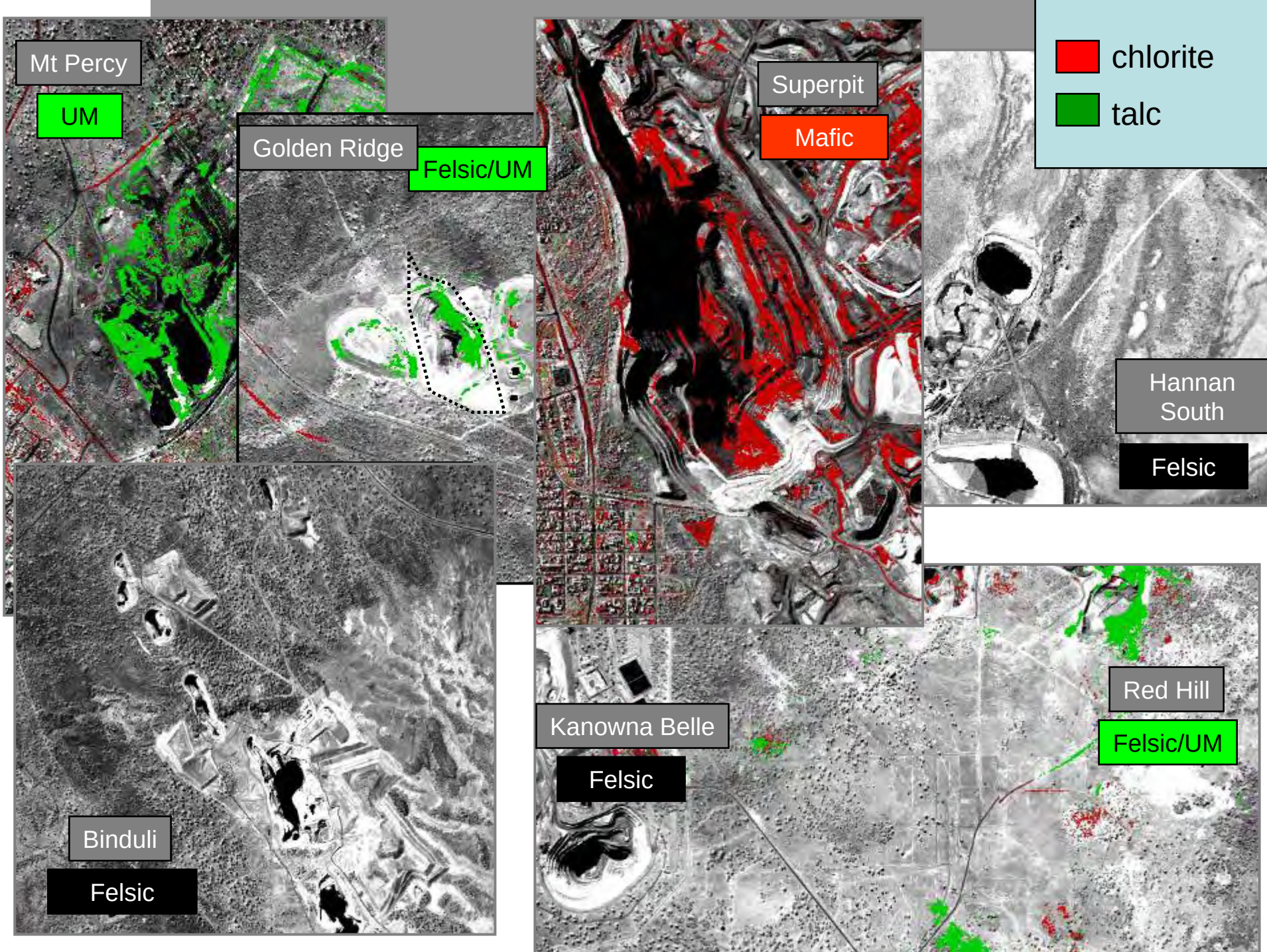


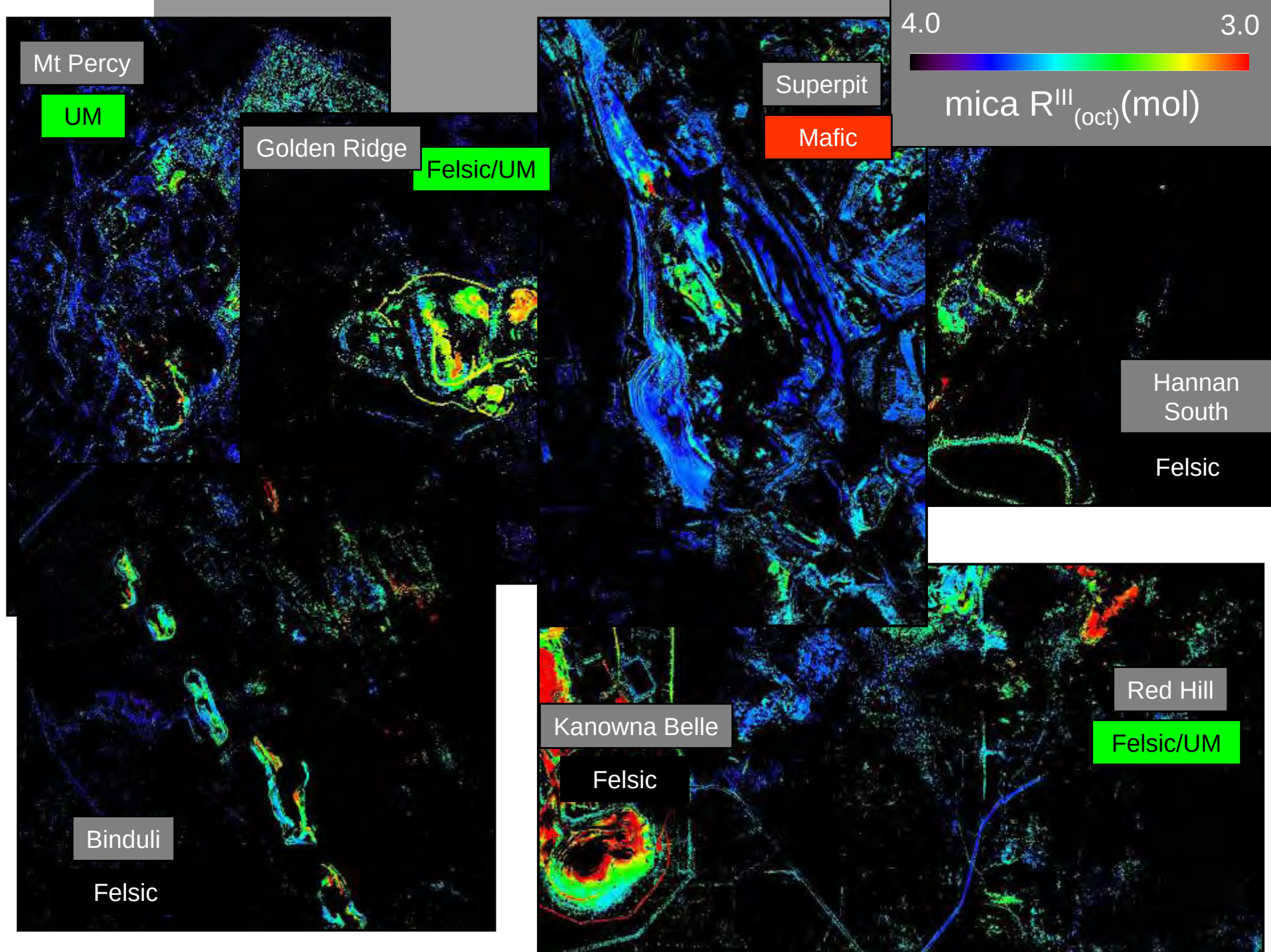
Published

Kalgoorlie-Kanowna 1:100 000 scale geology

- conglomerates
- sediments
- ultramafic rocks
- mafic rocks
- mafic rocks
- felsic volcaniclastics
- felsic volcaniclastics
- felsic intrusives




chlorite
talc
Mt Percy
UM
Golden Ridge
Felsic/UM
Superpit
Mafic
Hannan South
Felsic
Binduli
Felsic
Kanowna Belle
Felsic
Red Hill
Felsic/UM


4.0
3.0
mica $R^{III}_{(oct)}$(mol)
Mt Percy
UM
Golden Ridge
Felsic/UM
Superpit
Mafic
Hannan South
Felsic
Binduli
Felsic
Kanowna Belle
Felsic
Red Hill
Felsic/UM

