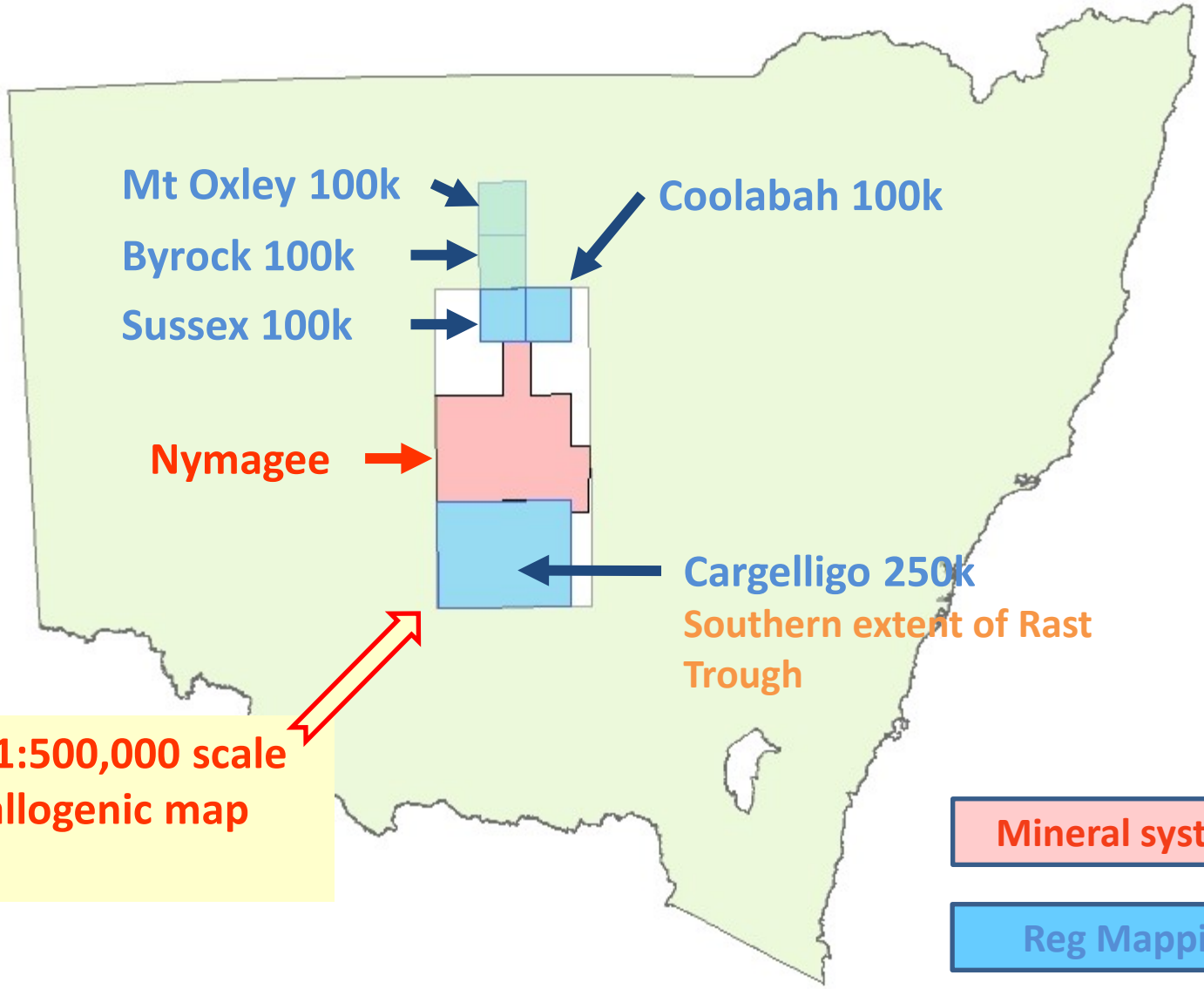
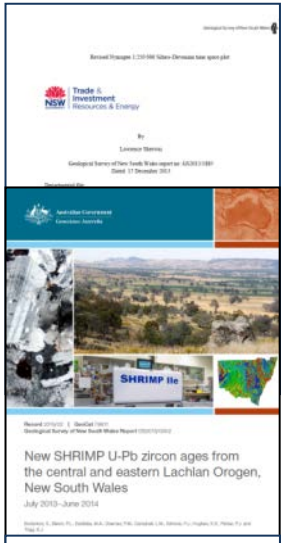
J.A. Fitzherbert, P.M. Downes, P. Blevin, R. Mawson, J.A. Talent, D. Mathieson, A.J. Simpson, C.J. Simpson and D.B. Forster

