Trade & Investment
Resources & Energy

Keys to understanding the Central Lachlan

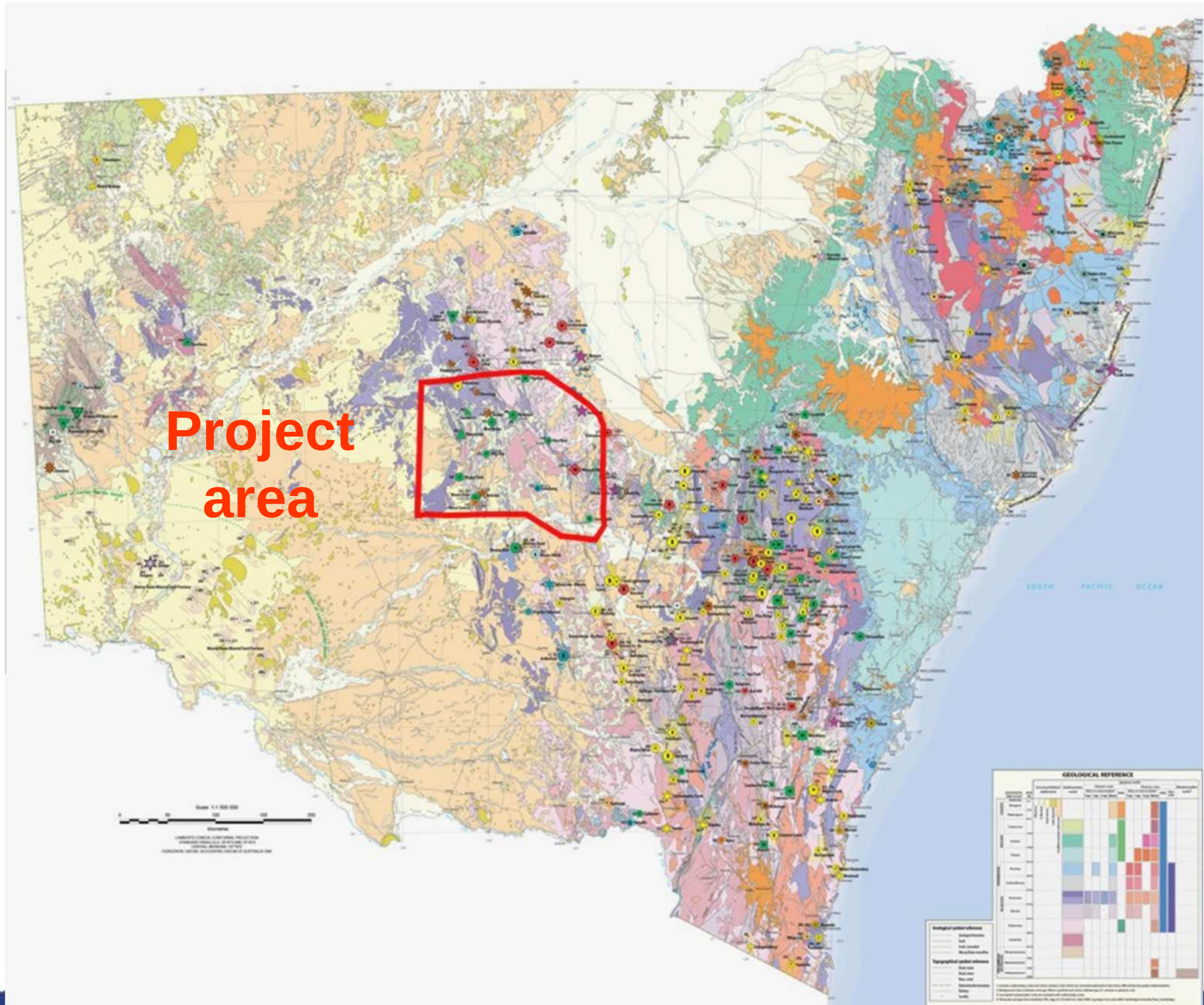
—

the Nymagee mineral systems (MinSys) study

Peter Downes & David Tilley
MinSys NSW group
Geological Survey of New South Wales

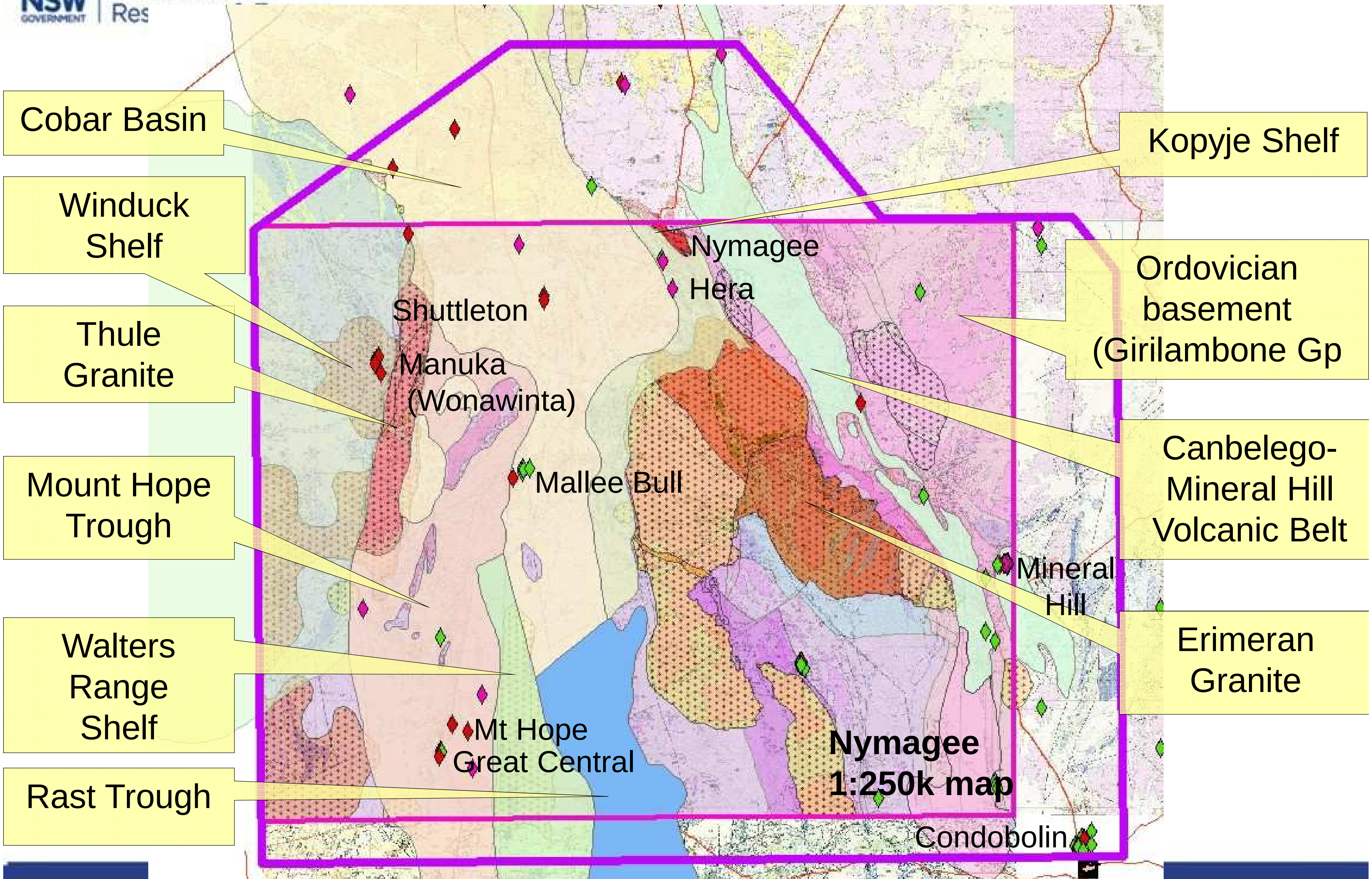
the Nymagee team

Location



Project covers the central part of the Central Lachlan

Geological setting



Project aims

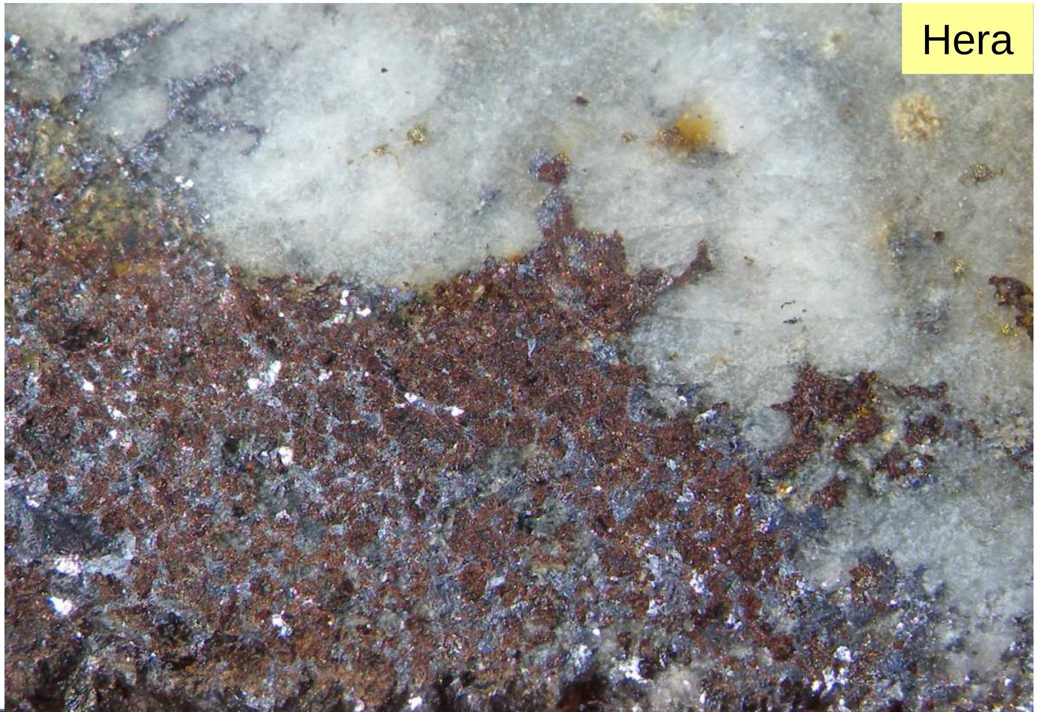
to upgrade the geological framework of the Nymagee 250k map sheet and adjacent area

to

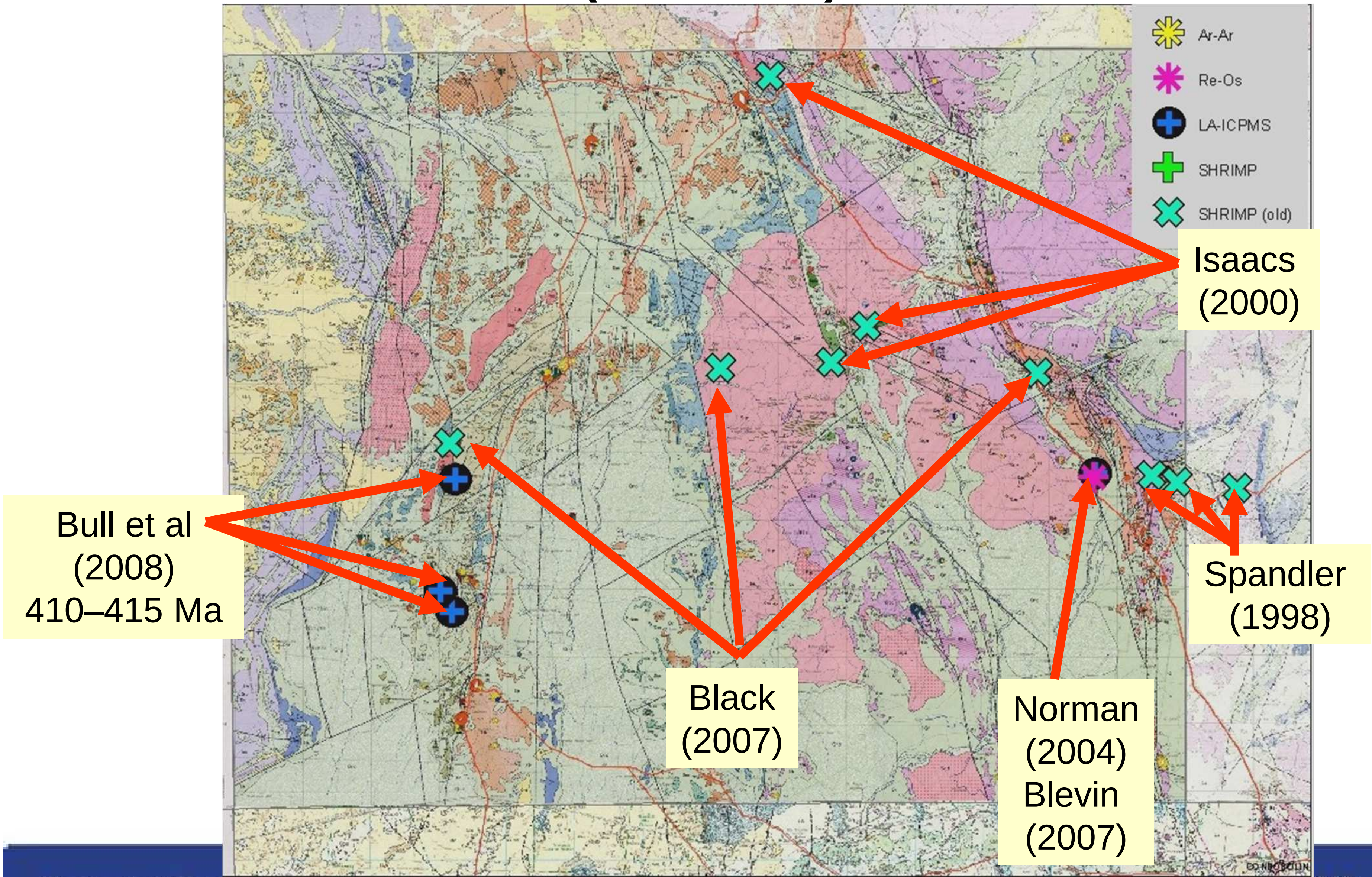
develop a better understanding of the controls to mineralisation and the prospectivity of the area

By

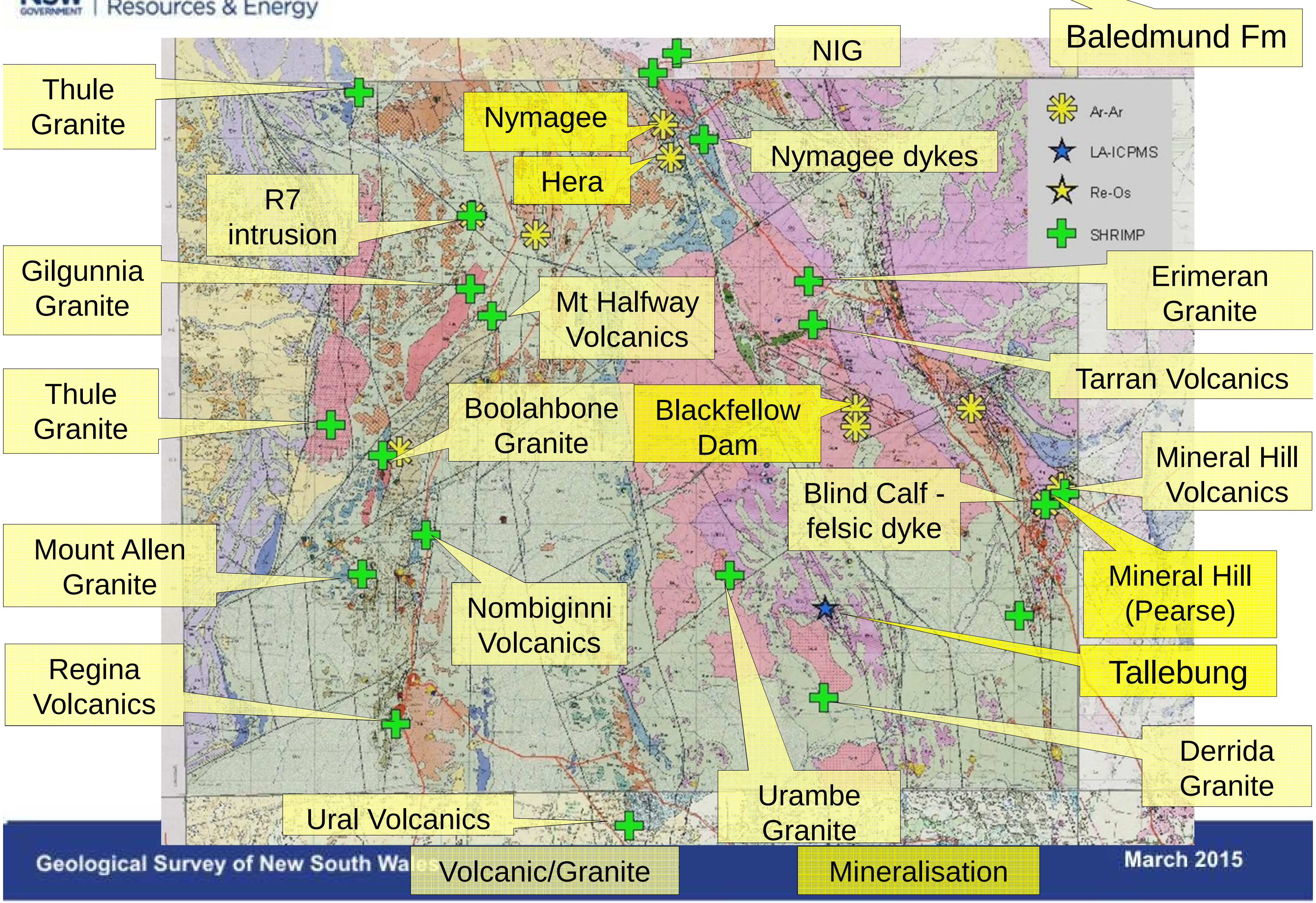
- New dating of rocks & mineralisation
- New isotope data
- Revised volcanic facies interpretation
- Updated time-space plot
- HyLogger alteration study



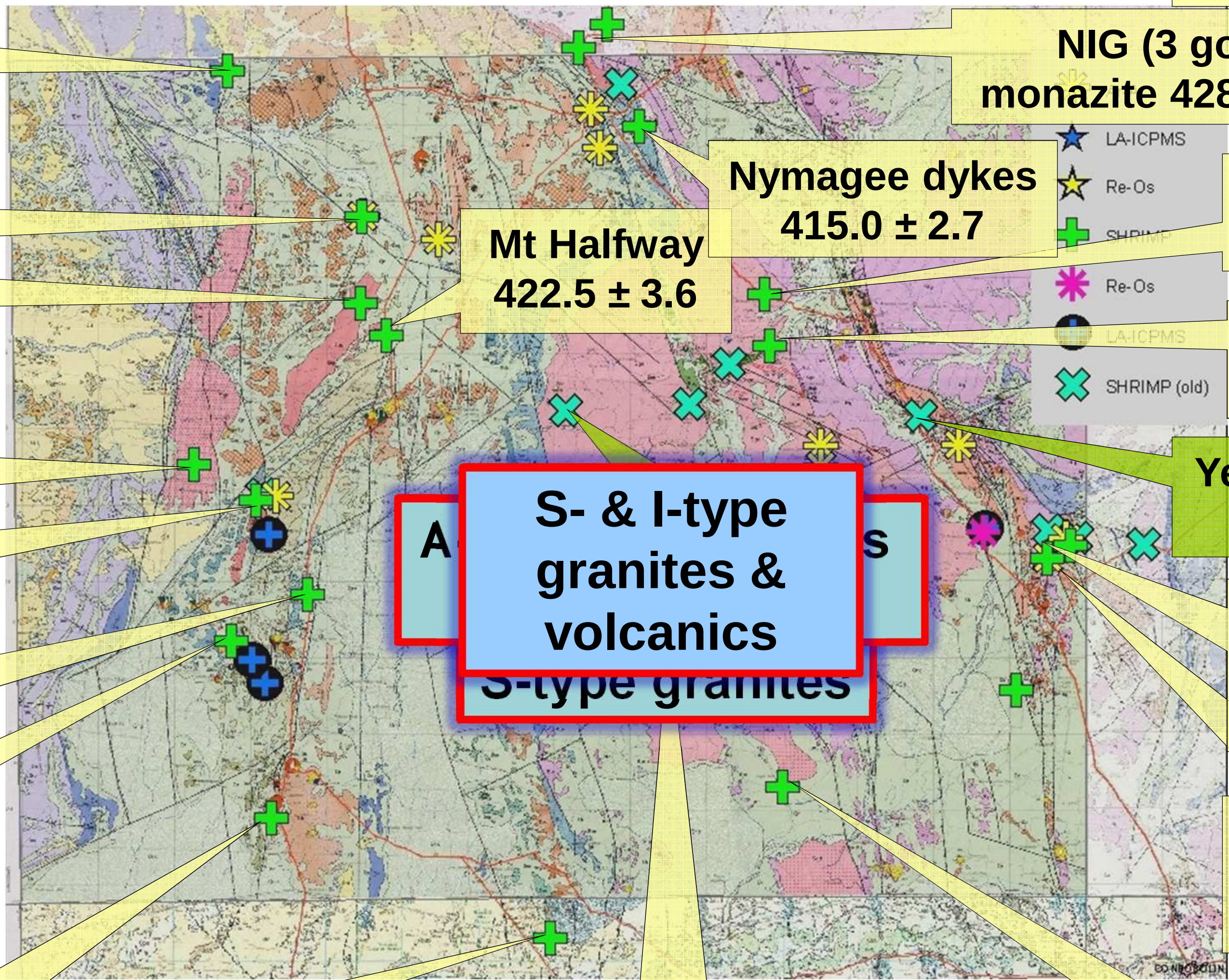
Focus — U–Pb dating
(1998-2008)