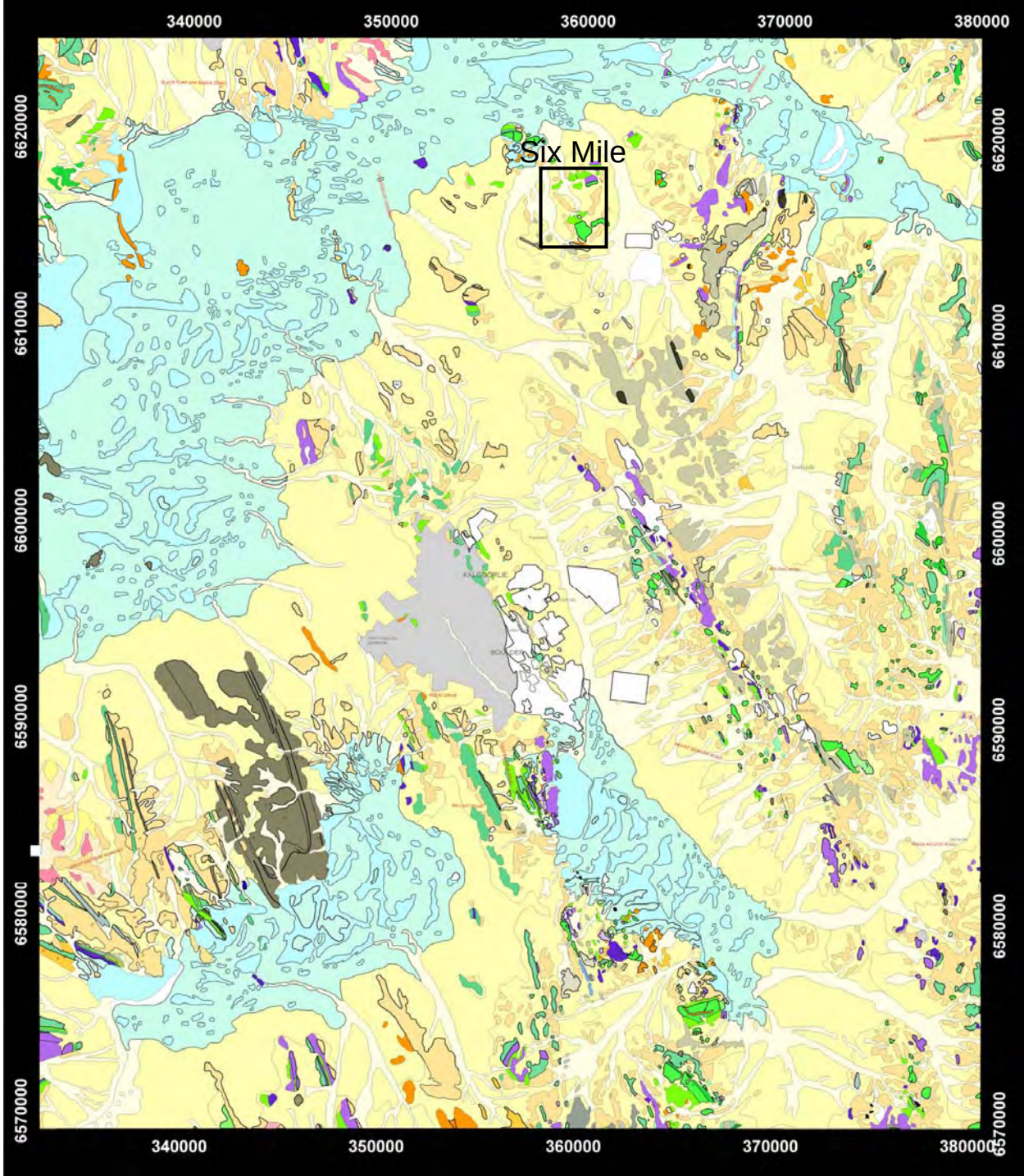
But…

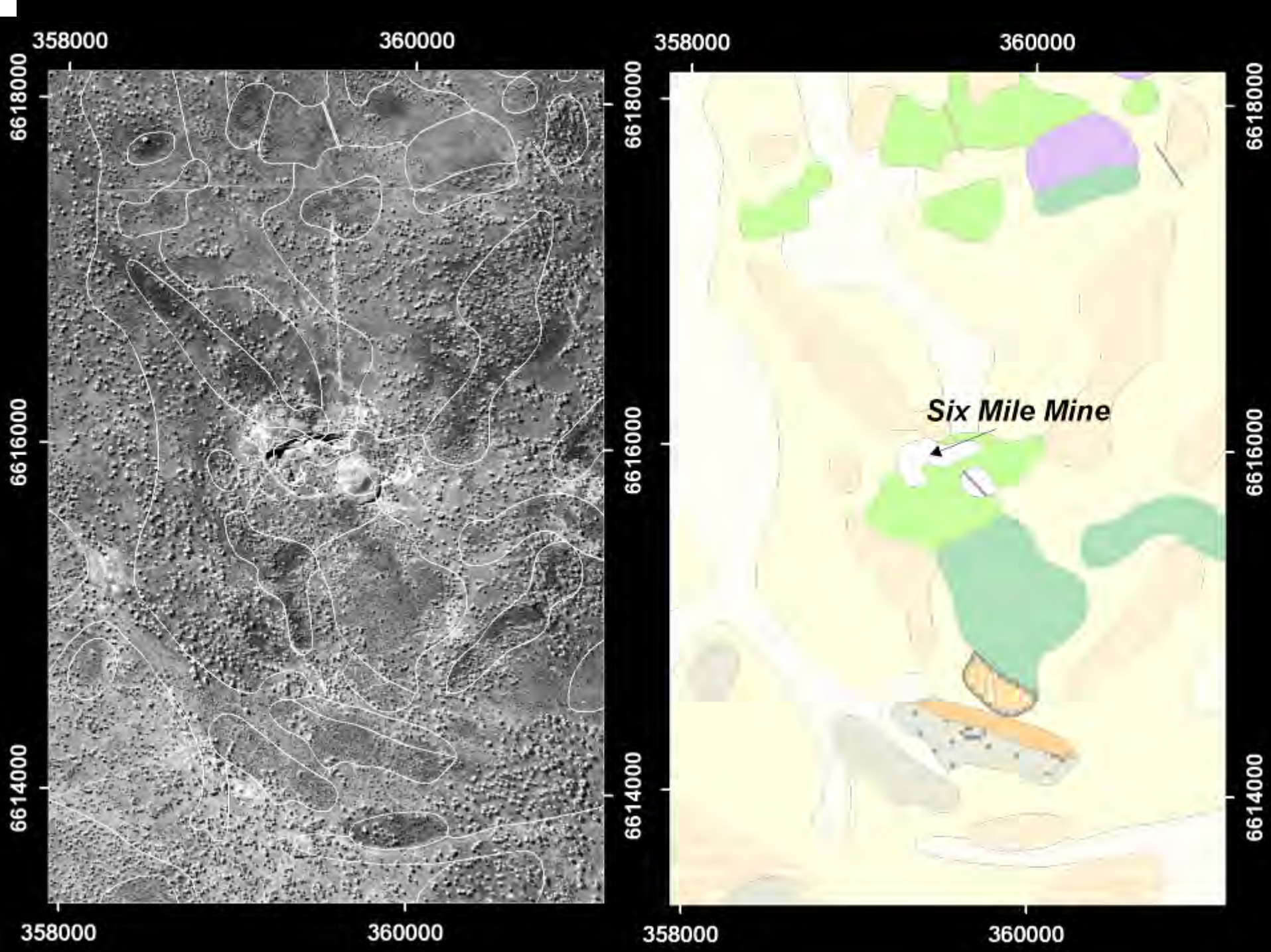
1. **Can this white mica alteration be mapped in weathered in situ materials?**
2. **Are all the Al-rich micas (blue) paragonite = hydric fluids?**
3. **If 1. and 2. are yes, then how big are the hydric fluid cells?**