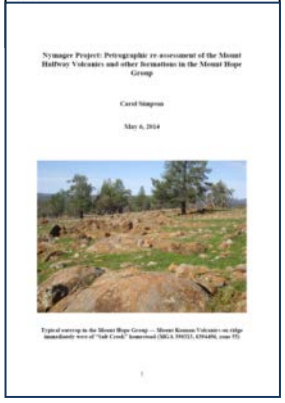
Recent GSNSW projects



Nymagee project
major findings

REPORTS





Hera

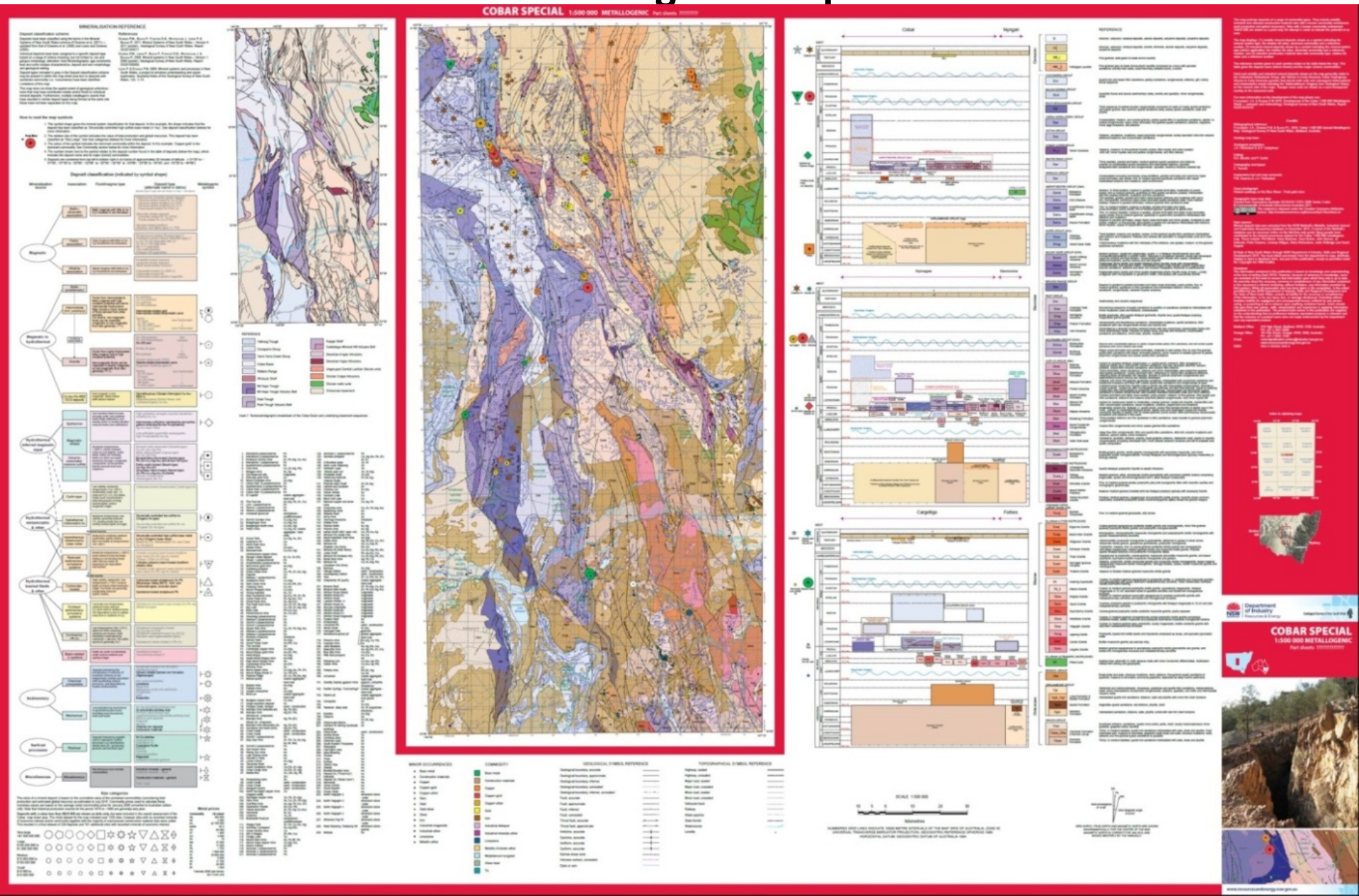
PAPERS (OTHER)