New dating


Baledmund Fm
NIG
Thule Granite
Nymagee
Nymagee dykes
Hera
R7 intrusion
Ar-Ar
LA-ICPMS
Re-Os
SHRIMP
Gilgunnia Granite
Mt Halfway Volcanics
Erimeran Granite
Tarran Volcanics
Thule Granite
Boolahbone Granite
Blackfellow Dam
Mineral Hill Volcanics
Blind Calf - felsic dyke
Mount Allen Granite
Mineral Hill (Pearse)
Nombiginni Volcanics
Tallebung
Regina Volcanics
Derrida Granite
Urambe Granite
Ural Volcanics
Volcanic/Granite
Mineralisation

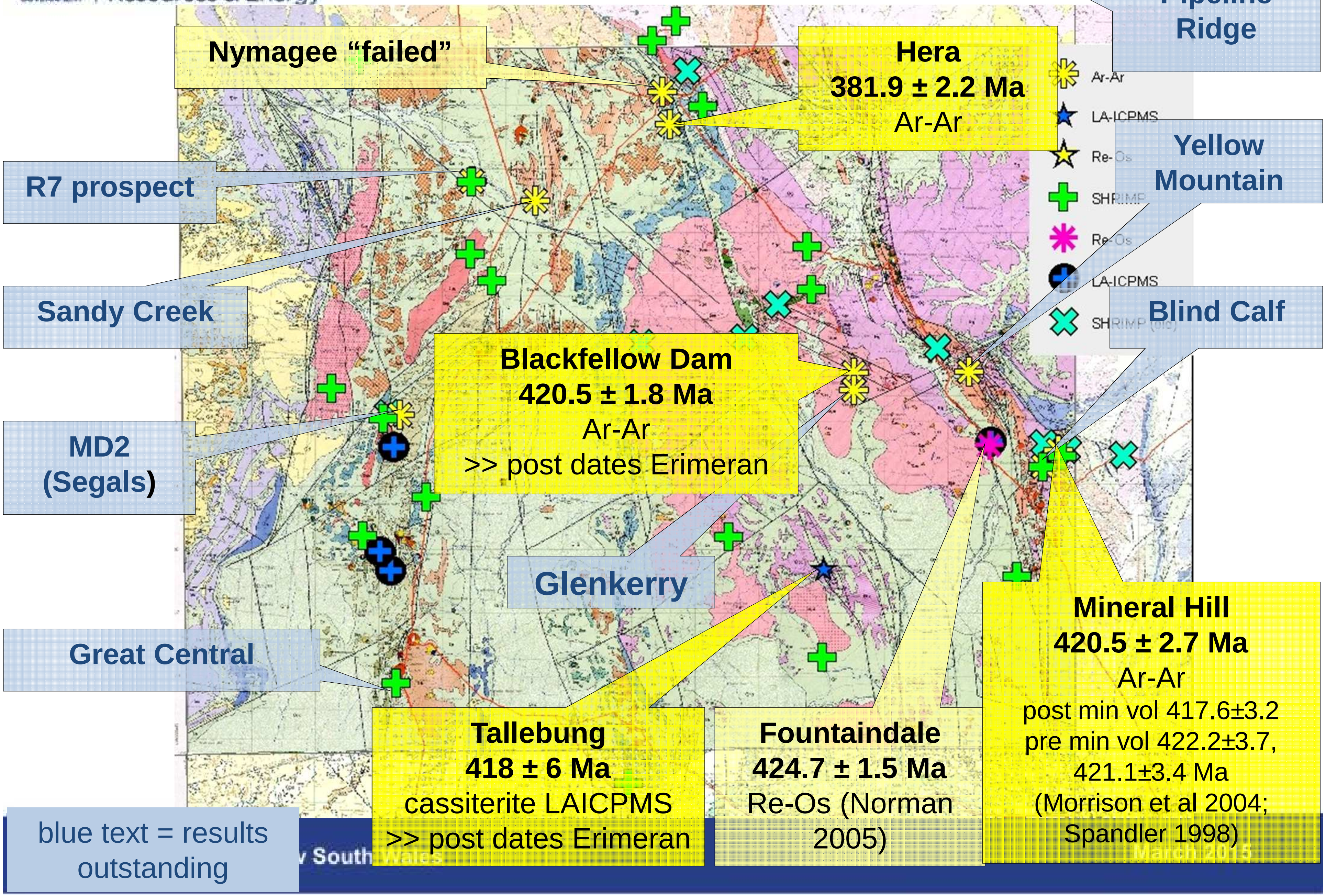
U–Pb SHRIMP dating



Present study

(Black 2007)

Dating – mineralisation



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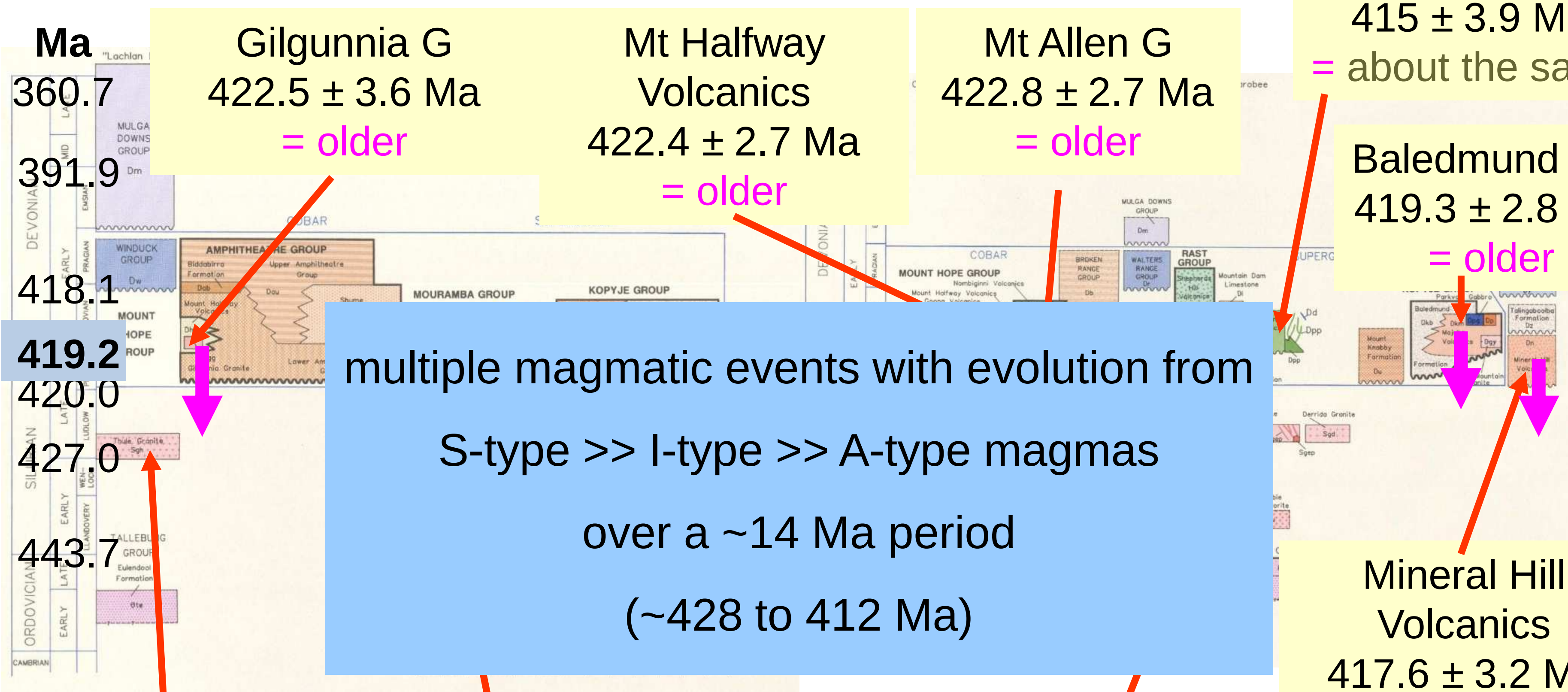
Summary — time-space



Gilgunnia G
422.5 ± 3.6 Ma
= older

Mt Halfway Volcanics
422.4 ± 2.7 Ma
= older

Mt Allen G
422.8 ± 2.7 Ma
= older

Tarran Volcanics
415 ± 3.9 Ma
= about the same

Baledmund Fm
419.3 ± 2.8 Ma
= older

multiple magmatic events with evolution from

S-type >> I-type >> A-type magmas

over a ~14 Ma period

(~428 to 412 Ma)

Thule G
425.7 ± 2.4 Ma
= about the same

Nymagee Igneous Complex
3 deformations
= ???older

Boolahbone G
415.8 ± 3.1 Ma
= younger

Erimeran G
424 ± 2.6 Ma
& Derrida G
426.3 ± 3.3 Ma
= about the same

Mineral Hill Volcanics
417.6 ± 3.2 Ma
Morrison et al (2004) & Spandler (1998)
428.2 ± 3.9
to 421.1 ± 3.4 Ma
= younger but not yet resolved

Note - 419.2 Ma = Silurian-Devonian boundary

Dating — summary

- Latest Silurian magmatic event >>> epithermal (Mineral Hill) & intrusion-related mineralisation (Blackfellow Dam)
  - timing of mineralisation same as Tara, Holbrook etc in Central Lachlan
  - coincident with volcanism and VAMS mineralisation in the Hill End Trough & Goulburn Basin (e.g. Lewis Ponds, Woodlawn etc)
- Timing of mineralisation at Hera correlates with Tabberabberan Orogeny >> same time as other orogenic Au-base metal deposits

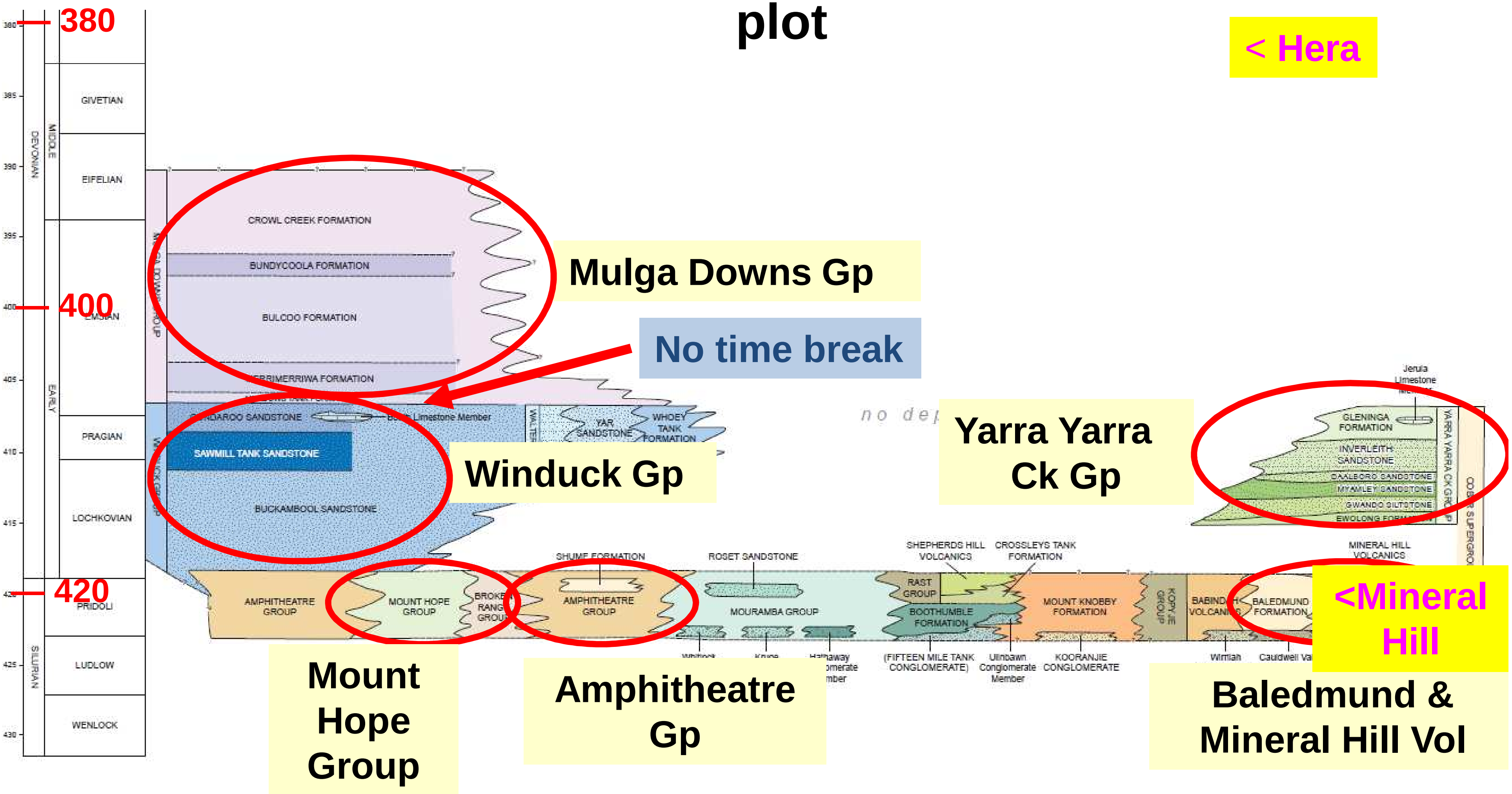
The new dating led us to ask Lawrie Sherwin to review the fossil controls to the Nymagee stratigraphy

Lawrie Sherwin

Palaeontology

- Windeck Gp is no younger than Pragian–Emsian with base of the Mulga Downs Gp of similar age — ie Mulga Downs Gp is conformable.
  - fish fossils of late Early Devonian to ?early Middle Devonian age (*Wuttagoonaspis)* in lower part of the Mulga Downs Gp.
  - The upper age limit of the Mulga Downs uncertain but ? late Eifelan.
- Mineral Hill Volcanics — very late Silurian (late Ludlow-Pridoli) — good agreement with SHRIMP dating.
- Cocoparra Group — Early to ?Middle Devonian

Revised time–space plot



Paleontology supports SHRIMP dating for R7 granite, Mineral Hill Volcanics, Mount Halfway Volcanics, Gilgunnia Granite etc

Cobar deformation

Timing of deformation in the Cobar area defined by the time-break between Mulga Downs & Winduck gps (Glen et al 1992).

- Supported by whole rock Ar-Ar and K-Ar dating on samples from high strain zones at Cobar**, but detrital micas are present**.
- Suggested deformation occurred around 395 to 400 Ma with a near complete rejuvenation of detrital micas
- Suggested deformation in western part of basin is Carboniferous

These data are interpreted as reflecting a low-grade cleavage-forming inversion event which took place at ca. 395–400 Ma. Isotopic data from Zone 1 suggest (near) complete rejuvenation of detrital phases during the 395–400 Ma event. In

Only whole-rock ages were determined in this study because it was not possible to obtain concentrates of metamorphic cleavage micas which were uncontaminated by ground-up detrital micas.

Quotes from Glen et al (1992)

Cobar deformation

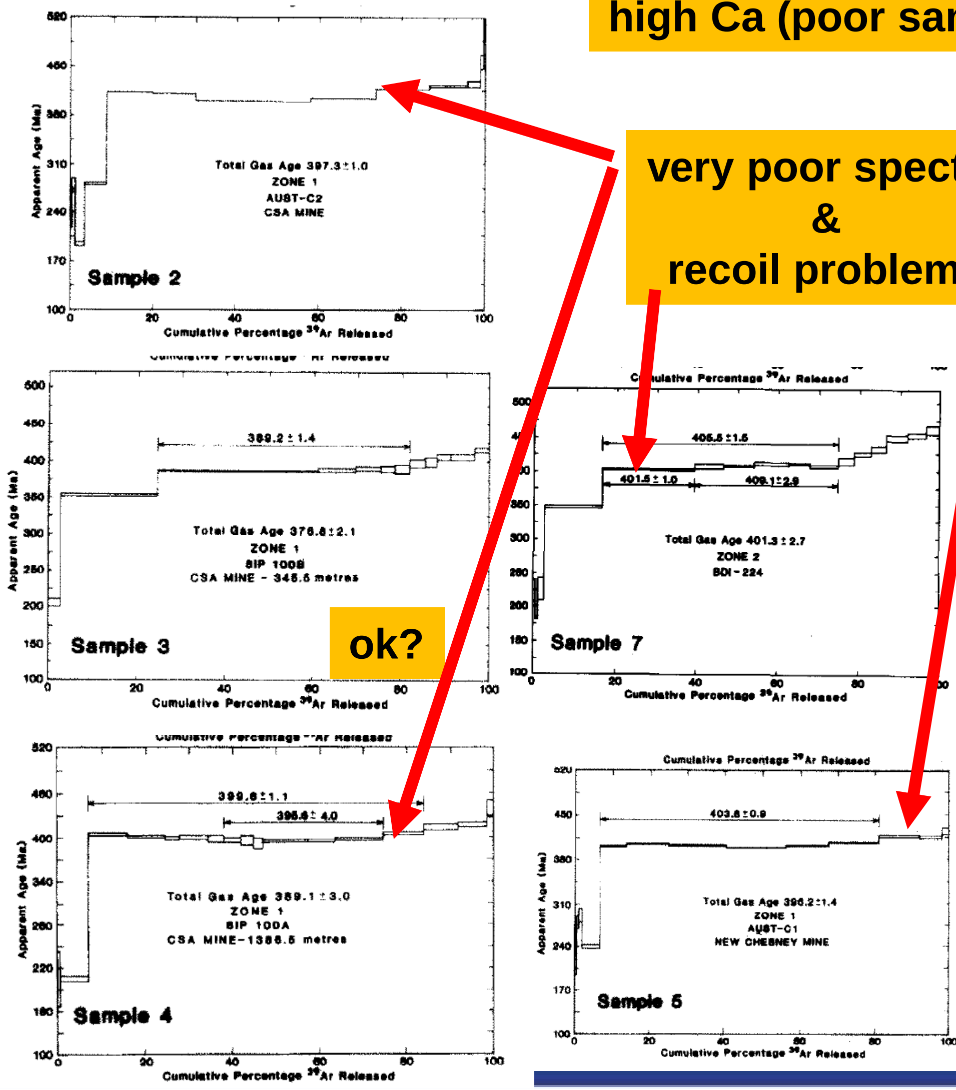
Glen et al (1992)

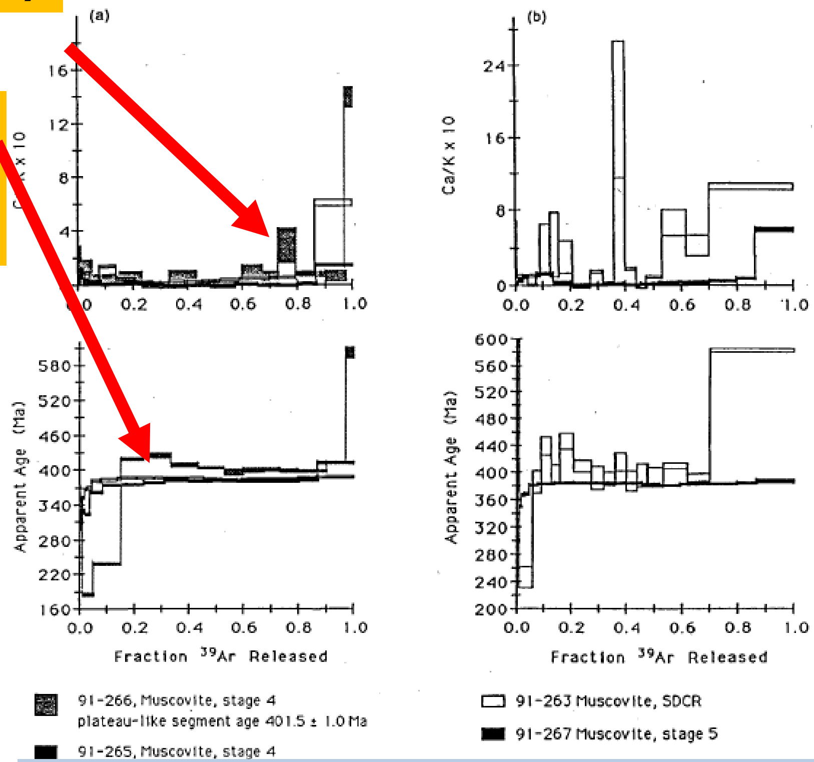
Perkins et al (1994)

high Ca (poor sample)

very poor spectra & recoil problems

ok?