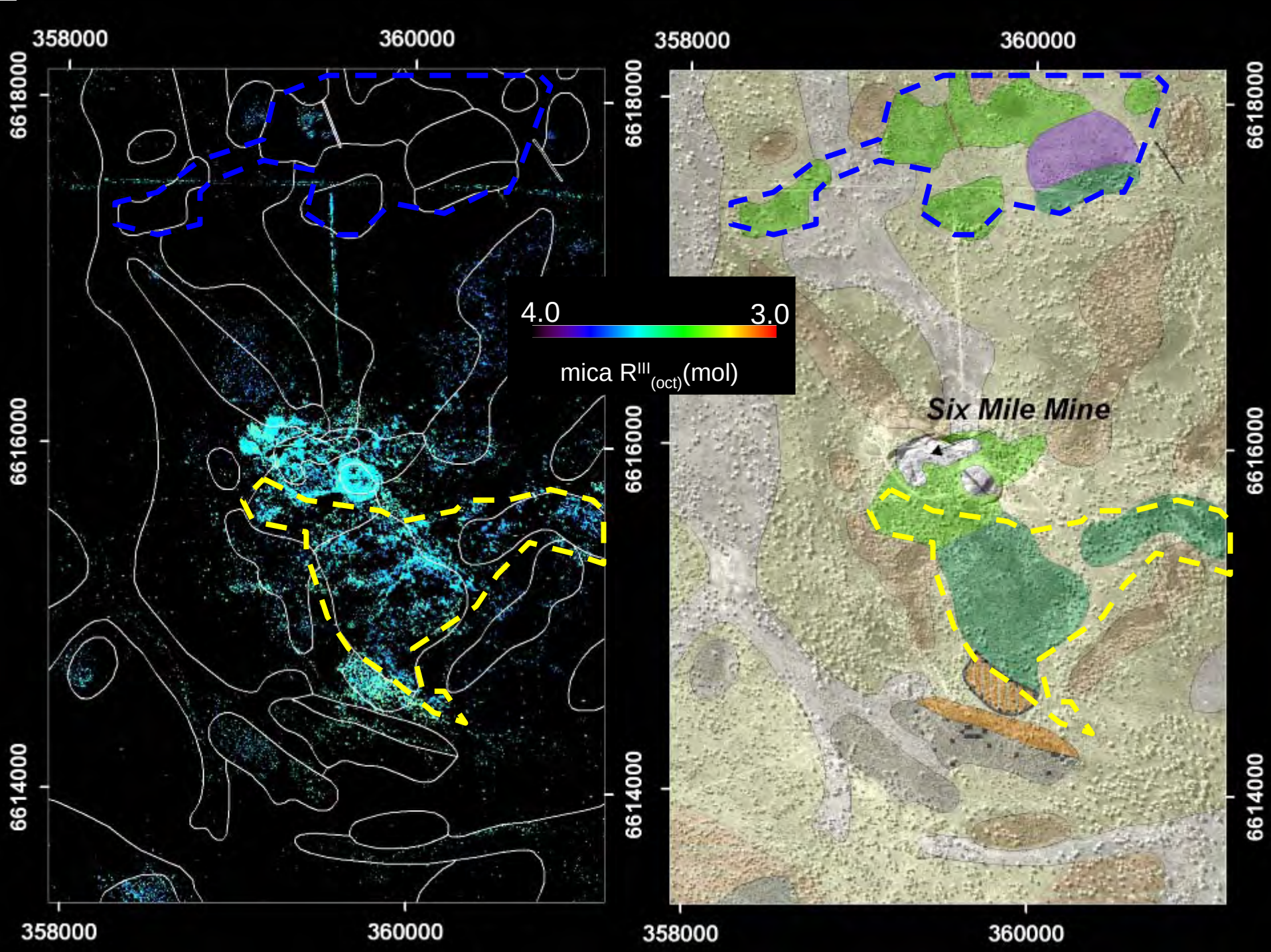
Big cells = big footprints = vectors to deep mineralisation

Mapping alteration in weathered natural exposure?

white mica in ferromagesian rocks
⇒ K metasomatism

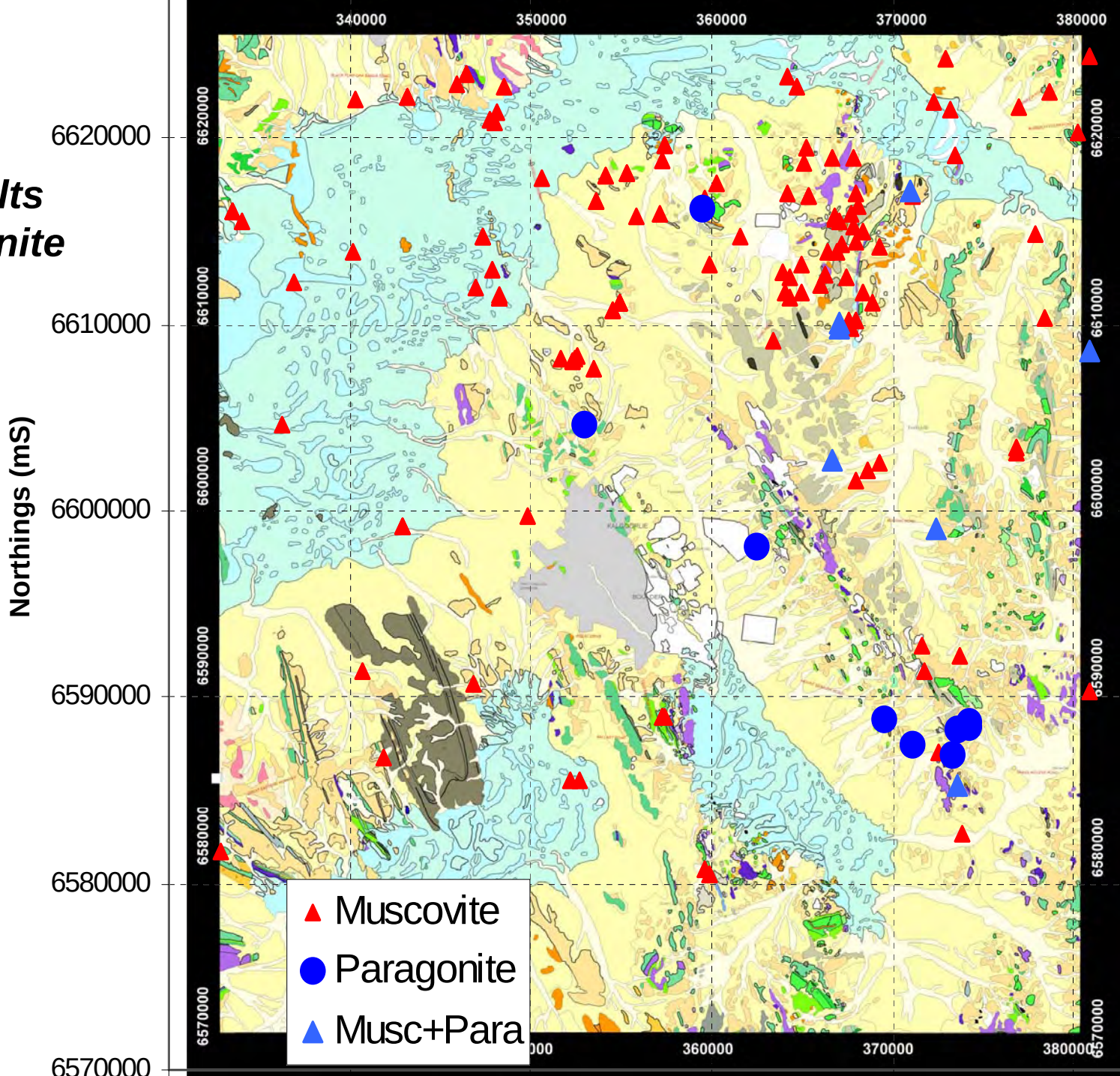



358000
360000
6618000
6616000
6614000
Six Mile Mine


358000
360000
6618000
6616000
6614000
4.0
3.0
mica R$^{III}_{(oct)}$(mol)
Six Mile Mine