DOWNES P.M., BLEVIN P.L., BURTON G.R., CLISSOLD M.E. & SIMPSON C.J. 2013. Keys to understanding the Central Lachlan — the Nymagee mineral systems project. *AIG Bulletin* **55**, pp 53–59.

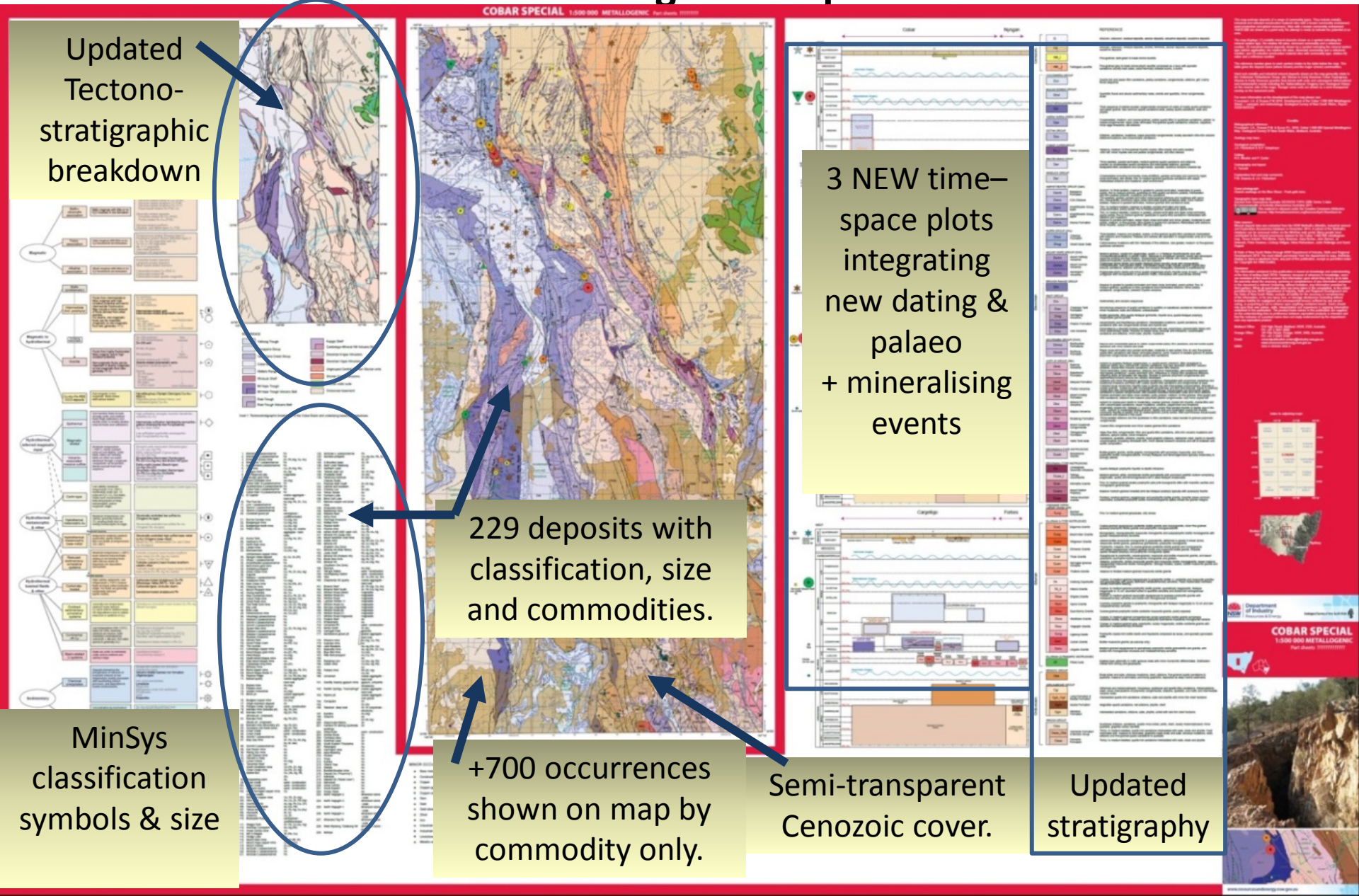
DOWNES P.M, TILLEY D.B., FITZHERBERT J. & CLISSOLD M.E. (in press). Regional metamorphism and the alteration response to selected Silurian to Devonian mineral systems in the Nymagee area, Central Lachlan Orogen, New South Wales — a HyLogger™ case study. *Australian Journal of Earth Sciences.*