Notes - Reset T for muscovite ~375ºC
Fluid inclusion CSA - `300°C
Elura 298-354°C (320°C)
Peak met 221-310°C (276°C), min 270-370°C

Cobar deformation

and

- field checking & fossil data — no apparent time-break.
- Mulga Downs Gp is pre-major deformation (same as Winduck Gp).
- Metamorphic grade = lower greenschist <<300°C (max)
- Pragian–Emsian boundary now ~407.6 ± 2.6 Ma (ICS chart v2013/01).
- **Hera** — **381.9 ± 2.2** Ma.
- **Elura** — **386.2± 2.0 to 388.8 ± 1.6** Ma (Sun et al 2000).
- **Peak** alteration — **384.0 ± 1.4** Ma (Perkins et al 1994)

Implications for the Cobar deformation

Based on the available data

deformation in the Cobar Basin

is not a separate event in the Early Devonian

but

part of the

<u>Middle Devonian Tabberabberan Orogeny</u>

i.e. high sulfide “Cobar-type” deposits

(Peak, Hera etc) formed during the

Middle Devonian Tabberabberan Orogeny

Other studies

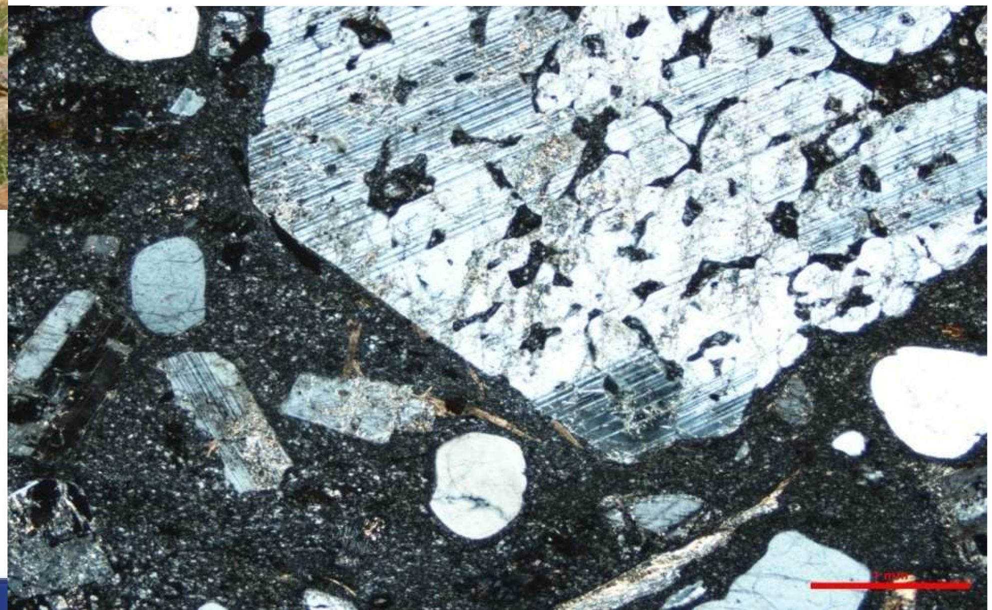
Larson

- Mount Hope Group
- HyLogger
- Isotopes
  - S
  - Pb

Volcanic facies study
— Mount Hope Group —

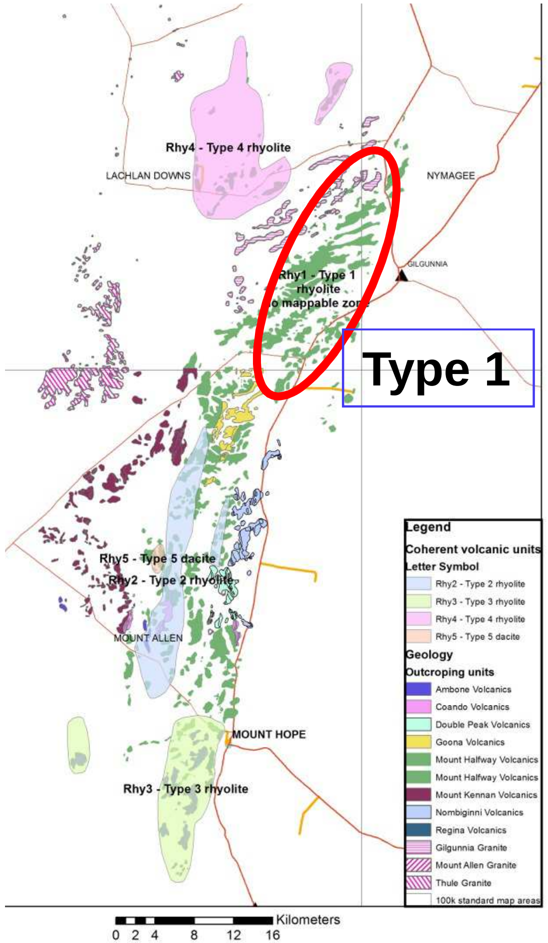
Looking at:

- volcanic facies
- unit/facies correlation
- depositional environment
- volcanic centres



Study based on thin sections from previous GSNSW projects

Mount Halfway Volcanics
— coherent rhyolite lavas —



6 lava types recognised

(based on phenocryst type & proportion, grainsize, textures, geographic distribution etc)

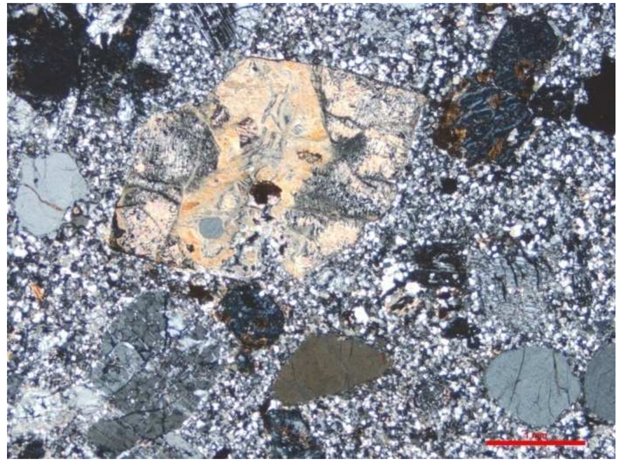
Type 1

•crystal-rich rhyolite; >35% plag+qtz + replaced mafics ± kspar

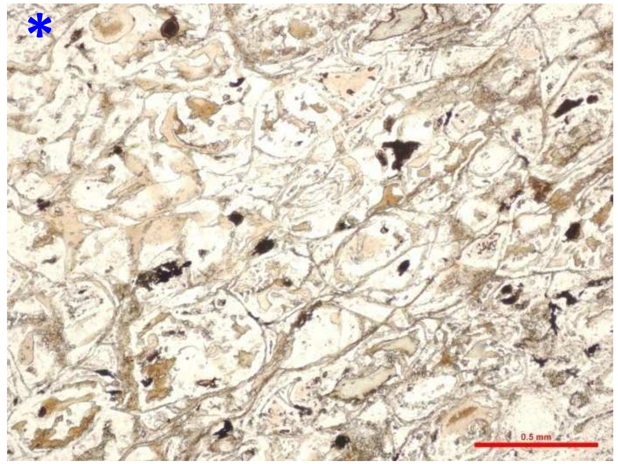
•possibly the oldest of the more extensive lava units

•microspherulitic or perlitic groundmass

•associated with volcaniclastic rocks

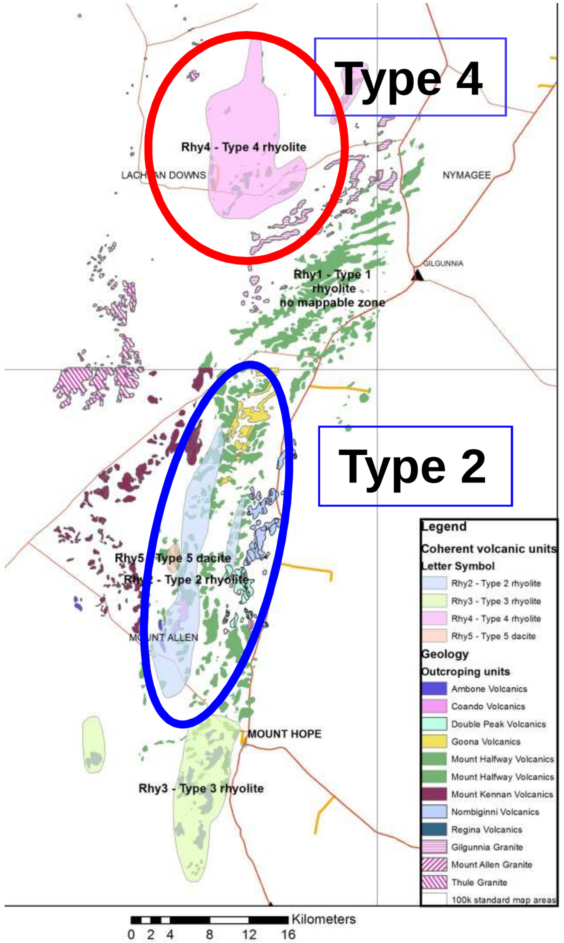


? replaced fayalite



perlitic groundmass

Mount Halfway Volcanics
— coherent rhyolite lavas —

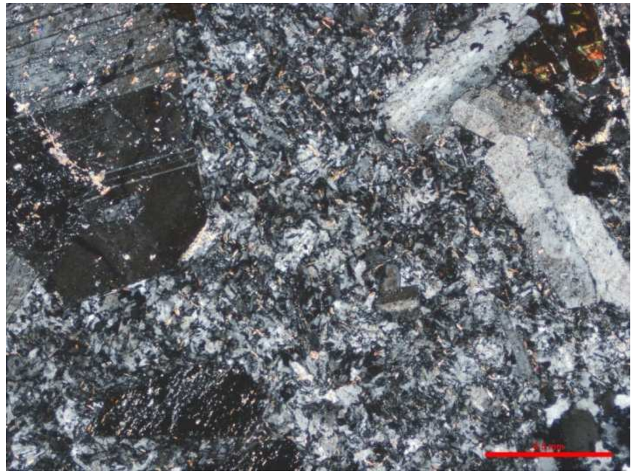


Type 2

- less crystal-rich <25% phenocrysts: plag + qtz + Ksp
- remarkably uniform
- slowly cooled groundmass
- extensive sill/lava pile

Type 4

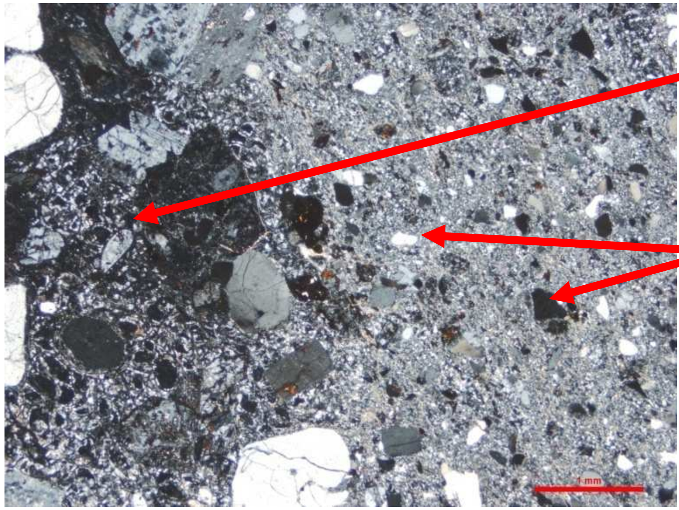
- very uniform
- crystal-rich >35% phenocrysts, characterised by fresh biotite
- micropoikilitic/granophyric groundmass
- extensive lava flow/sill?



Type 2

Type 4

Mount Halfway Volcanics
— volcaniclastic rocks —

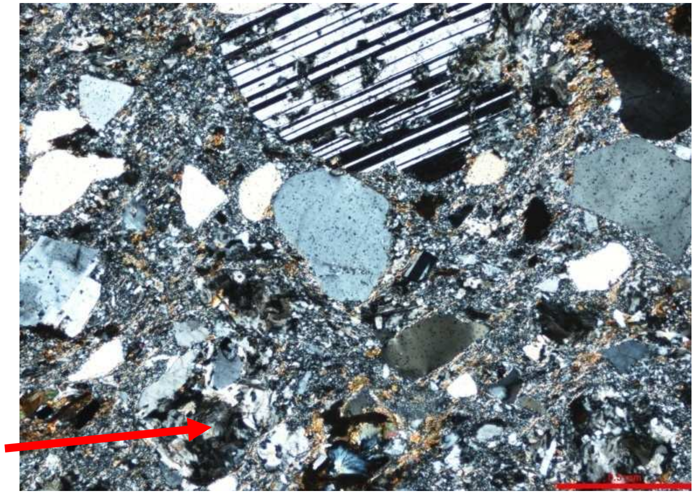


Volcanic lithic breccia/sandstone

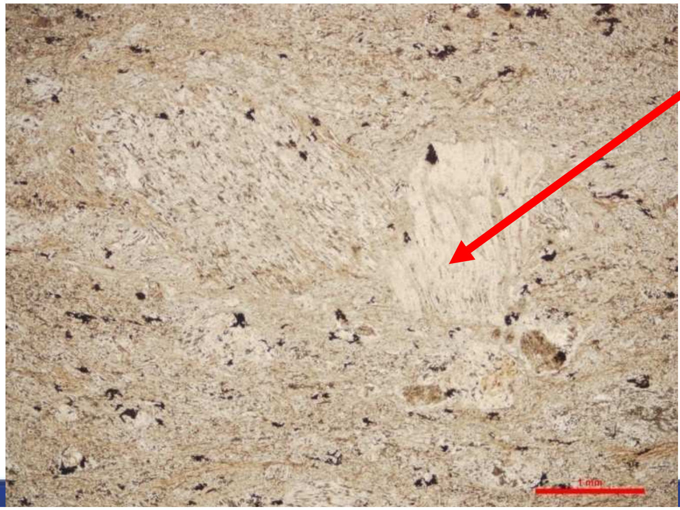
Large perlitic rhyolite clasts

Angular crystals in matrix

Individual 'glass pearls'



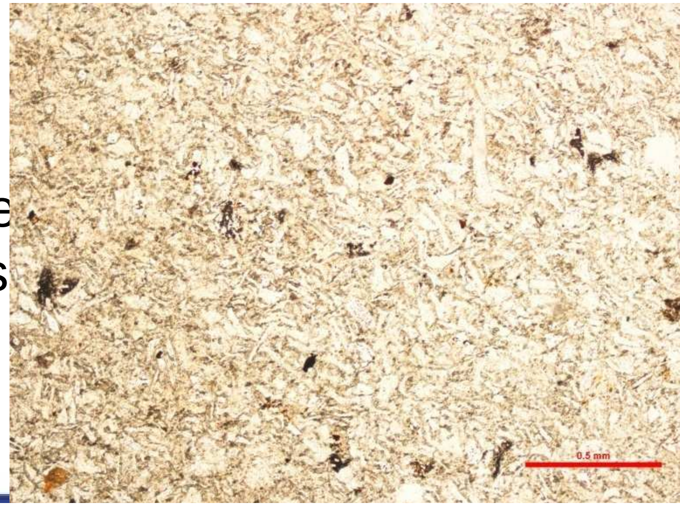
Crystal-vitric volcanic sandstone



Collapsed vesicles

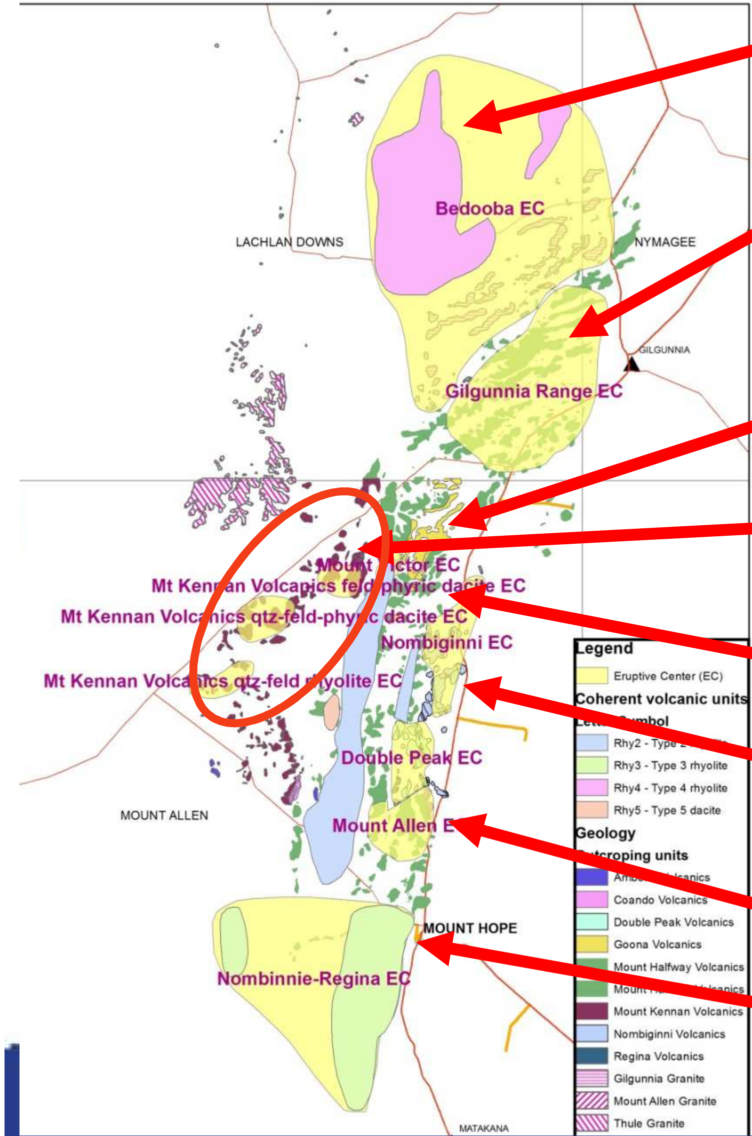
Pumiceous breccia/sandstone

Volcanic sandstone and vitric-rich units form potential marker horizons



Shard-rich vitric volcanic mudstone

Mount Hope Group
— Eruptive centers —



- Bedooba EC — Type 4 rhyolites >> composition similar to Gilgunnia G
- Gilgunnia Range EC — inc. Type 1 rhyolite lava flows and possible sills >> includes explosive volcanism
- Mount Victor EC — complex interplay of coherent & volcaniclastic facies (?Type 2)
- Three possible lava-dominated EC associated with the Mount Kennan Vol
- Nombiginni EC — dacitic!
- Double Peak EC — predominantly rhyolite and dacite lava.
- Mount Allen EC.
- Nombinnie-Regina EC — Type 3 rhyolite

Mount Hope Group
— summary —

Lavas

- small to extensive flows on basin floor
- abundant evidence of interaction with water (i.e. marginal breccias, perlite etc)
- high-temperature mineralogy >> ?fayalite

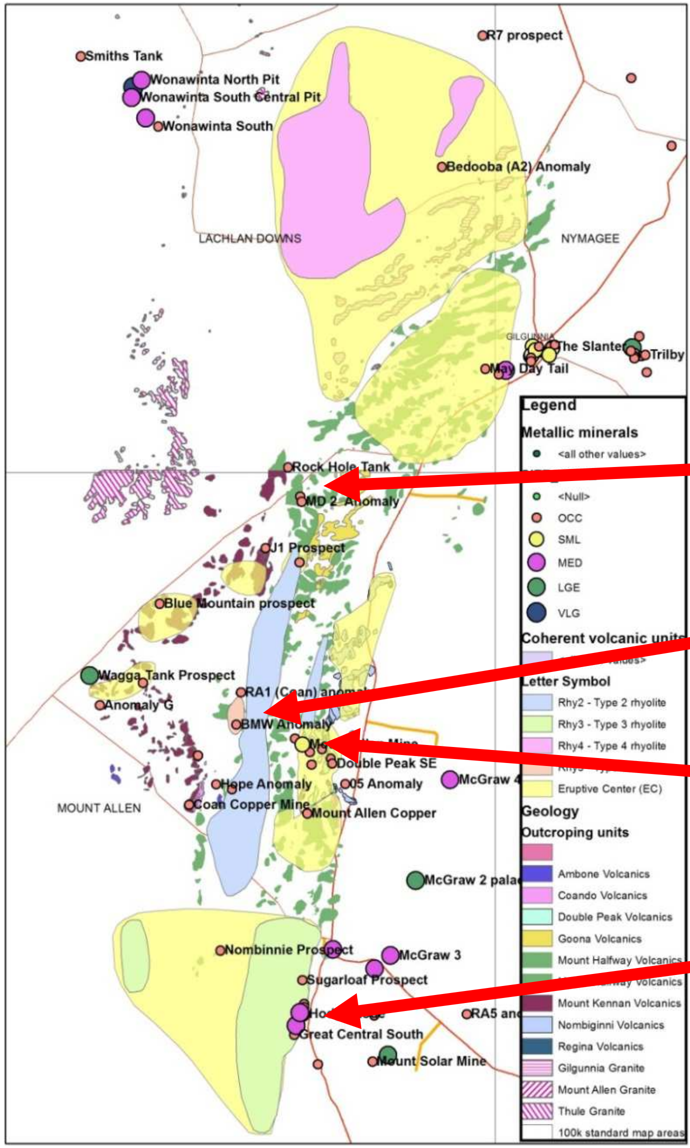
Volcaniclastic rocks

- no evidence of welding or high T emplacement
- cold-state high-particle concentration and dilute mass flows
- mostly unmodified pyroclastic components
- contain abundant shattered ex-glassy particles