CSIRO

XRD Results for Paragonite



CSIRO

HyMap

White Mica Chemistry

Kaolin-filtered

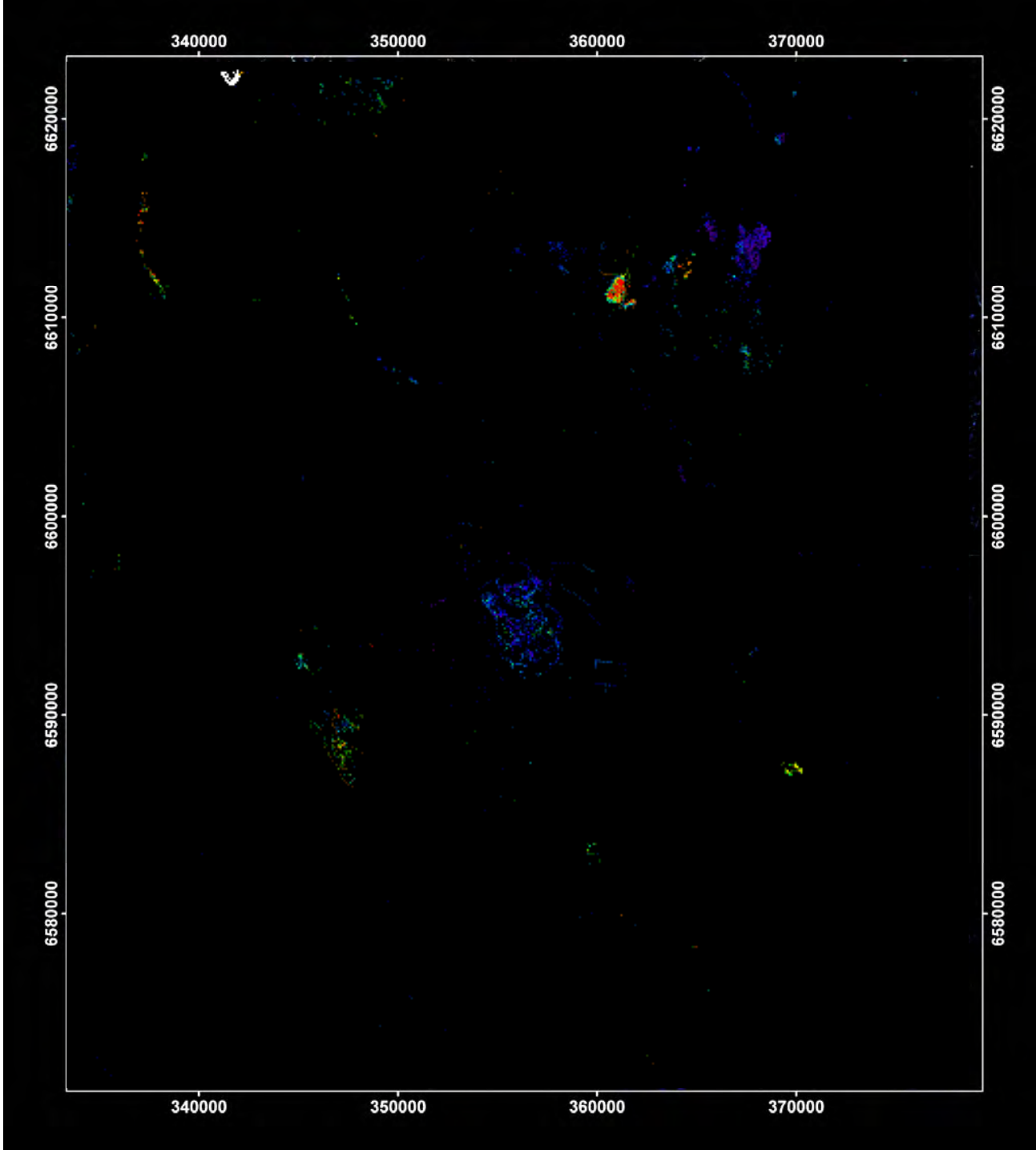
AlOH wavelength *(nm)*

- 2.185 - 2.193
- 2.193 - 2.197
- 2.198 - 2.201
- 2.202 - 2.21
- 2.211 - 2.215
- 2.216 - 2.227

white mica chemistry

4.0 3.0

mica $R^{III}_{(oct)}$(mol)



HyMap

White Mica Chemistry

No kaolin-filter

AlOH wavelength *(nm)*

- 2.185 - 2.193
- 2.193 - 2.197
- 2.198 - 2.201
- 2.202 - 2.21
- 2.211 - 2.215
- 2.216 - 2.227