DOWNES P.M & POULSON S. (in prep) Isotope signatures of selected Silurian to Devonian mineral systems in the Nymagee area — Central Lachlan Orogen, New South Wales.

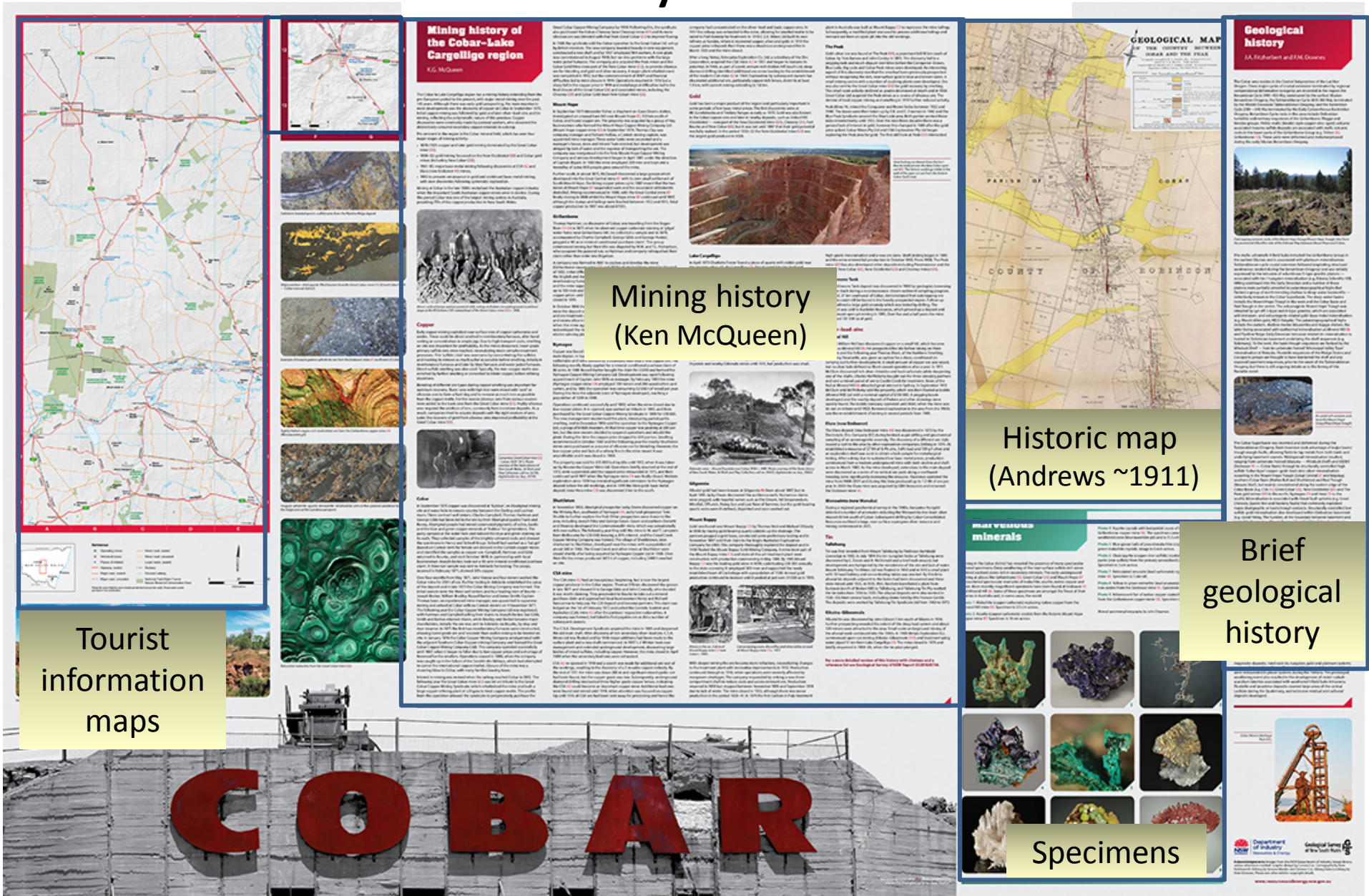