Environment

- sub-wave base setting
- suggestions of both complex lava/explosive volcanic centres and lava-dominated piles

Mount Hope Group
— implications for exploration —



Siegals –MD2

BMW

Mount Allen Au

Great Central

- Mineralisation has close spatial association with specific EC/lava types

- Volcanic stratigraphy too complex
  - Goona, Ambone & Regina volcs >> part of the Mt Halfway Volcanics
  - Nonbiginni & Mt Kennan units should remain separate
  - insufficient data for Coando Vol

NSW NOW The new state of business

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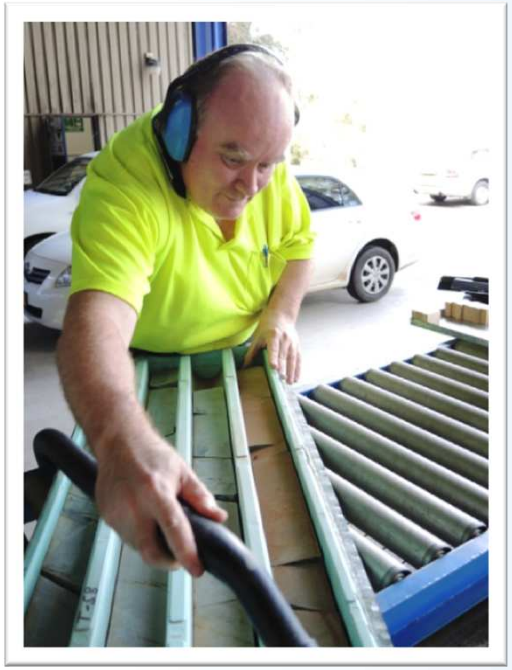
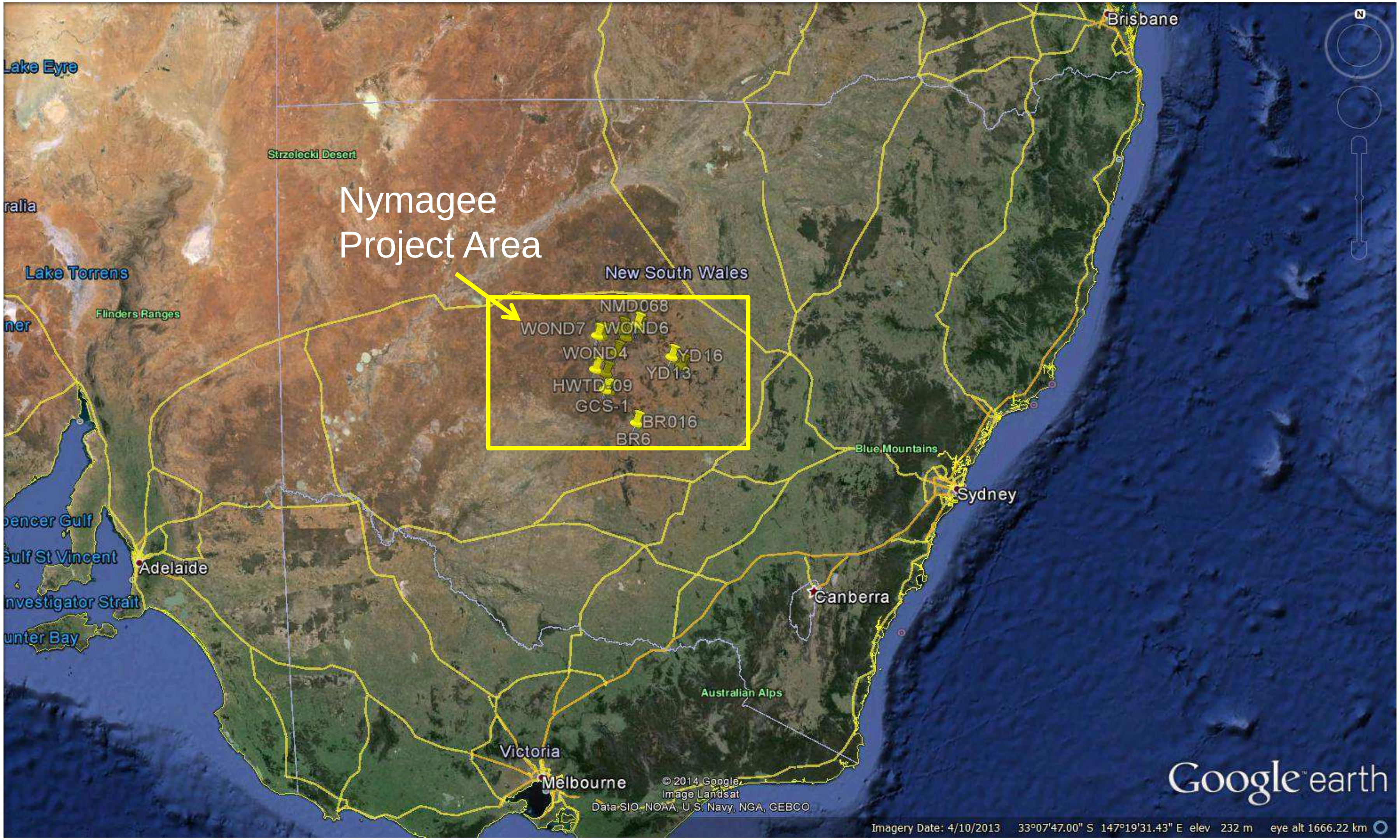


Keys to understanding the Central Lachlan: the GSNSW Nymagee mineral systems study

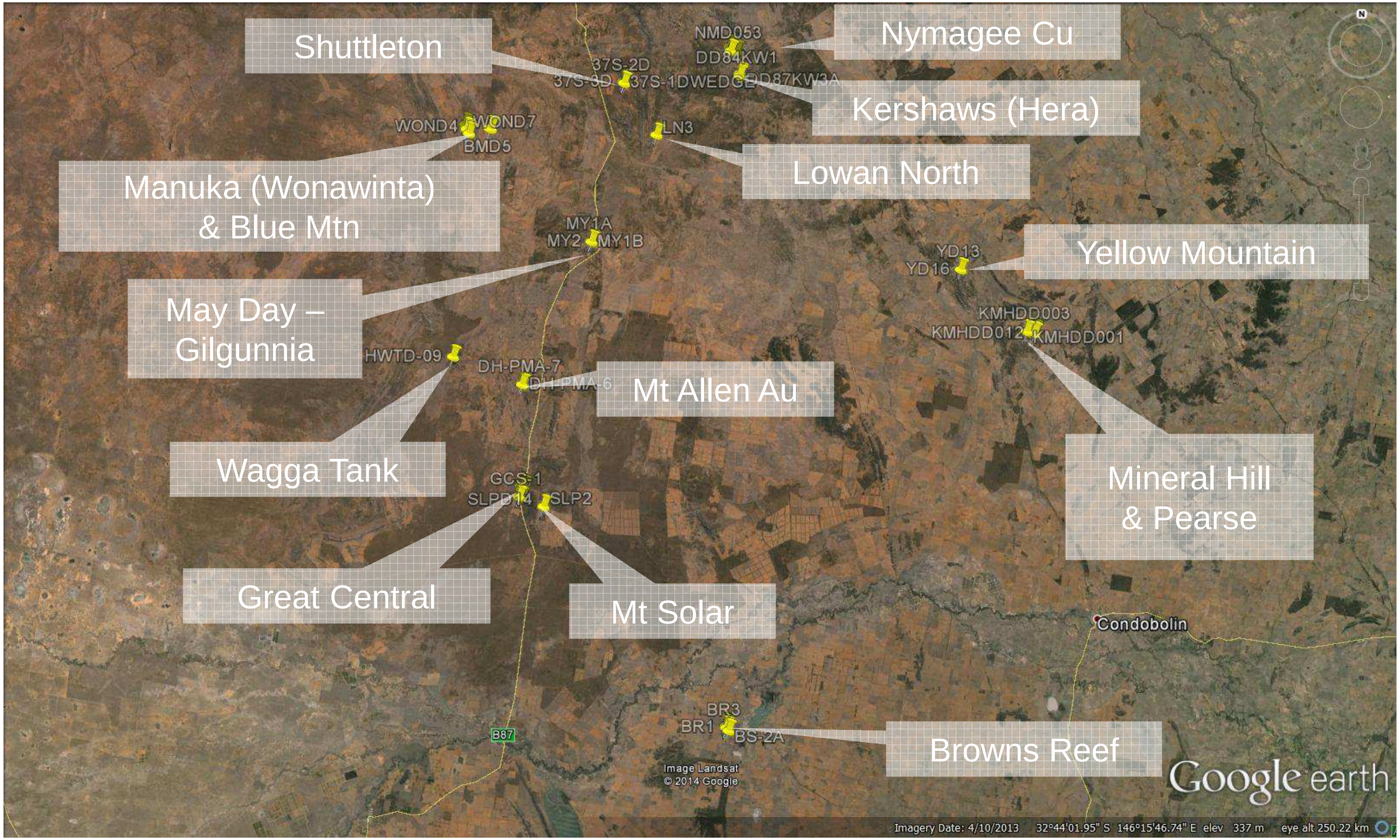
- the HyLogger alteration study

David Tilley, Peter Downes and Meagan Clissold
MinSys NSW group, GSNSW - SMEDG Meeting - 26 March 2015

Project area



HyLogged prospects



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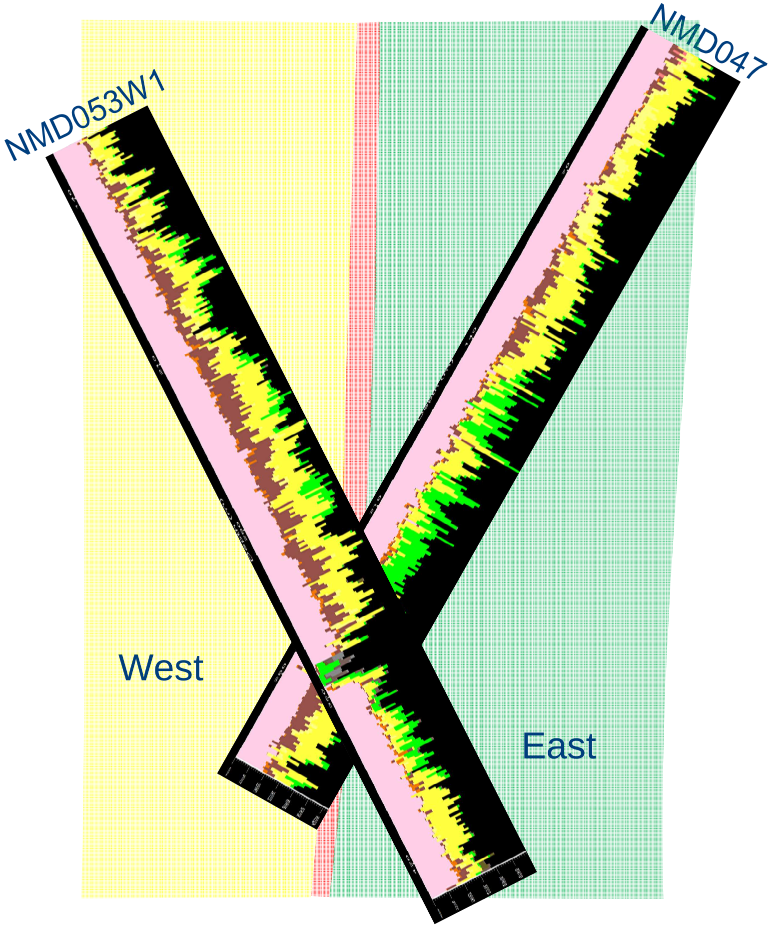
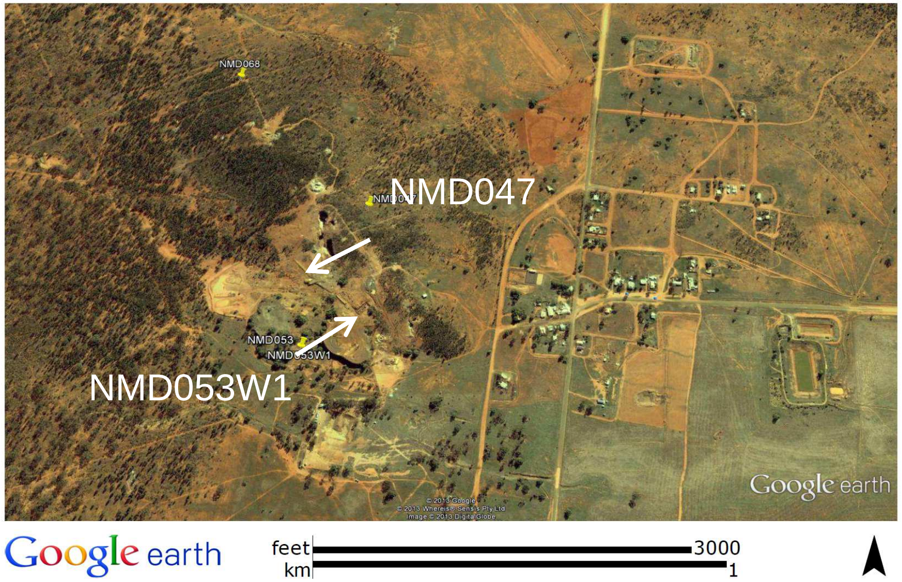
Nymagee Cu Mine



Western side - quartzo-feldspathic unit
- quartz–muscovite-plagioclase
- minor chlorite
- trace K-feldspar

Eastern side - metamorphosed clay-rich unit
- quartz–muscovite/illite
- minor scattered plagioclase & chlorite
- trace K-feldspar



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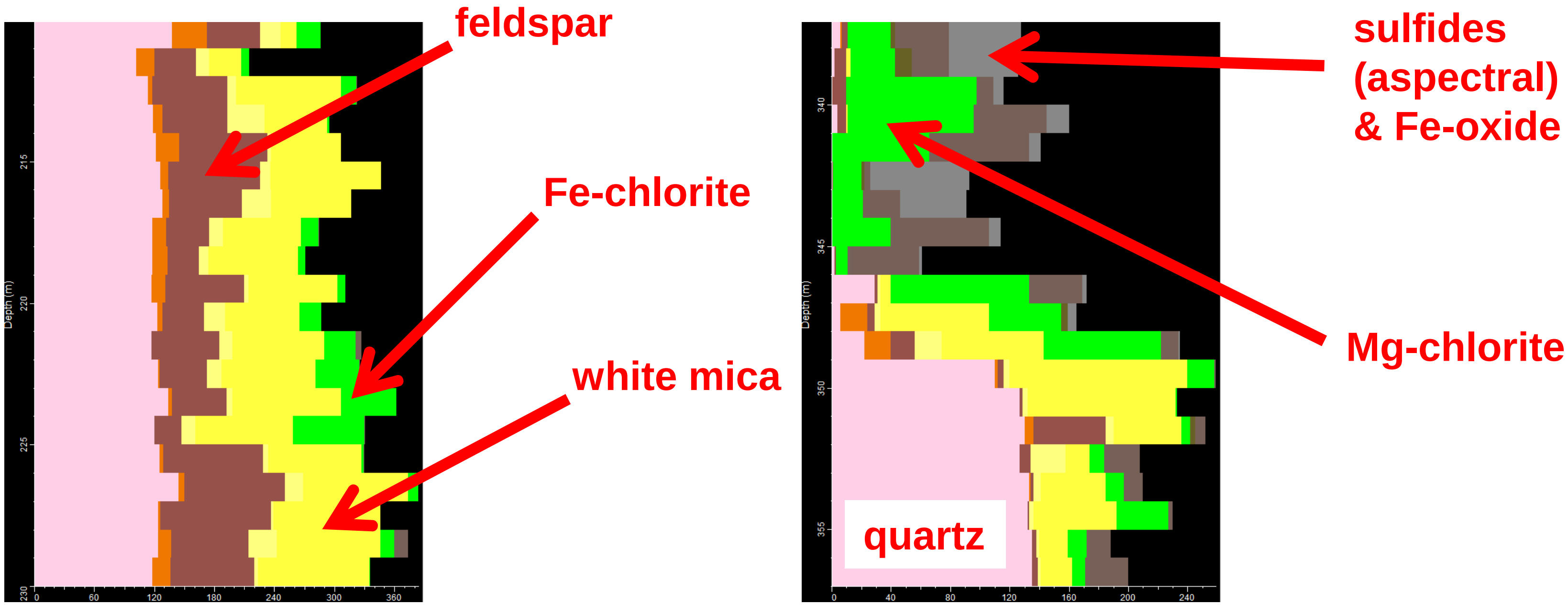
Nymagee Cu Mine