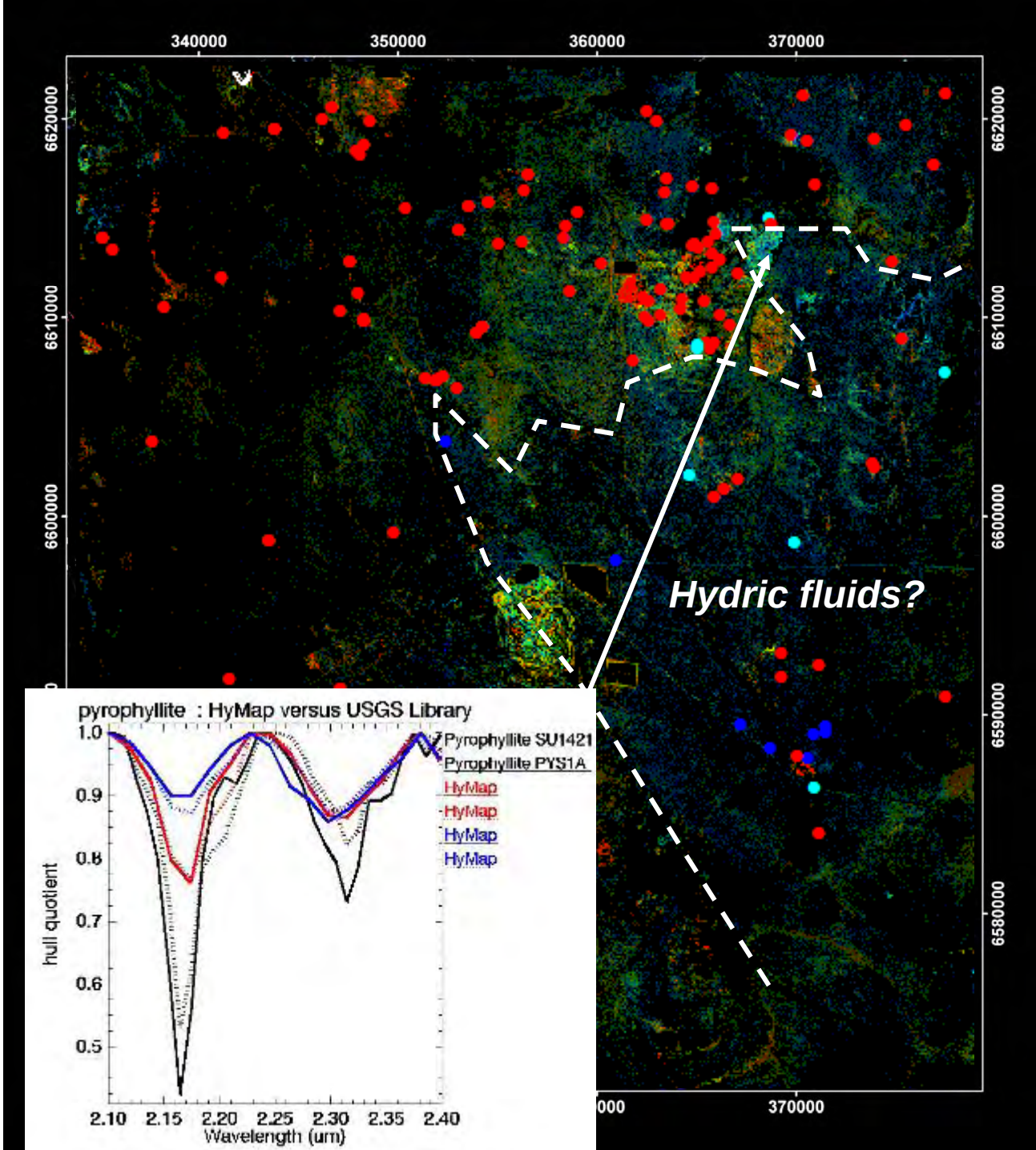
white mica chemistry

4.0 — 3.0

mica $R^{III}_{(oct)}$(mol)

Laboratory XRD

- muscovite
- paragonite+muscovite
- paragonite



CSIRO

HyMap

White Mica Chemistry

No kaolin-filter

AlOH wavelength *(nm)*

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- 2.193 - 2.197
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white mica chemistry