New Cobar 1:500 000 scale metallogenic map



New Cobar 1:500 000 scale metallogenic map



Back of the map
— key elements —



Tourist information maps

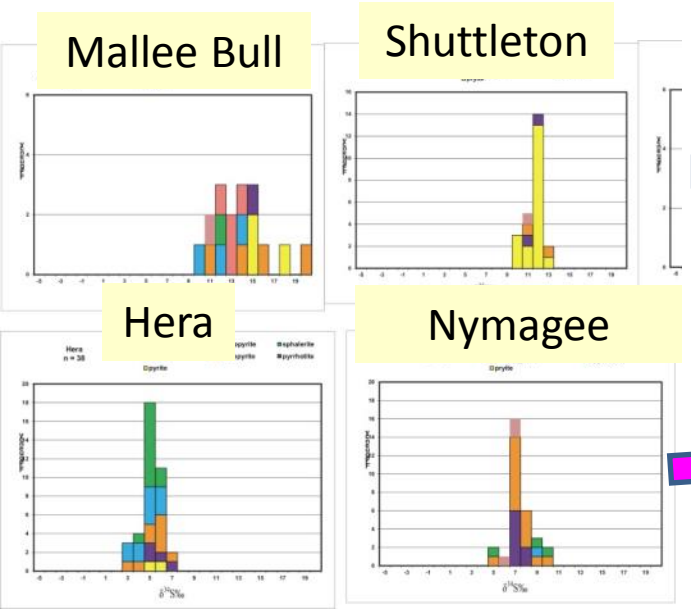
Mining history (Ken McQueen)