NMD053W1 - Host Rock

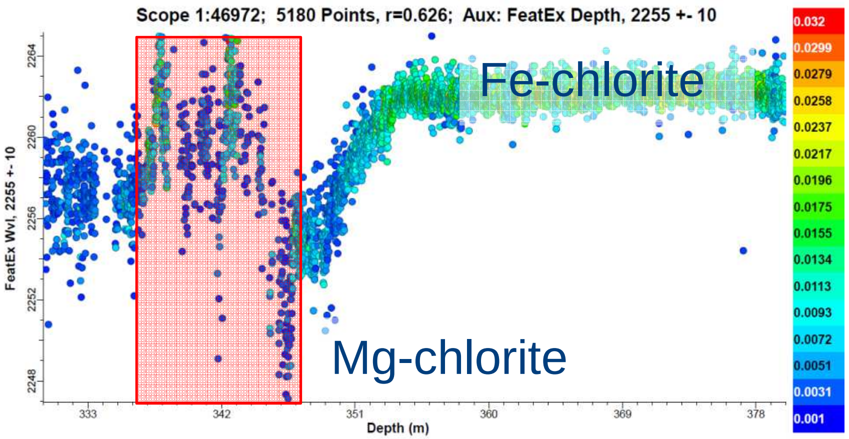
NMD053W1 - Mineralised Zone



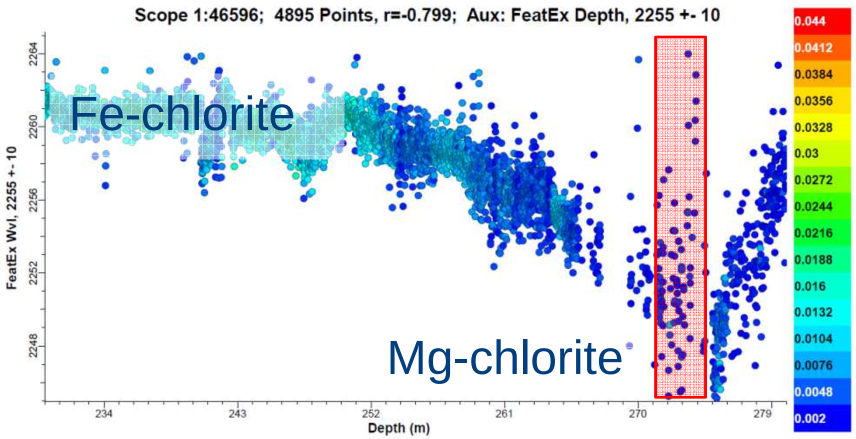
Nymagee Cu mine
— chlorite composition—

Adjacent to mineralised zone

NMD053W1



NMD047

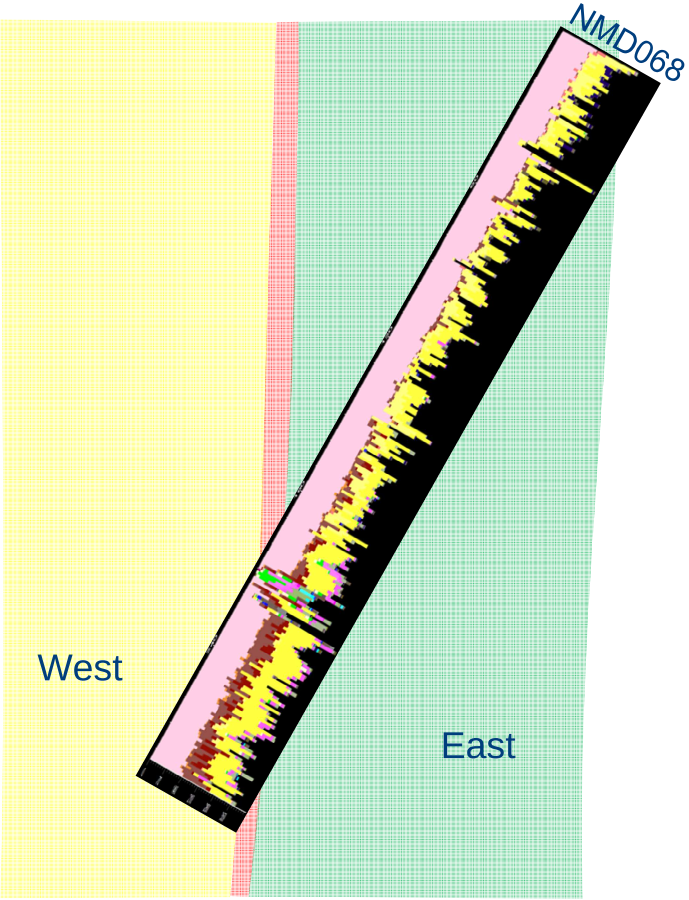


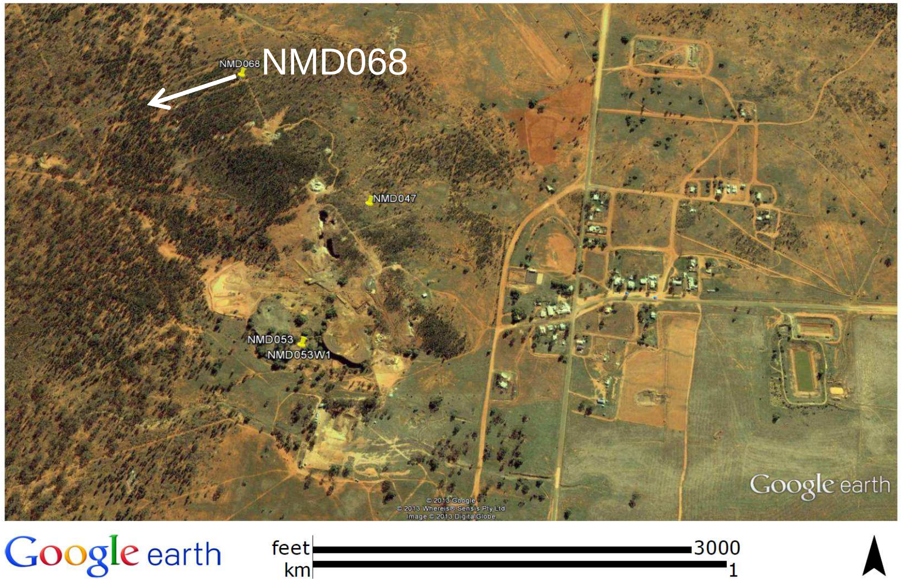
= mineralised zone

Nymagee North

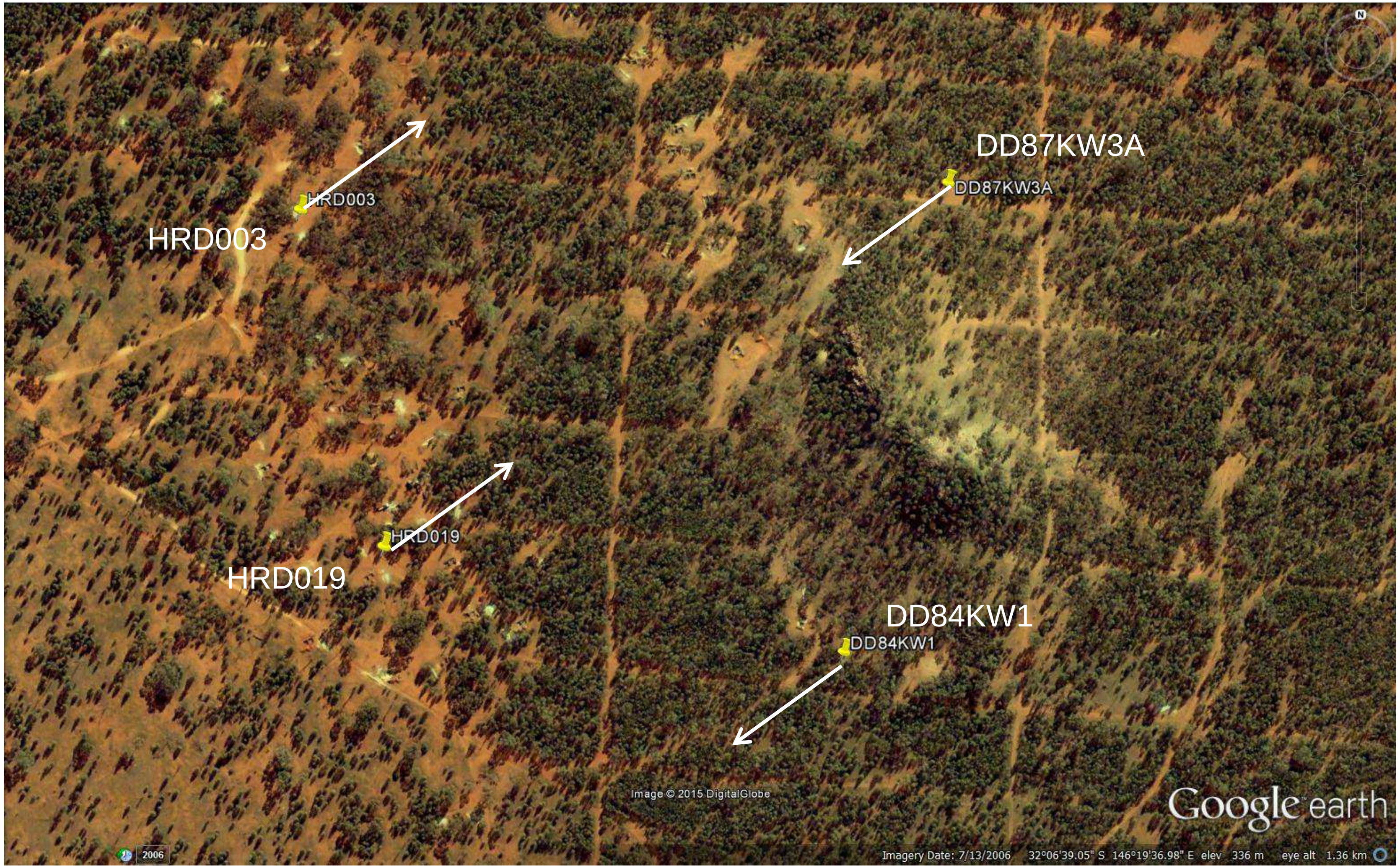
NMD068

- distinctively different from Nymagee Mine
- actinolite within a silver-rich zone at 209m
- anomalous copper and gold present
- separate ore zone to the main Nymagee Mine





Hera

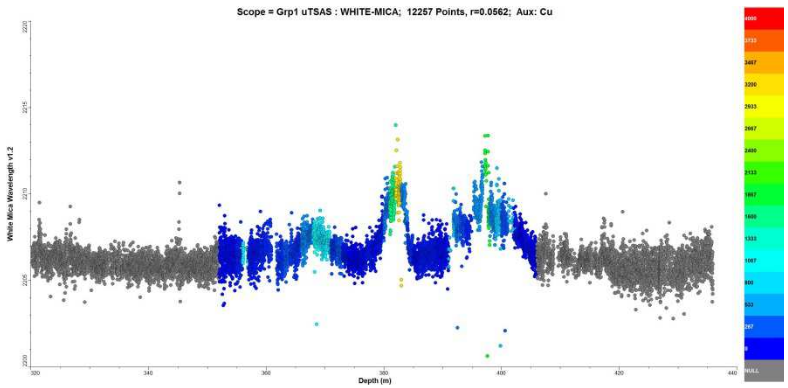


DD87KW3A
DD87KW3A
HRD003
HRD003
HRD019
HRD019
DD84KW1
DD84KW1
Image © 2015 DigitalGlobe
Google earth
2006
Imagery Date: 7/13/2006 32°06'39.05" S 146°19'36.98" E elev 336 m eye alt 1.36 km

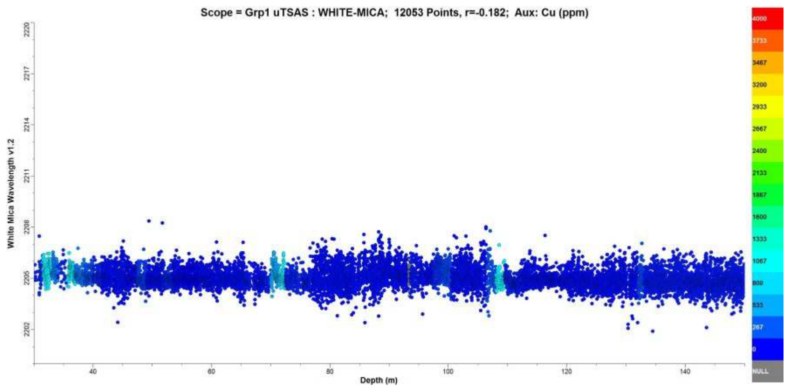
Hera

— white mica composition vs copper —

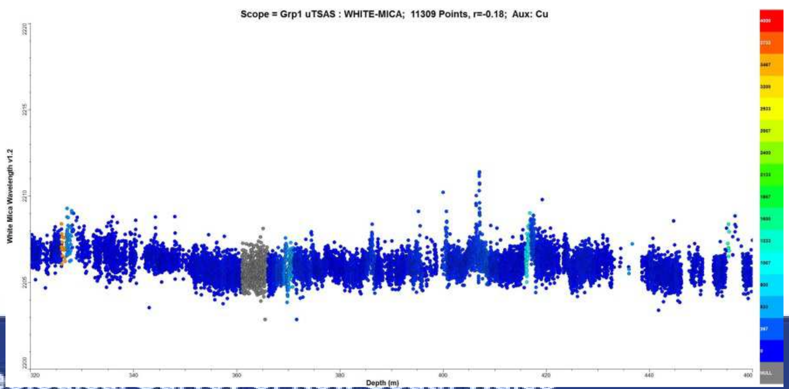
HRD003 – ore grade Cu



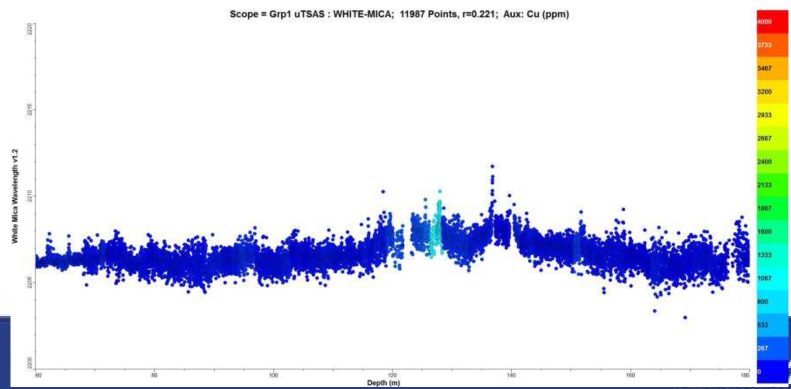
DD87KW3A – anomalous Cu



HRD019 – narrow Cu-rich zone

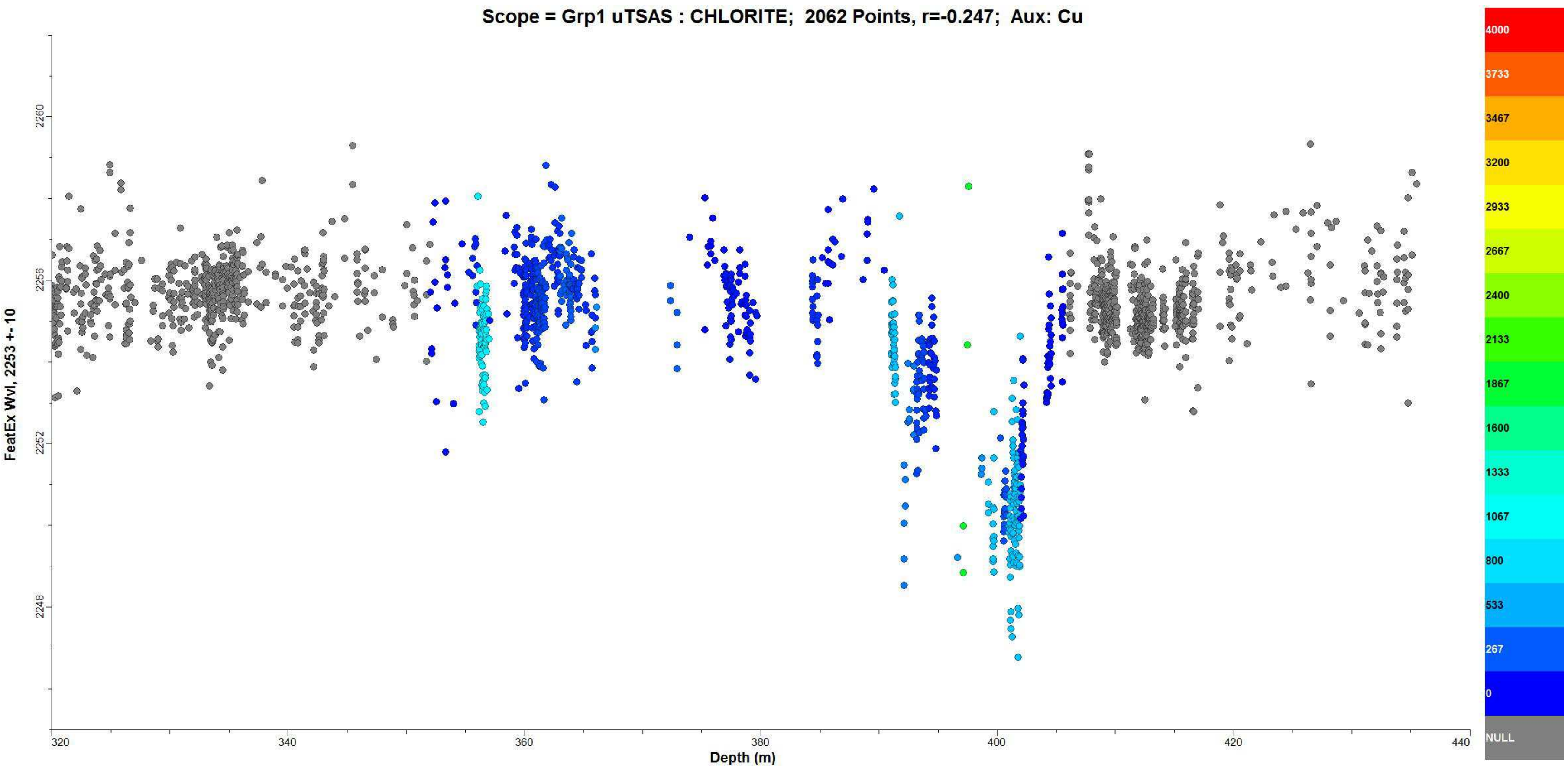


DD84KW1 – anomalous Cu



Hera
— chlorite composition vs copper—

HRD003

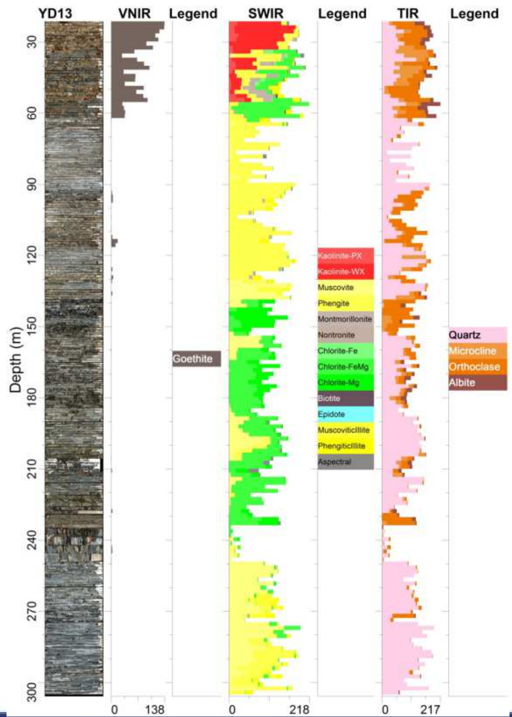


Yellow Mountain

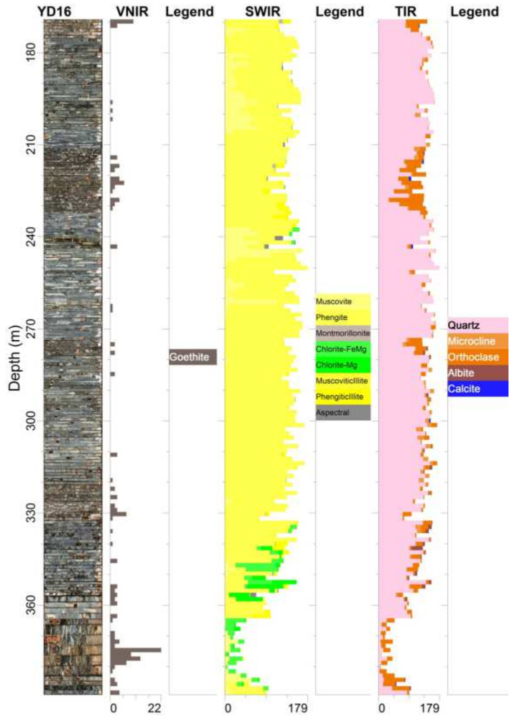
Background Response

- Dependent on host rock mineralogy
  - quartz–K-feldspar dominant with variable plagioclase, minor white mica and variable minor chlorite
  - Consistent with felsic volcanic/volcaniclastic host rock

YD13



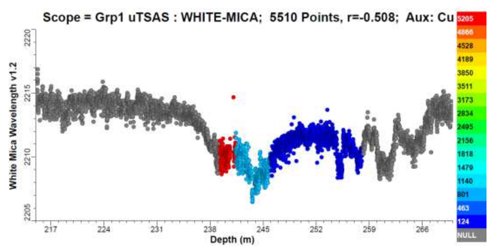
YD16

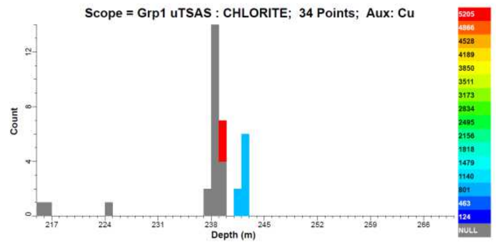


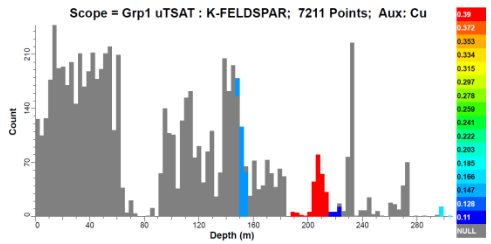
Yellow Mountain

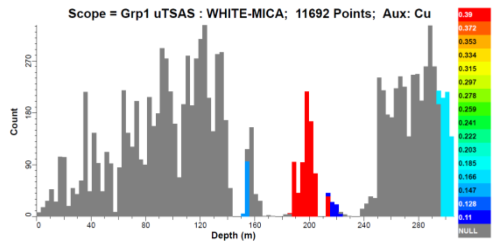
Adjacent to mineralised zone

- YD16: change from phengitic to an intermediate white mica composition about a 2.1m mineralised zone with very minor Mg-rich chlorite present
- YD13: 29m wide mineralised zone where K-feldspar is less abundant and there is an increase in intermediate white mica abundance