4.0 — 3.0

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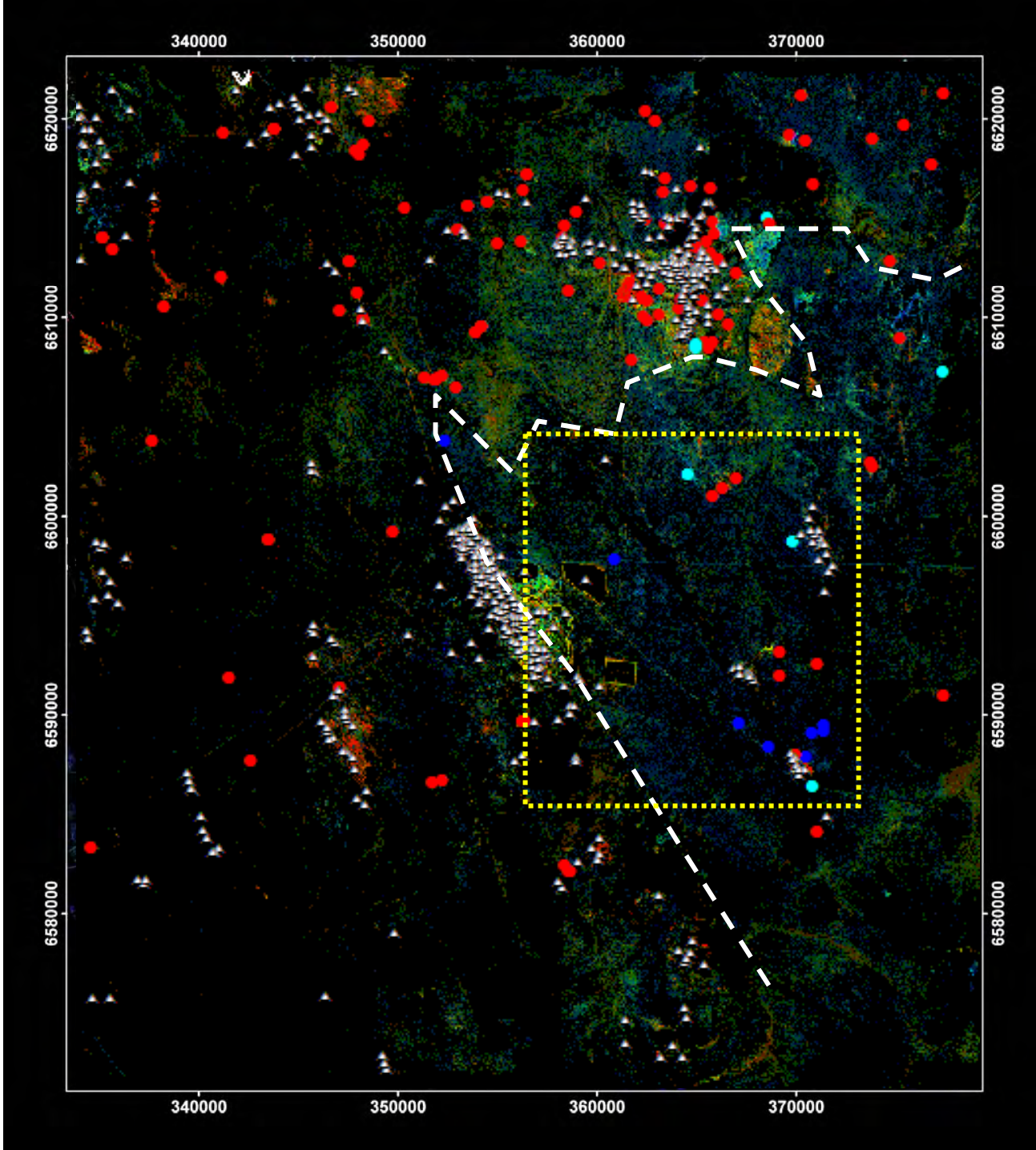
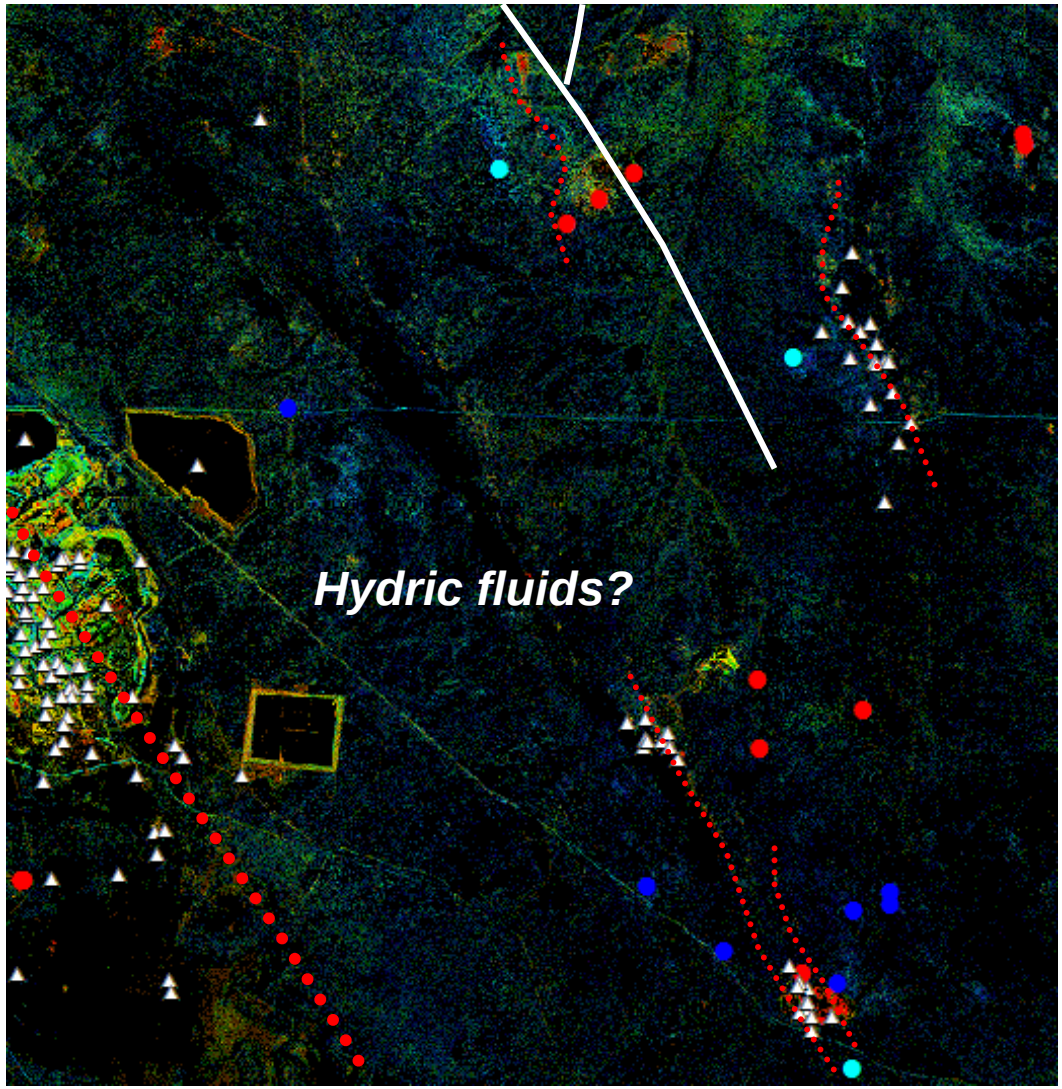
- paragonite

△ Au



East of Kalgoorlie-Boulder

no recorded mining!



Balagundi

Nimbus

Golden Ridge

white mica chemistry

4.0 3.0

mica $R^{III}_{(oct)}$(mol)