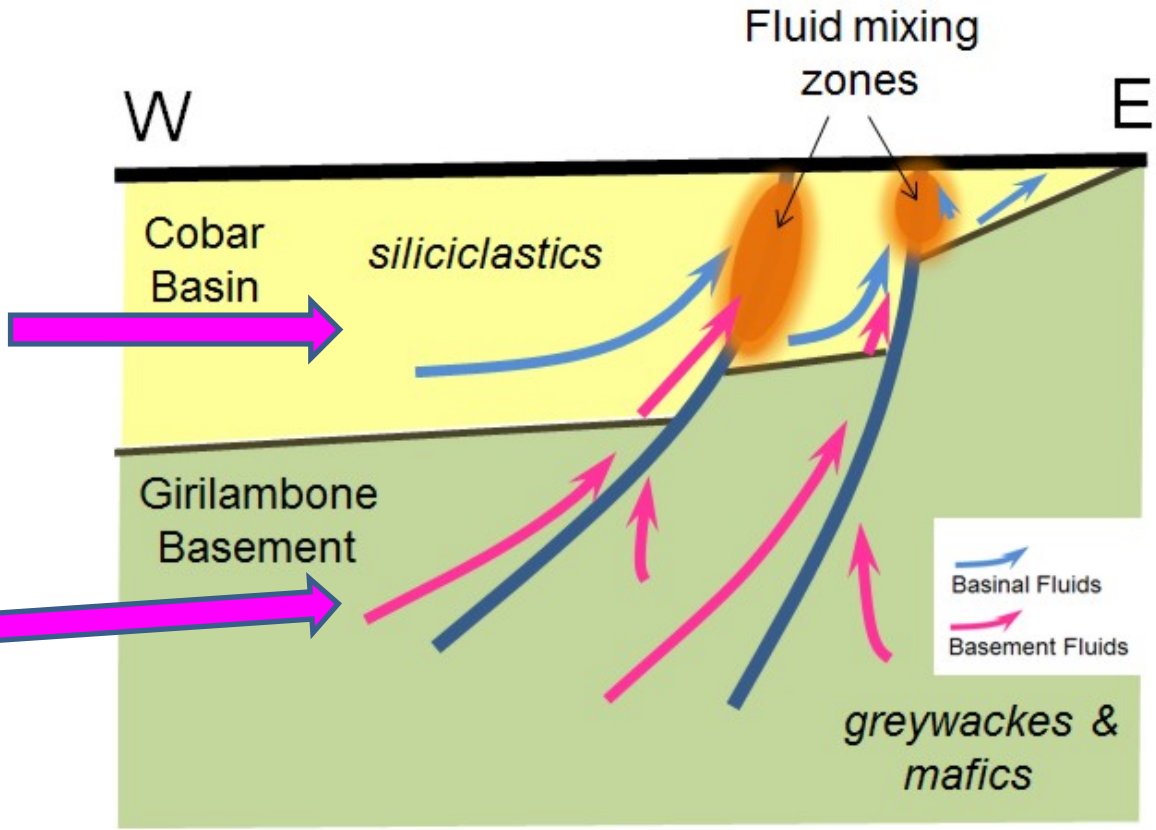
Historic map (Andrews ~1911)