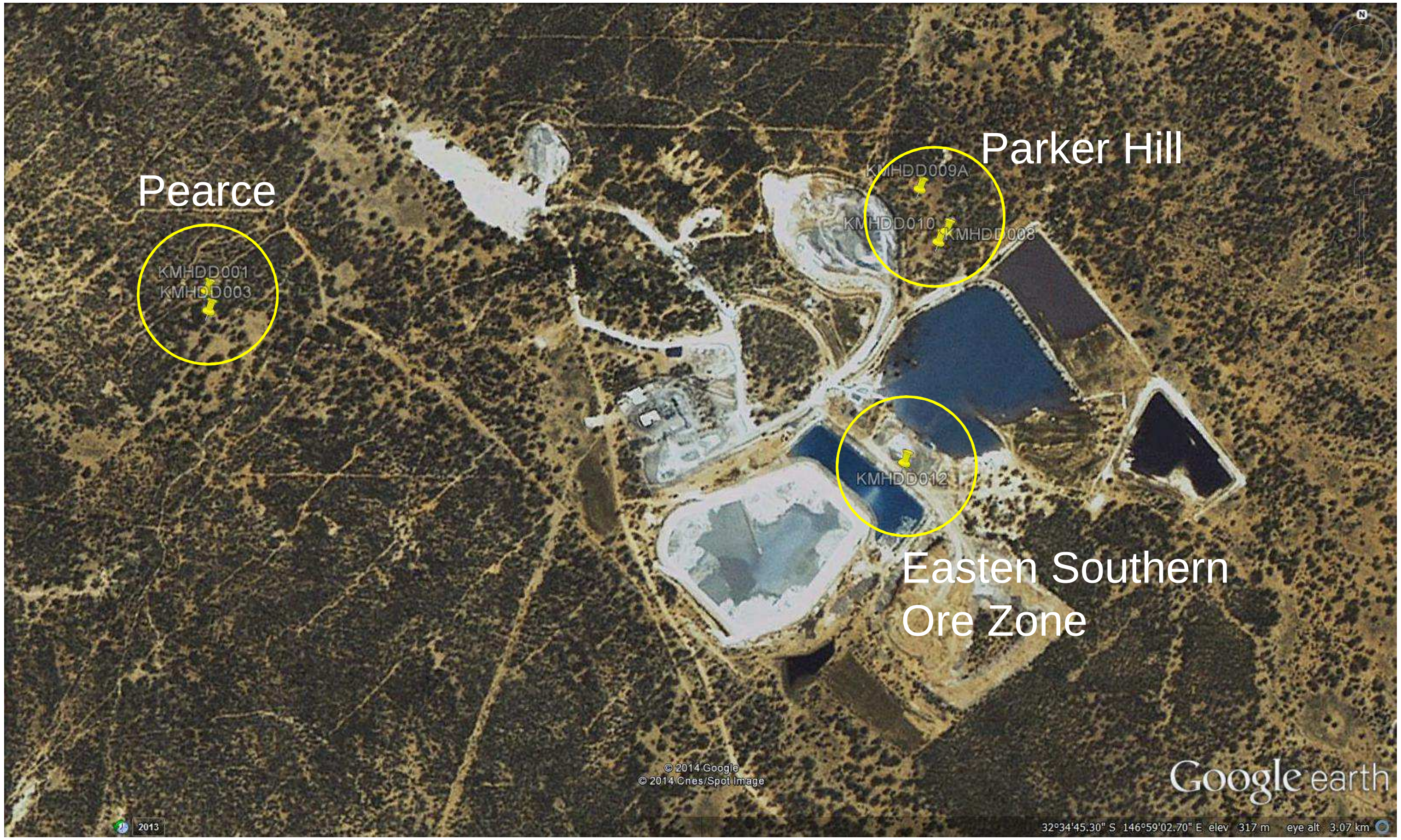






These subtle changes are probably alteration-related but the dominant spectral response in these holes are host rock related

Mineral Hill



Background Response

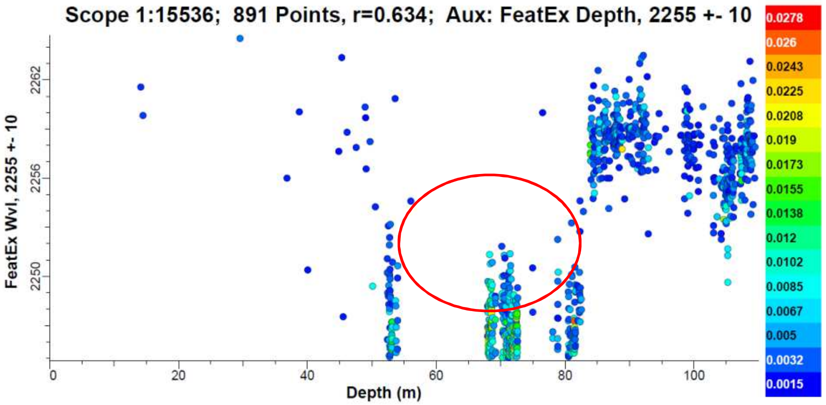
- The deposit is hosted by felsic volcanic rocks, limestone and siltstones

Mineral Hill
— Pearce —

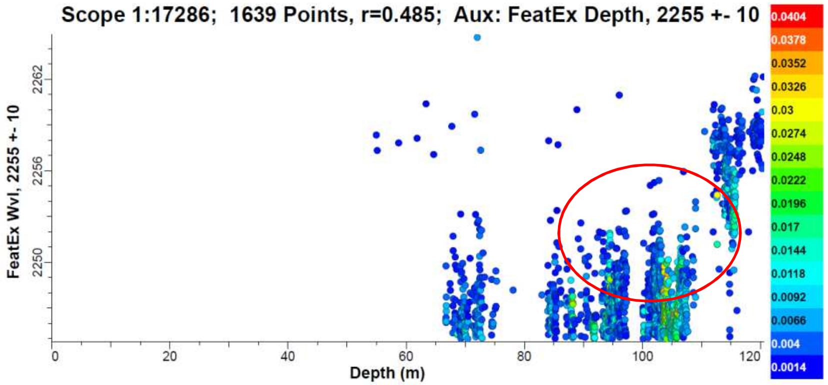
Adjacent to mineralised zone

- Alteration consists of a chlorite-quartz-white mica assemblage with intense zones of argillic alteration, some of which are associated with mineralisation.

KMHDD001 Chlorite Composition



KMHDD003 Chlorite Composition



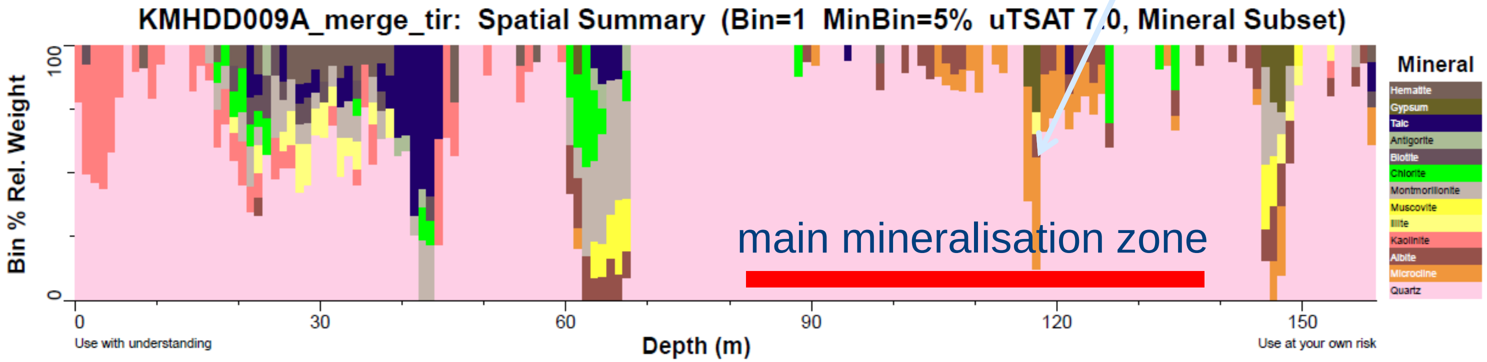
Mineral Hill
— Parker Hill TIR results —

Distal

- quartz and talc, minor Fe-chlorite, feldspar, hornblende and trace white mica.

Proximal

- Mg-chlorite associated with talc more proximal to mineralisation.
- Silicification and K-feldspar (potassic) alteration.



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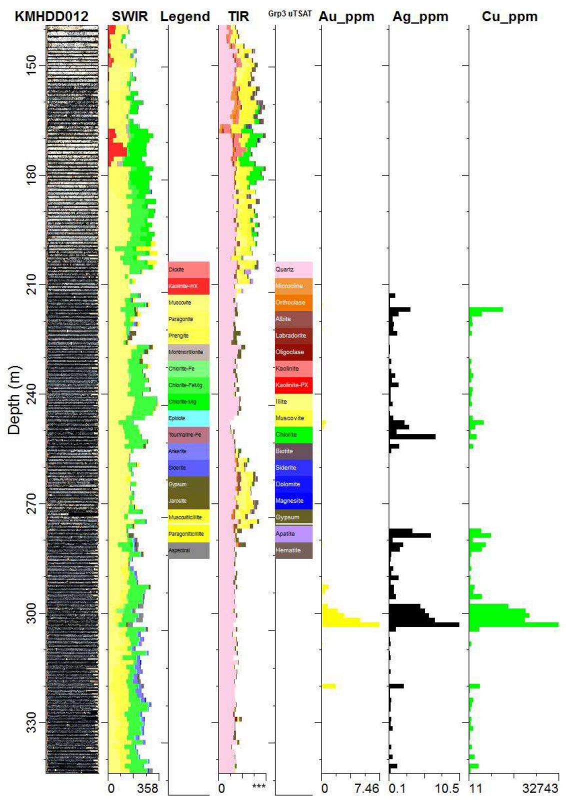
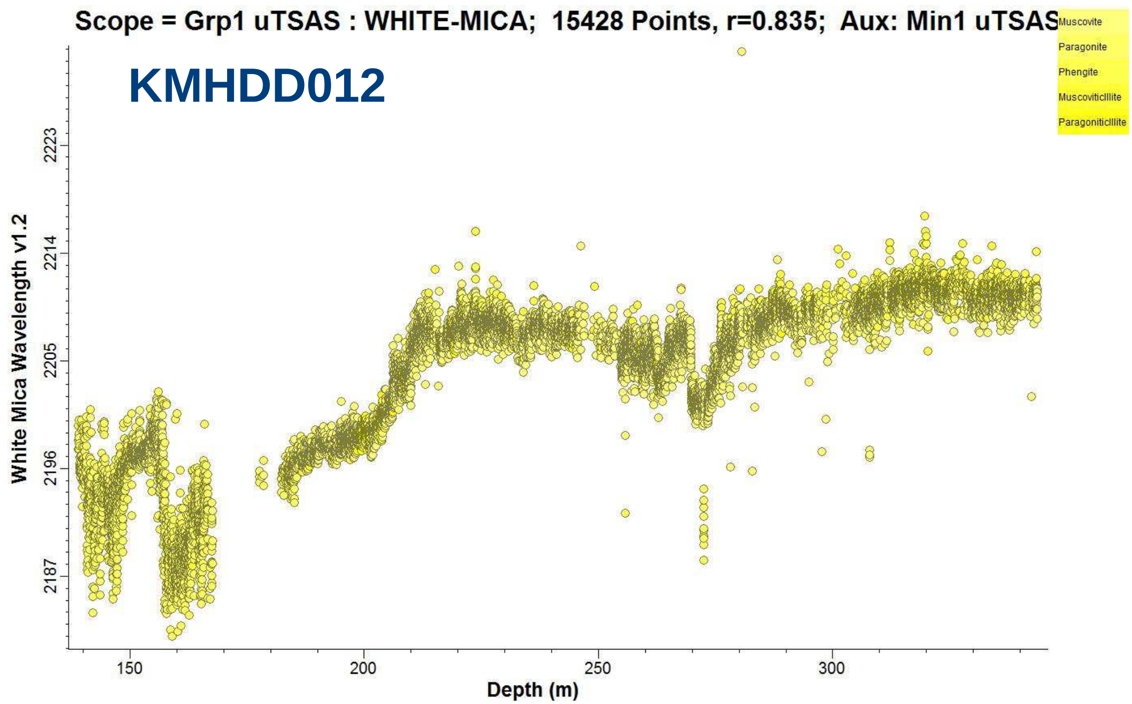
Mineral Hill
— Eastern Southern Ore Zone —





- Host rock composed of quartz–chlorite–white mica (no talc)
- Both Mg and Fe-Mg chlorite present
- Al-OH absorption feature (2175-2200nm) indicates paragonite

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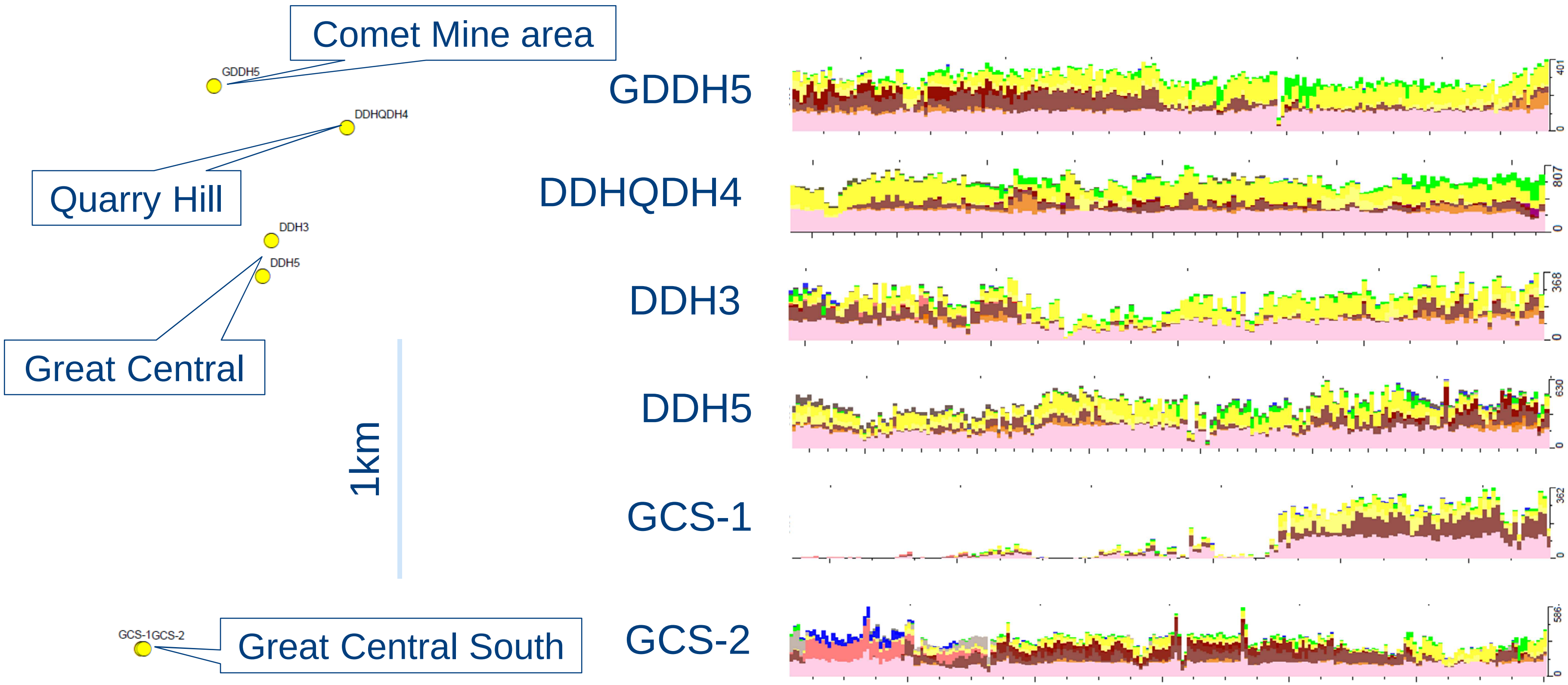
Great Central mine



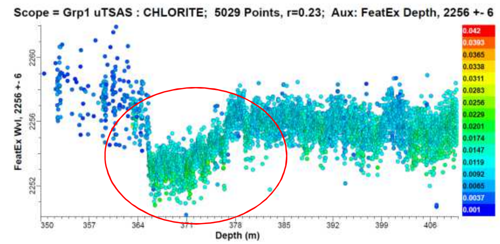
Background Response

- Quartz–muscovite–phengite–chlorite with zones of feldspar (both K- and Na-rich varieties)
- The feldspars are consistent with host rock mineralogy

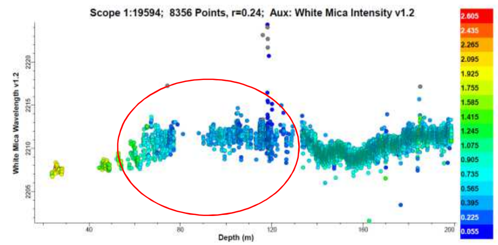
Great Central mine

Adjacent to mineralised zone

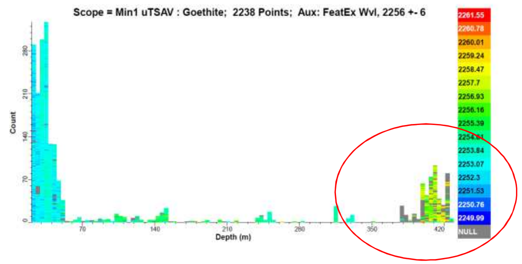
- Chlorite content increases & changes from Fe- to Mg-rich
  - ➢ chlorite zone 40m wide at Great Central, 10m at Quarry Hill



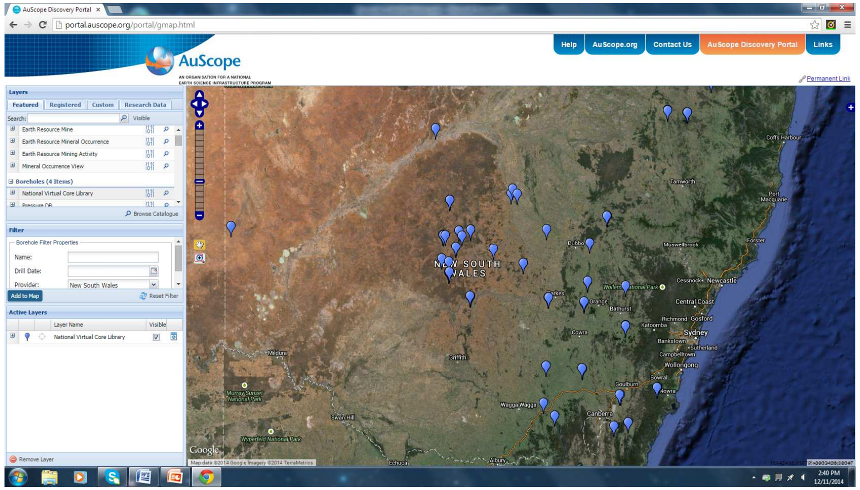
- At Great Central South, white mica becomes more phengitic

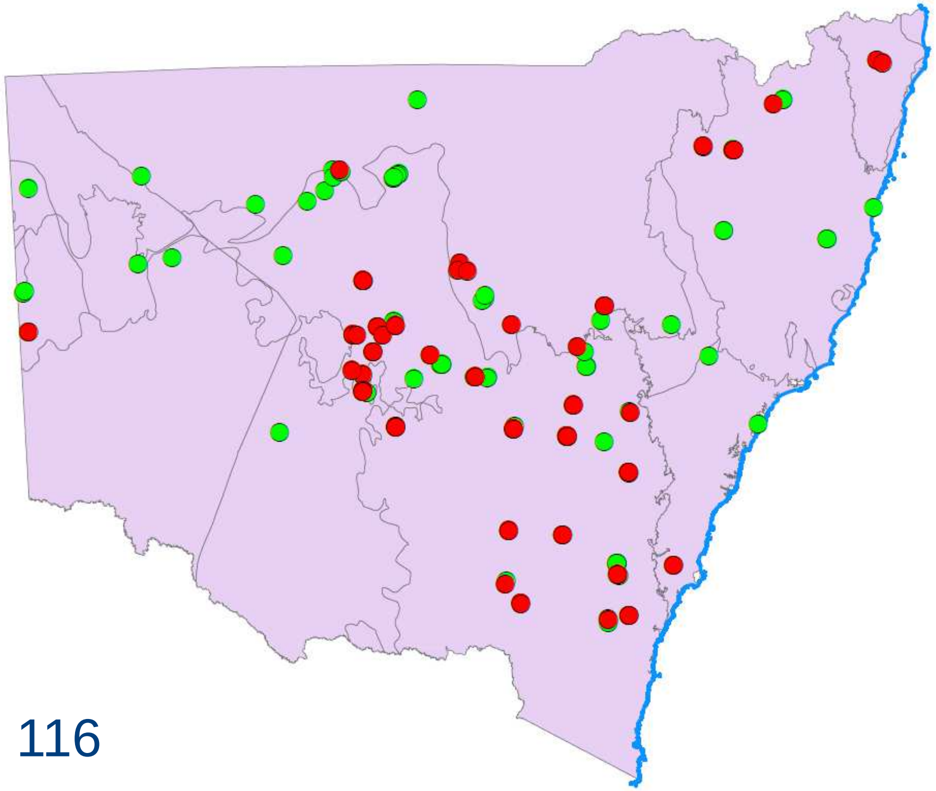


- An alteration zone associated with a possible breccia at the bottom of DDH5 (Great Central mine area) has not been fully assayed. The spectral response shows an increase in goethite and Fe-rich chlorite
  - ➢ goethite suggests an increase in oxidised sulfides in this zone



AuScope Portal





Total holes scanned = 214

- Uploaded to the portal = 98
- Awaiting upload to the portal = 116

HyLogger wrap-up

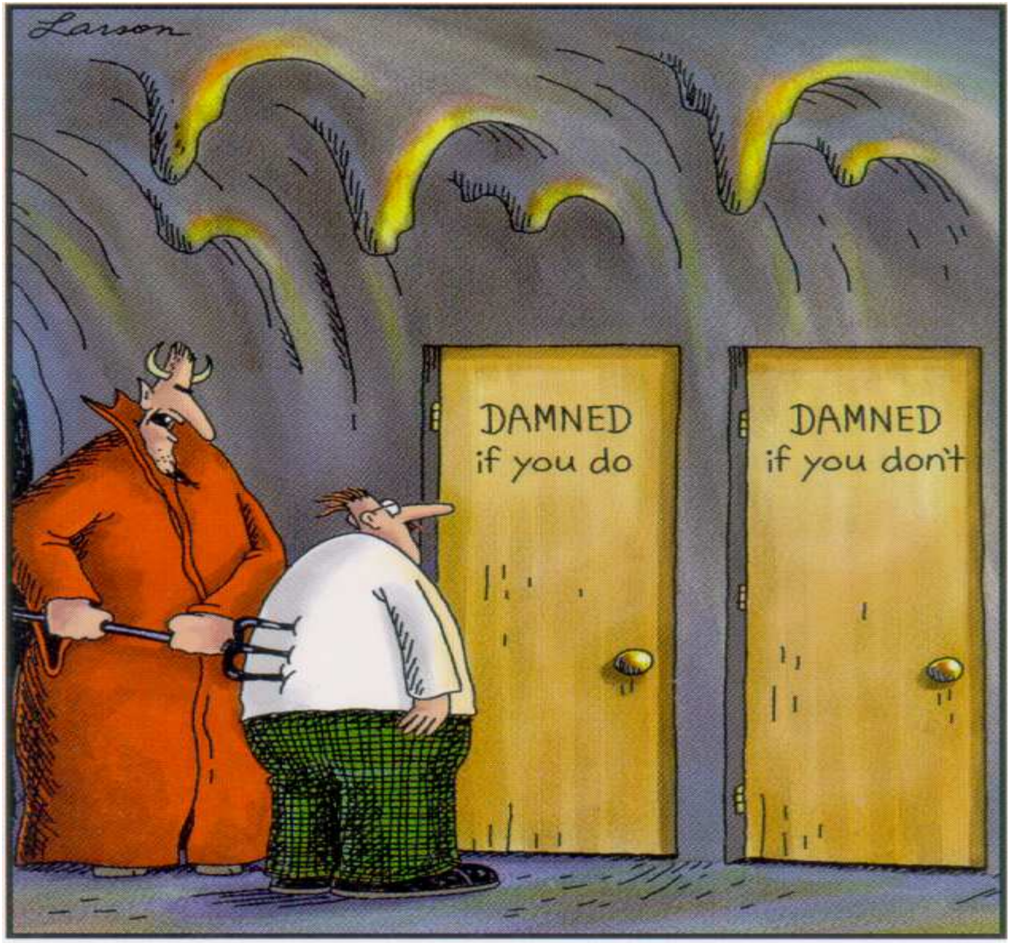
Conclusions

- Differentiate alteration and background host-rock responses
- Estimate relative mineral abundances with TIR
- Identify changes in mineral chemistry
- Validate minerals present within assemblages
- Compare and contrast variations in alteration/host rock mineralogy

Where do we go from here?