Laboratory XRD

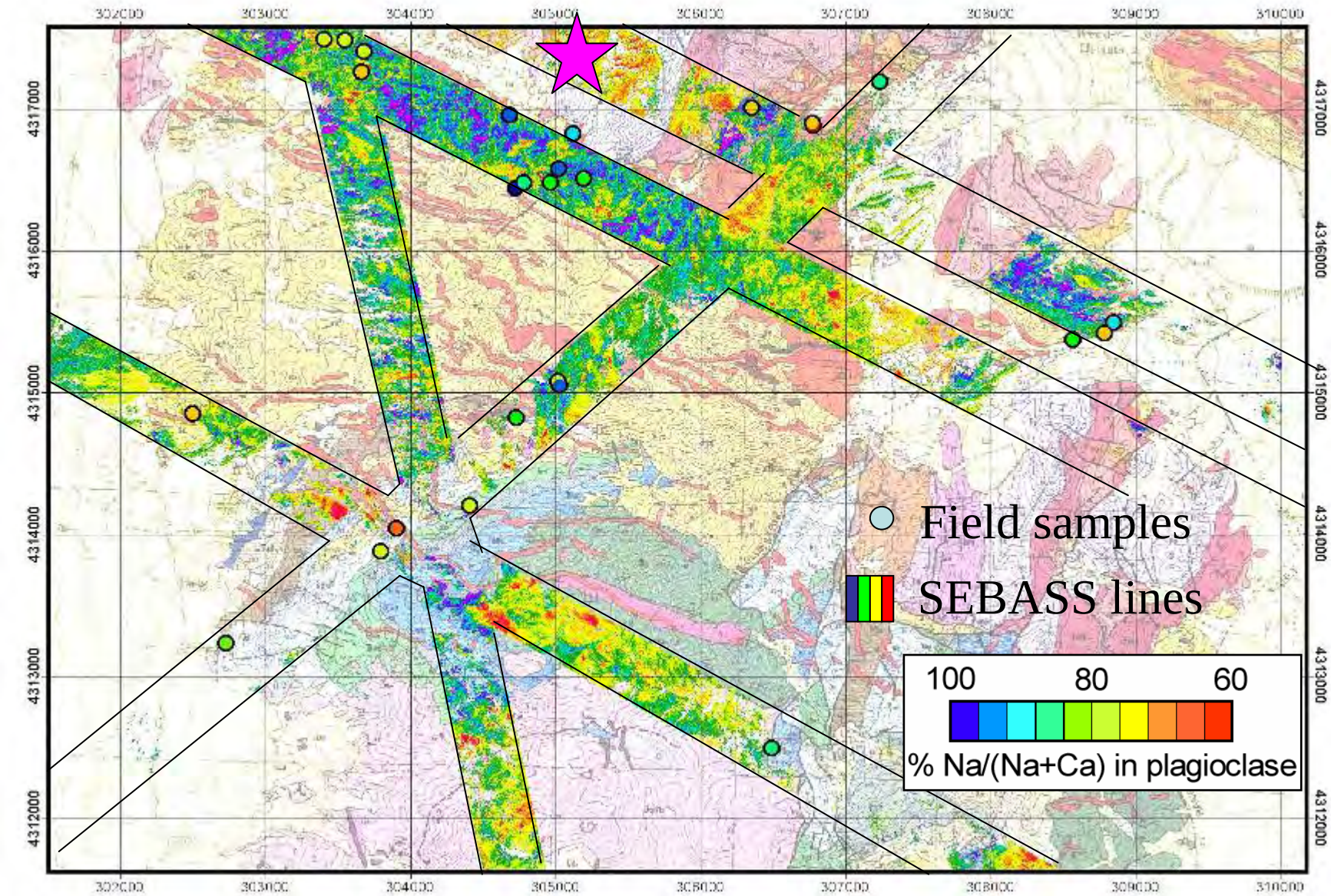
- muscovite
- paragonite+muscovite
- paragonite

△ Au

Conclusions and Closing Remarks

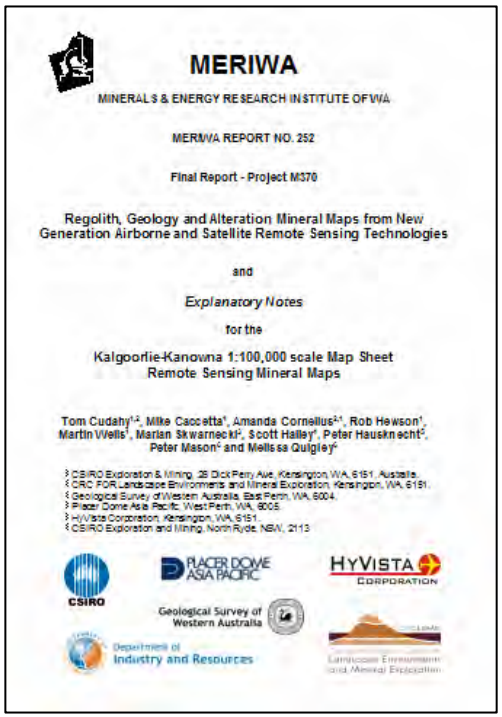
- **Accurate mapping of alteration mineralogy and mineral chemistry now achievable from airborne hyperspectral data**
- **Requires mineralogical models to unlock the value for mapping the regolith and alteration footprints**
- **Even in deeply weathered and well explored areas like Kalgoorlie, this mineral mapping technology can add value to exploration**
- **New layer of pre-competitive geoscience information is potentially available if there is industry demand**
- **Further R&D required to:**
  - extract more accurate mineralogical information from the data (~90% is thrown away) and
  - new sensors (e.g. TIR for feldspars)

Plagioclase Na-Ca Chemistry Mapping (albitisation)
Yerington Porhyry



Now Selling : M370 Project Products and HyMap surveys

Composite map (below) + 23 Mineral GIS products through the GSWA



MERIWA

MINERALS & ENERGY RESEARCH INSTITUTE OF WA

MERIWA REPORT NO. 252

Final Report - Project M370

Regolith, Geology and Alteration Mineral Maps from New Generation Airborne and Satellite Remote Sensing Technologies

and

Explanatory Notes

for the

Kalgoorlie-Kanowna 1:100,000 scale Map Sheet Remote Sensing Mineral Maps

Tom Cudahy[1,2], Mike Caccetta[1], Amanda Cornelius[2,1], Rob Hewson[1], Martin Wells[1], Marian Skwarnecki[2], Scott Halley[1], Peter Hausknecht[3], Peter Mason[3] and Melissa Quigley[2]

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[2] CRC FOR Landscape Environments and Mineral Exploration, Kensington, WA, 6151.
[3] Geological Survey of Western Australia, East Perth, WA, 6004.
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[5] HyVista Corporation, Kensington, WA, 6151.
[6] CSIRO Exploration and Mining, North Ryde, NSW, 2113

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Final Report No. 252 though MERIWA/GSWA