Brief geological history

Specimens

Basement vs Basin derived fluids
S-isotope data



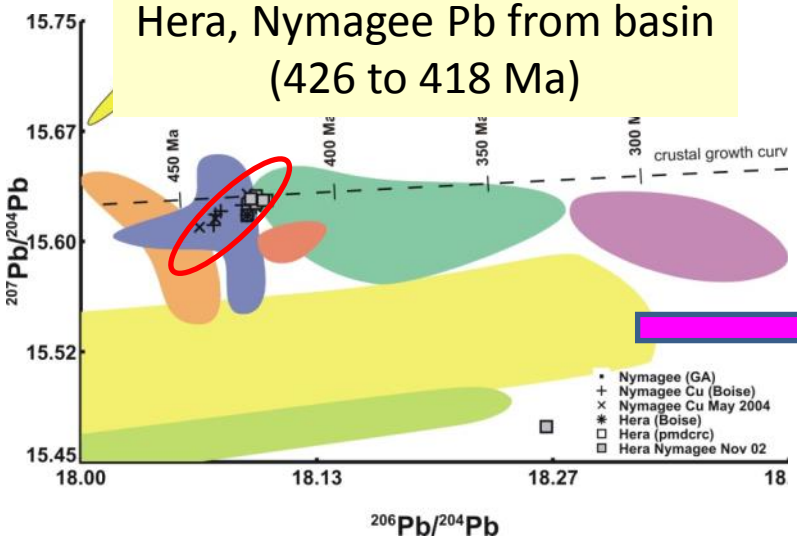


Basinal derived fluids S >8
Basement derived fluids S <~8

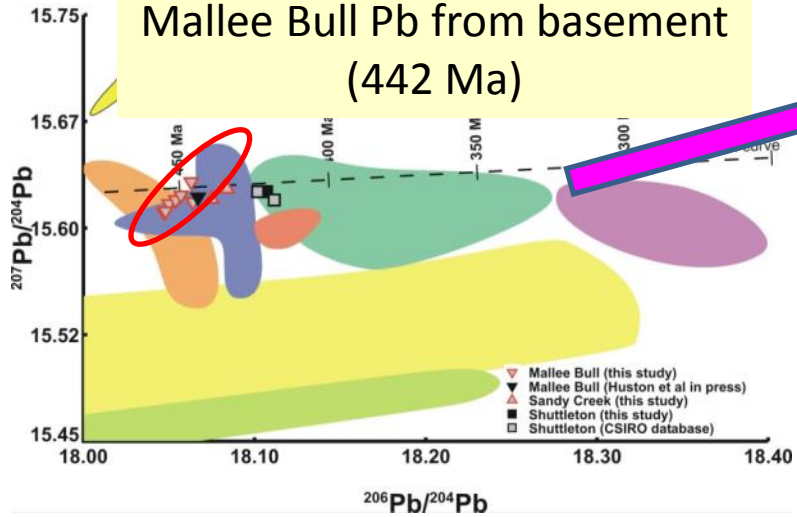
garnet at Hera

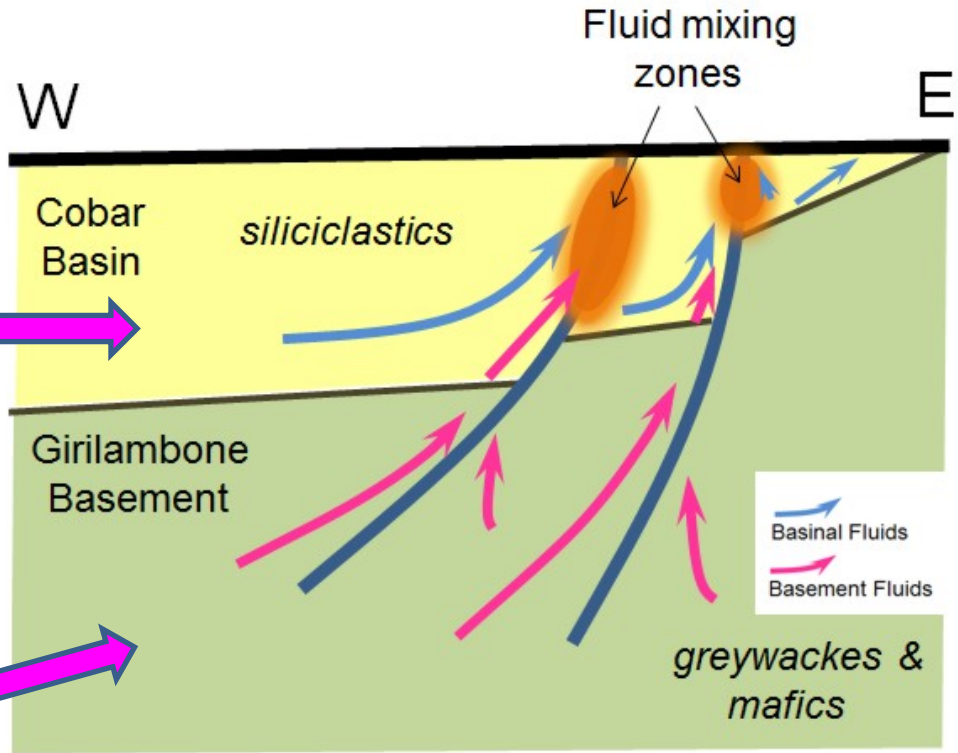
Basement vs Basin derived fluids
Pb-isotope data