- Update AuScope portal with all non-confidential data
- Results to be published in GSNSW Quarterly Notes in September 2015 – to be released at Mines & Wines 2015, Queanbeyan

S- & Pb-isotopes



"C'mon, c'mon—it's either one or the other."

Regional S- and Pb-isotope data combined with insights from the actual deposits provide constraints as to:

- sources of metals
- sources of fluids
- ore forming processes
- timing (Pb-isotopes)

at both deposit and district scales

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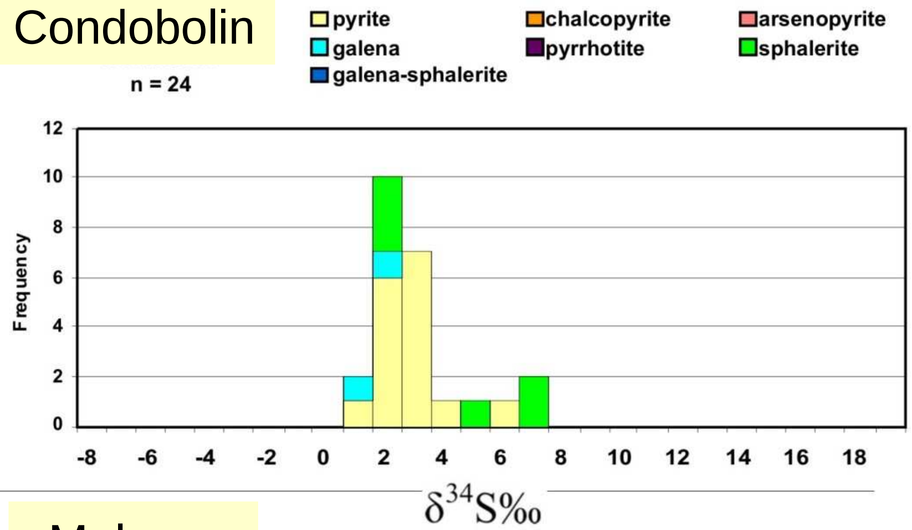
S-isotope results
— magmatic reservoirs —

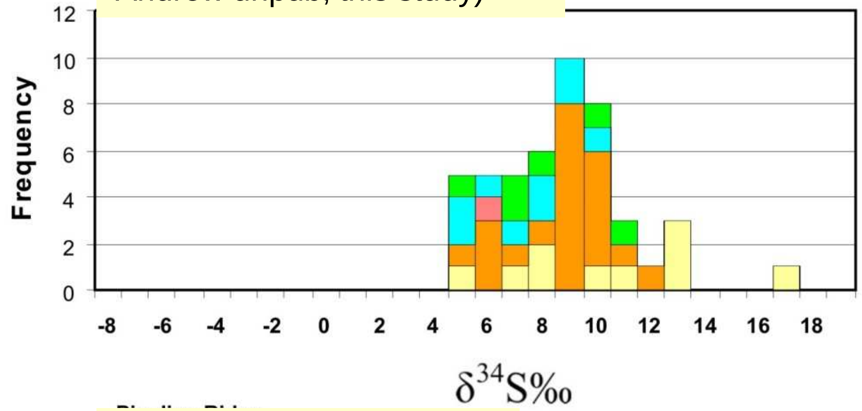
Magmatic dominant

Epithermal - mixed

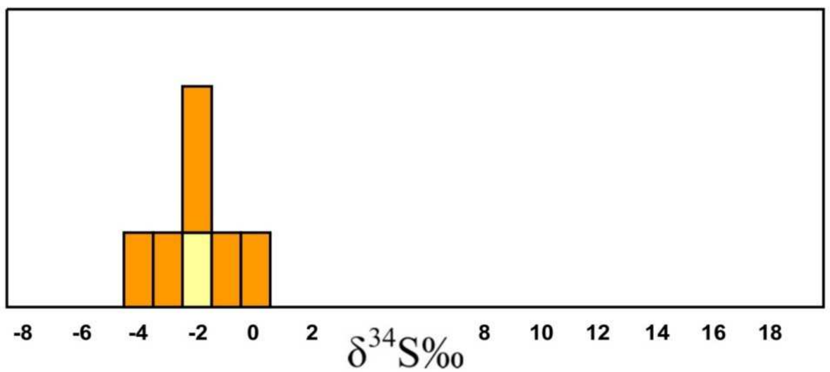
Condobolin



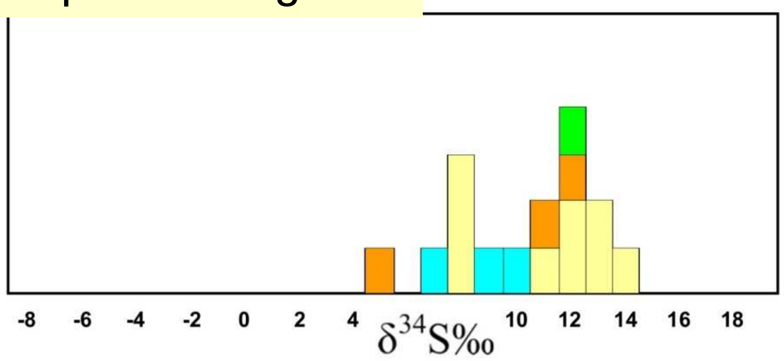
Mineral Hill
(Bush 1980, Spandler 1998, Andrew unpub, this study)



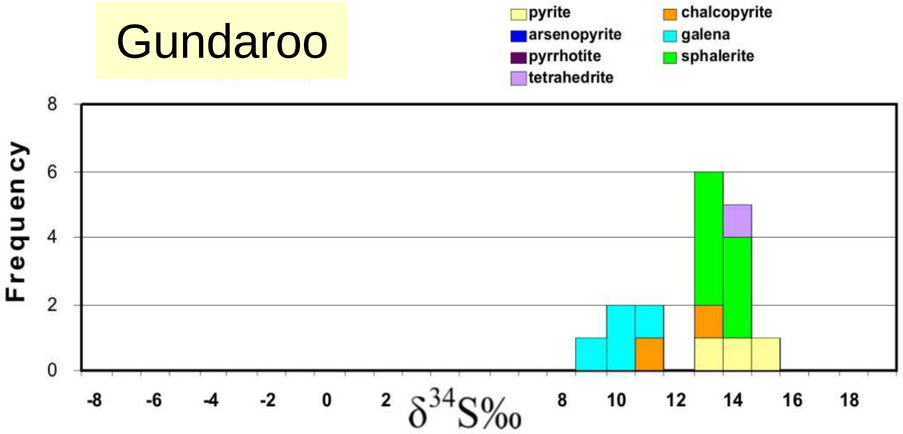
Melrose

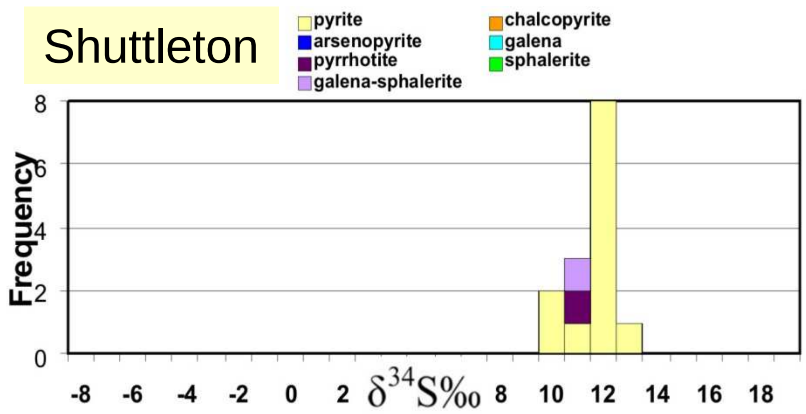


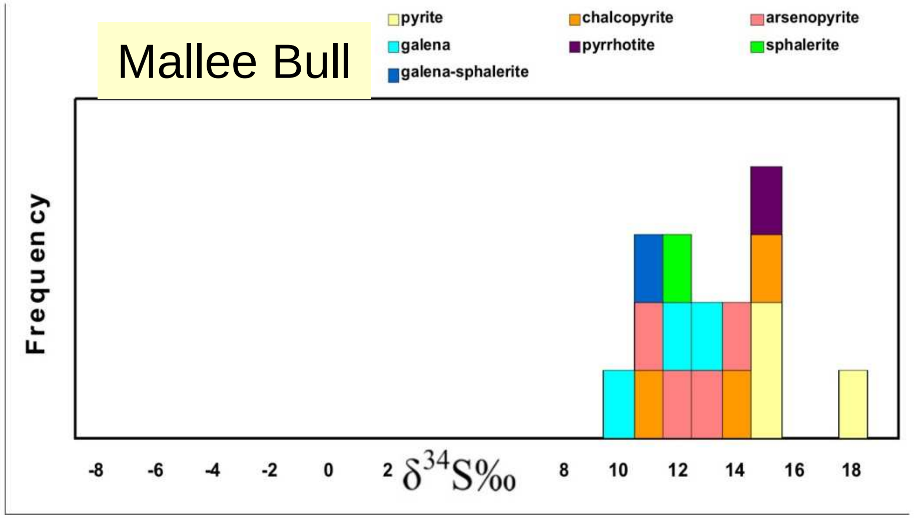
Pipeline Ridge

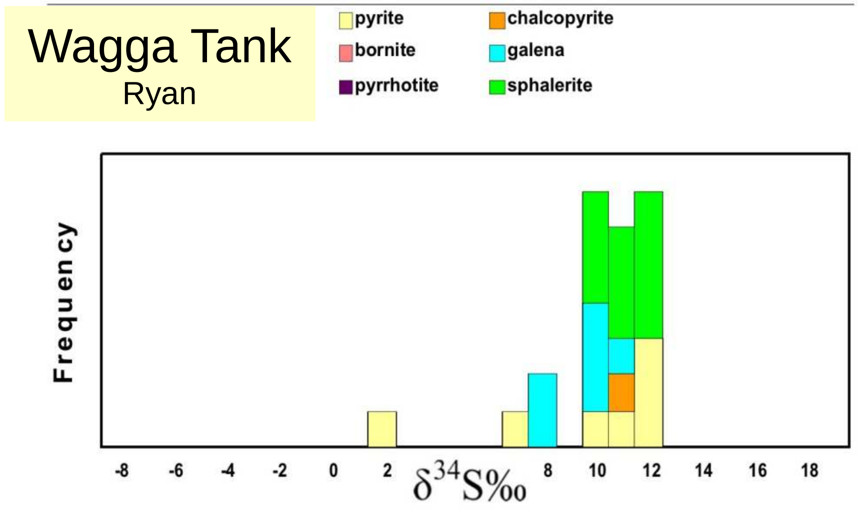


S-isotope results
— basinal fluid dominant —



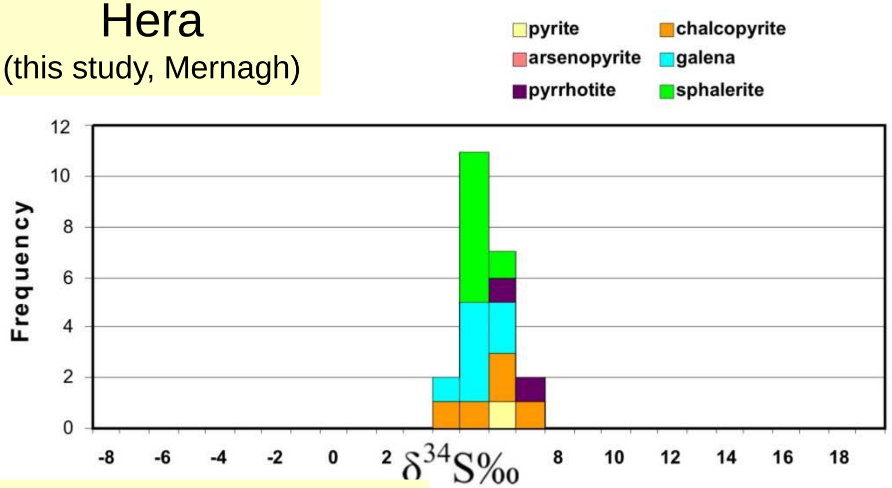




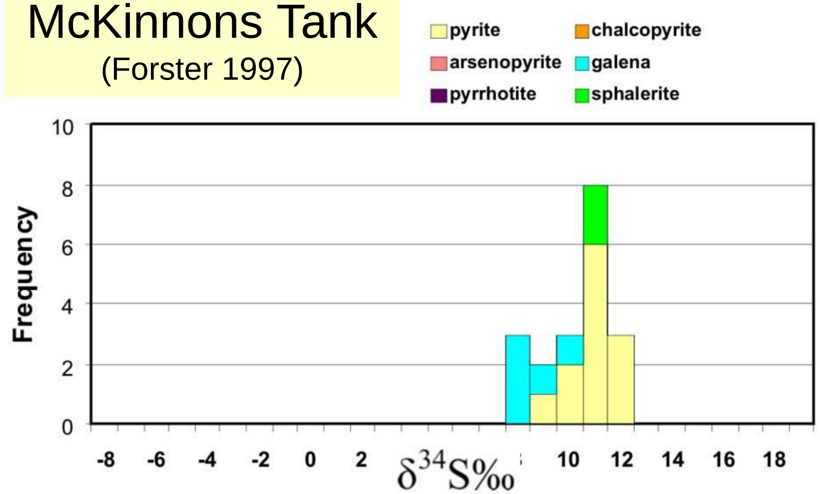


S-isotope results
— other —

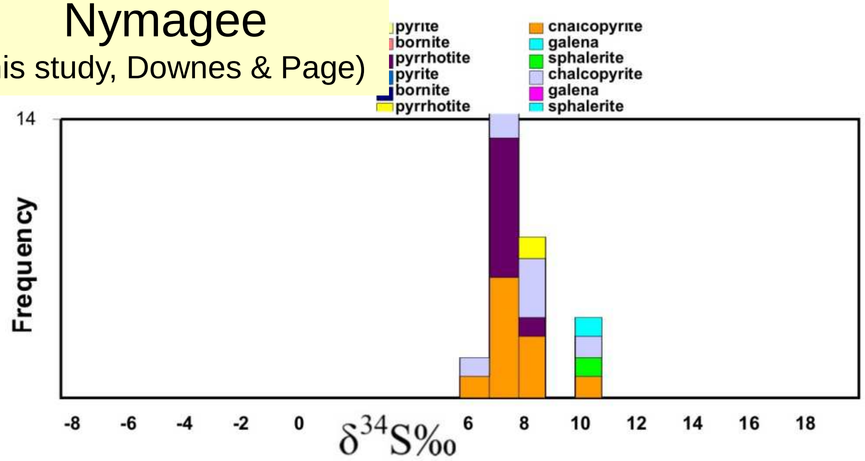
Hera
(this study, Mernagh)



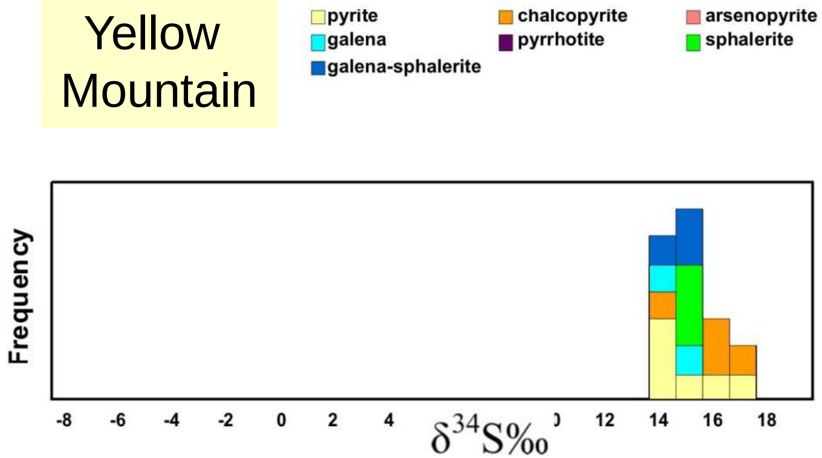
McKinnons Tank
(Forster 1997)



Nymagee
(this study, Downes & Page)



Yellow Mountain



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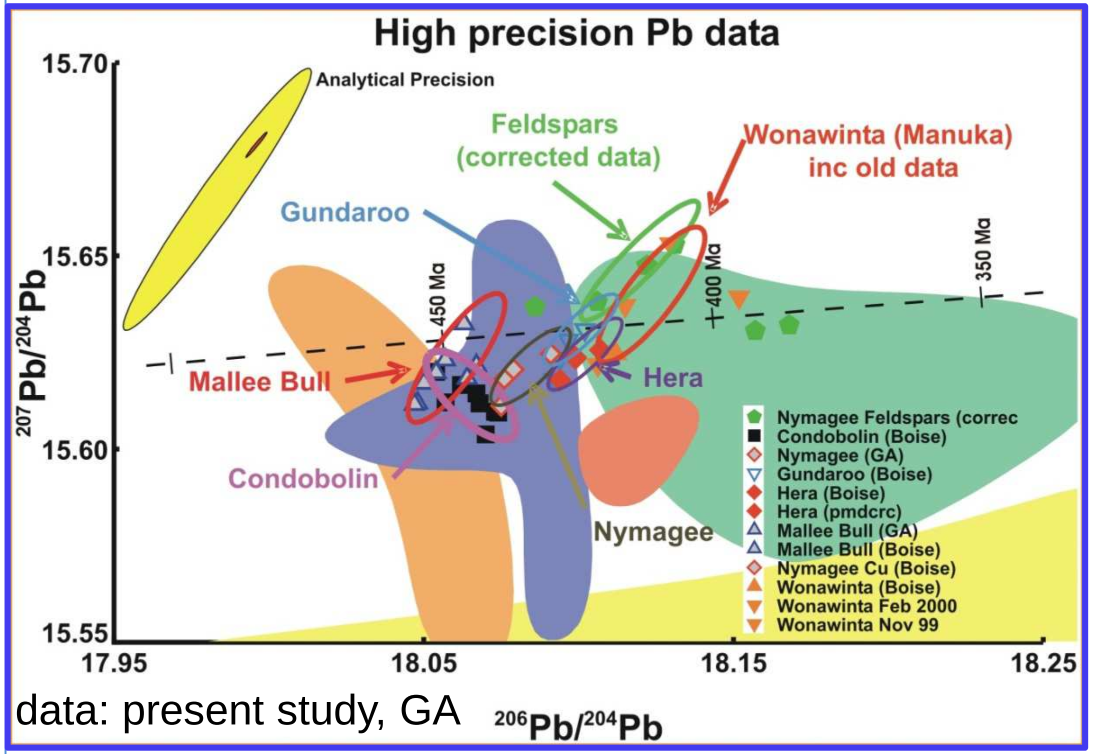
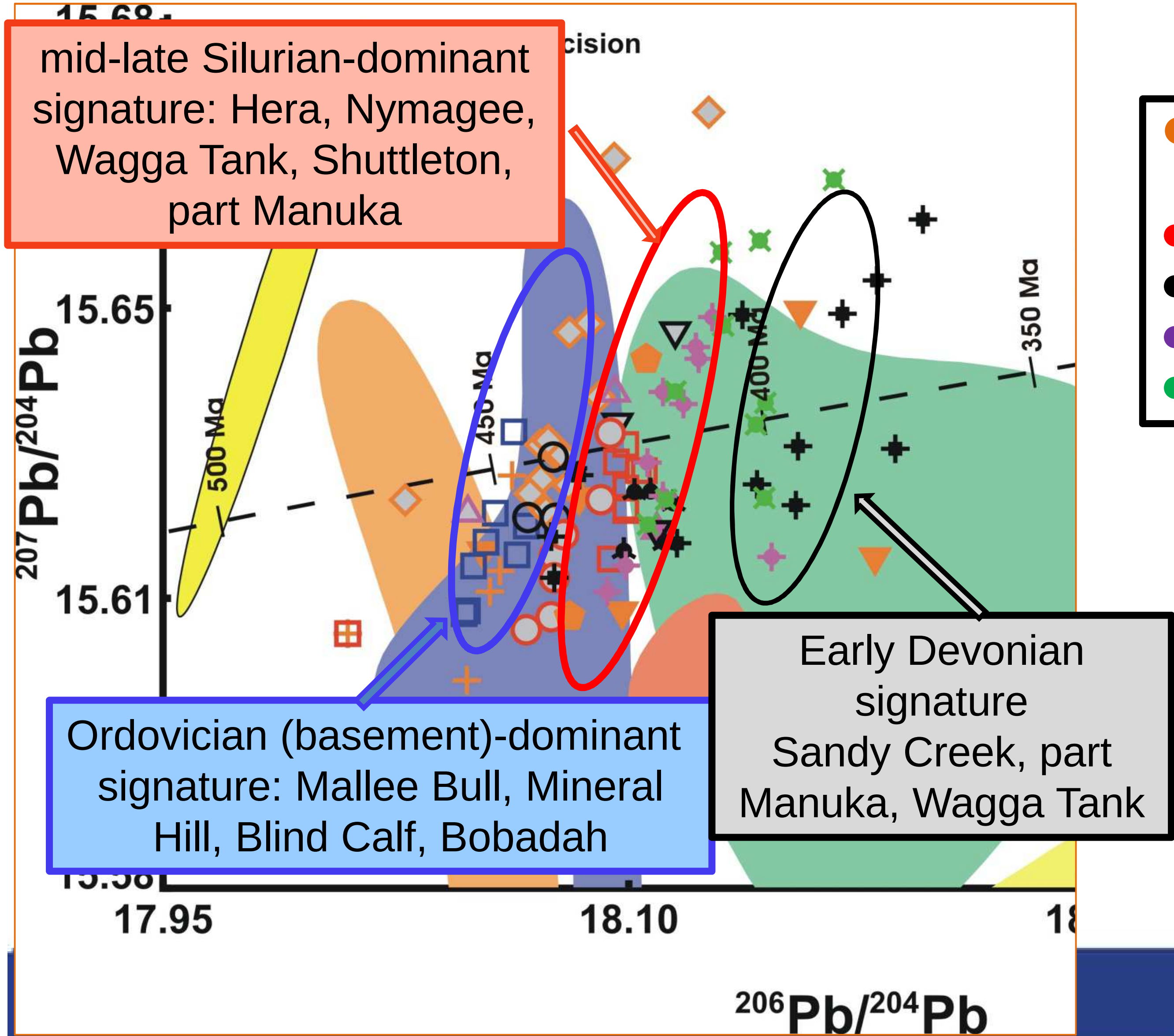
Pb-isotope study



- Mallee Bull (Cu-rich) – old Pb from beneath the basin
- Nymagee (Cu-rich) – crustal dominant but some lead from basement
- Hera (Au-base metal) different signature to Nymagee
- Condobolin – possible mixing of Pb from crustal and mantle reservoirs
- Gundaroo & corrected feldspar data very similar

Dataset: new — 47 high Pb & 14 low Pb (granites /volcanics) +160 older analyses (CSIRO/pmdCRC)

Pb-isotope results
— mineralisation related data —



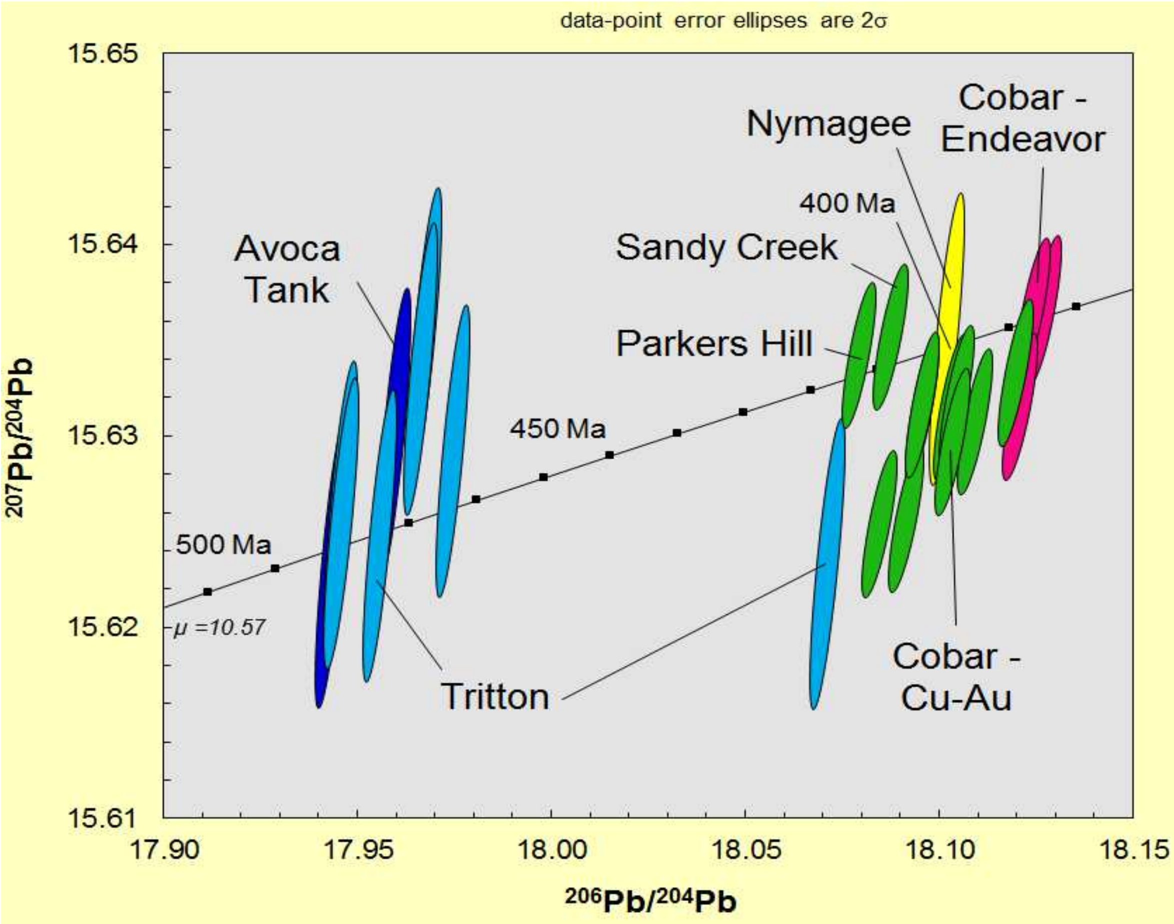
- Canbelego-Mineral Hill Belt
- Kopyje Shelf
- Cobar Basin
- Mount Hope Trough
- Winduck Shelf

Notes — data sources
- 2012/14 = this study
- pmdcrc
- CSIRO (selected only)

2012/14 and pmdcrc studies have higher precision than older analyses

Background: LFB major metallogenic events from Carr et al (1995)

Variation in Pb isotope data, Cobar & Nymagee areas (GA data)



Data for Endeavor and Cobar support interpretation of a Middle Devonian (~385Ma) timing of mineralisation

$^{206}Pb/^{204}Pb$ vs $^{207}Pb/^{204}Pb$ showing variations in high precision ICP-MS analyses of Pb-rich samples from the Cobar and Girilambone districts. The ellipses indicate the 95% confidence errors associated with the analyses.

from Huston et al in prep

Nymagee
— the wrap —

- Major late Silurian magmatic & mineralising event >> Mineral Hill, Blackfellow Dam and probably Tallebung
- Major deformation is Middle Devonian (Tabberabberan Orogeny), i.e Cobar Deformation is NOT a separate event,
- Hera/Nymagee >> mid Devonian with S from basinal & magmatic sources (not related to magmatism)
- Metals at Mallee Bull from basement, fluids basinal
- Pb data indicates clear basement input in some deposits and supports evolution of the basin until late in Early Dev.
- Volcanic stratigraphy of Mt Hope Group is more complex that required >> eruptive centres present, some are associated with mineralisation

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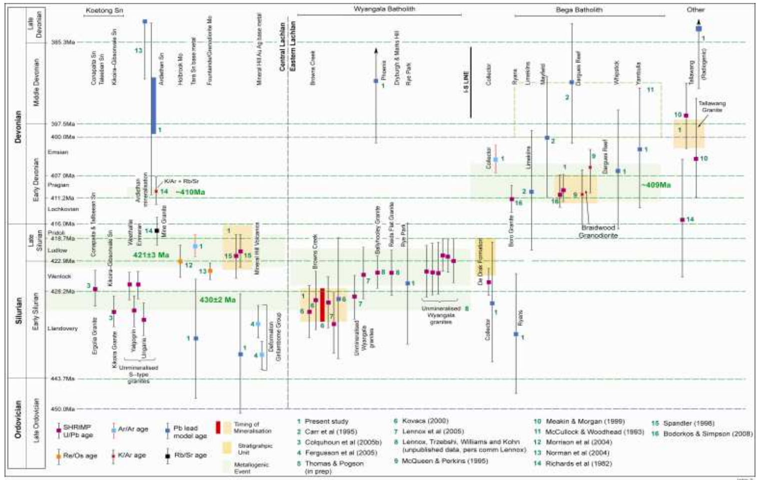
Current MinSys projects



+12 New commodity Flyers

- **Broken Hill 250k metallogenic map >> May 2015 release**
- **Metals in Time —** statewide time–space plot of metallogenic events
  - **3 to 4 year project**
  - **>> new dating!!**
- **NEW Cobar–Nymagee–Cargelligo 1:500k metallogenic map >>?late 2015**
- **Mineral Deposit models & commodity studies >> Mineral Deposits of NSW**
- **HyLogger studies**
  - Broken Hill alteration/metamorphism
  - Porphyry Cu–Au
  - VAMS

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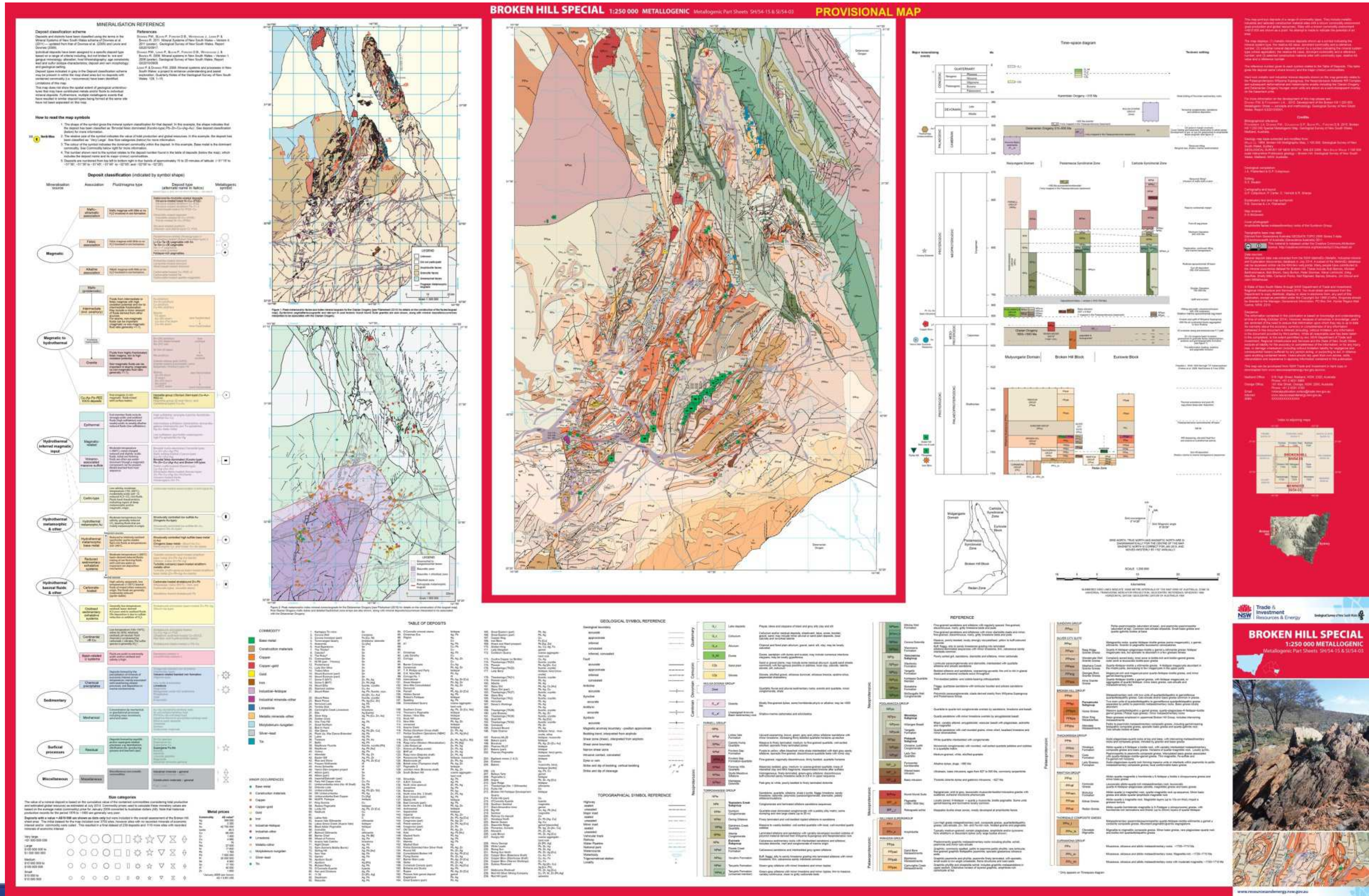
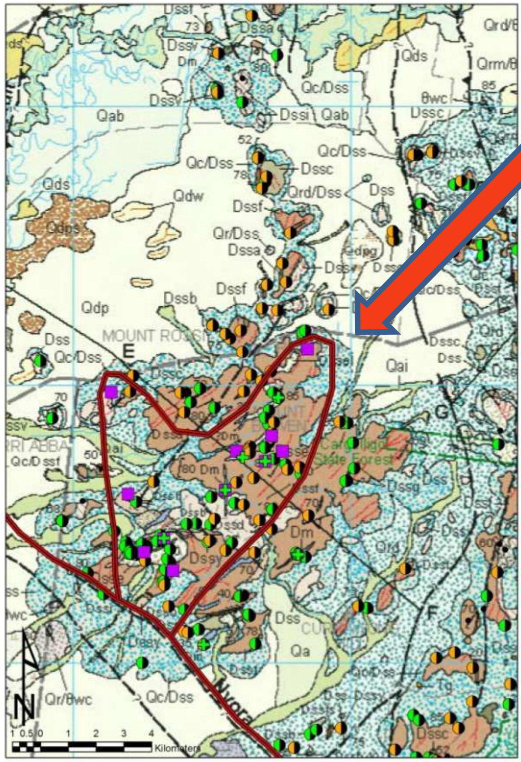
Broken Hill 250k metallogenic map



Cobar 500K metallogenic map

metamorphic Studies

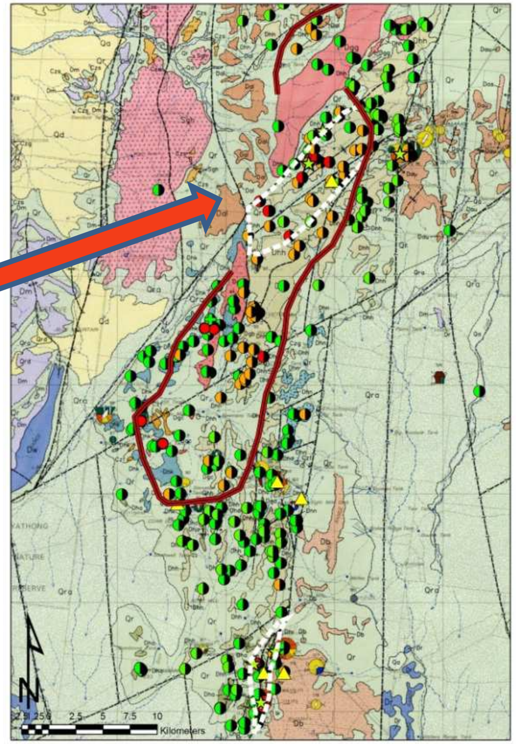


Ural Volcanics

- Extent of high grade hornblende/actinolite assemblages.

Mt Halfway Volcanics

- Extent of biotite/cordierite/ actinolite in granite aureoles.
- Mapping out biotite-bearing shear zones.



Ural Volcanics
- Purple points = metamorphic hornblende

Mt Halfway Volcanics
- Orange points = metamorphic biotite
  Red points = metamorphic cordierite
  White zones are zones of foliated biotite

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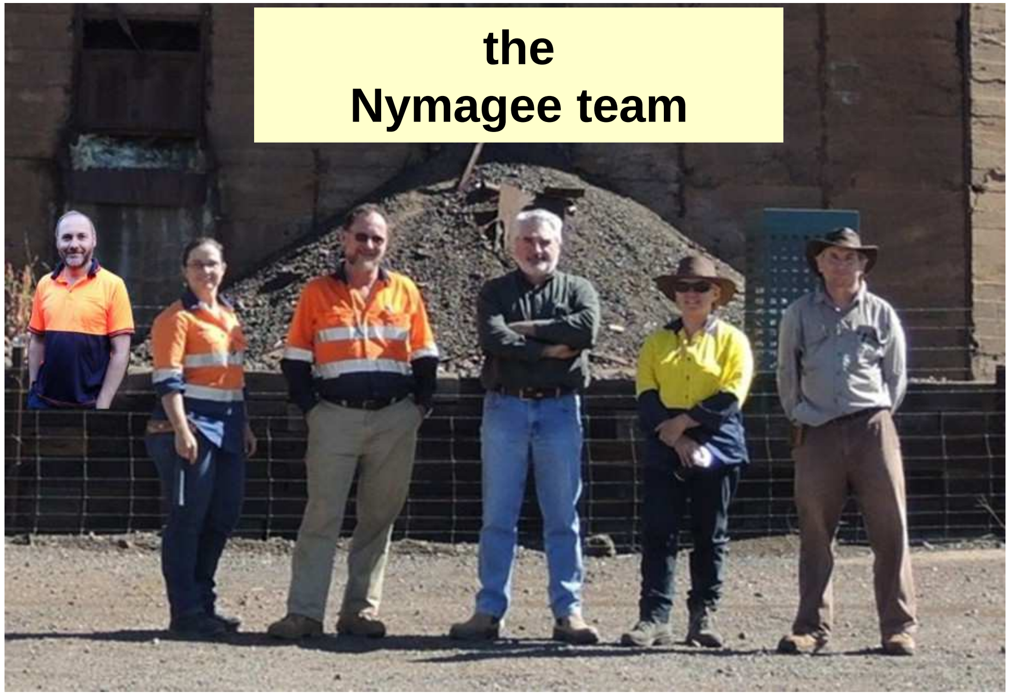
Acknowledgements

the Nymagee team



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Dave Forster

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Polymetals Mining Limited
The University of Newcastle Australia
Clancy Exploration
Mincor Resources NL
University of Wollongong
CSIRO
AuScope
newgold Peak Gold Mines Pty. Ltd.
五礦資源有限公司 Minmetals Resources Limited incorporating MMG


and no
I have not been
photo-shopped
THANK
YOU