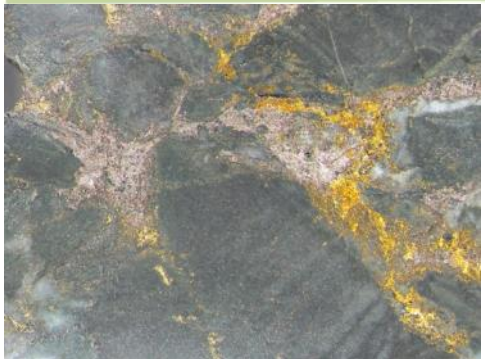
Hera, Nymagee Pb from basin (426 to 418 Ma)



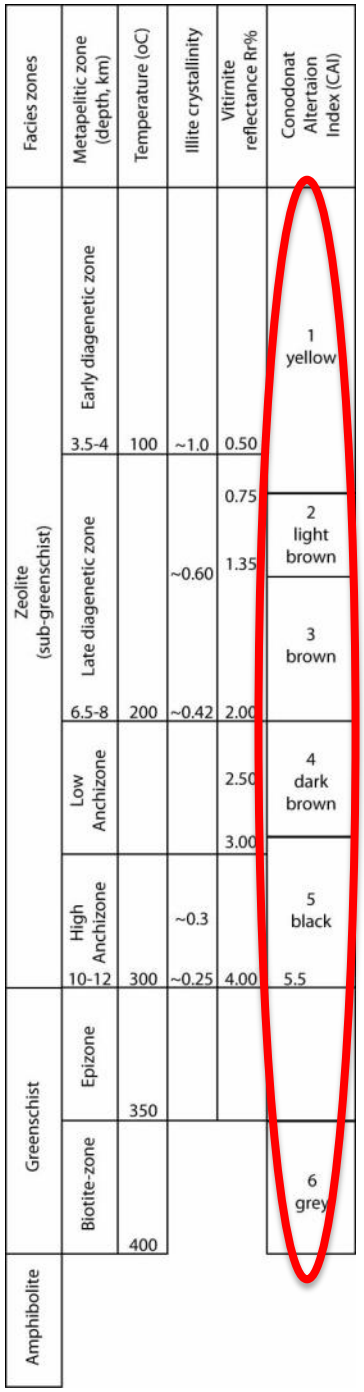
Mallee Bull Pb from basement (442 Ma)







Mallee Bull



Basin thermal maturity through to metamorphism

Diagenetic: 0-200°C
Anchizone: 200-300°C
Epizone: 300-350°C
Biotite zone: 350-400°C
Amphibolite facies >400°C

Number of methods to determine thermal maturity in very low grade pelitic rocks.

- Illite crystallinity (Kubler index)
- Vitrinite reflectance
- **CAI (Conodont Alteration Index)**

Baseline basin thermal maturity

CAI

Unaltered conodonts exhibit a pale yellow colour and a smooth surface with silky brightness (CAI 1). Exposure to increasing temperatures results in carbonization of conodont matter that produces a progressive colour sequence of light to dark brown (CAI 1.5–4) to black (CAI 5), then grey (CAI 6) and white (CAI 7).

R. Mawson, J.A. Talent,
D. Mathieson and A.J. Simpson

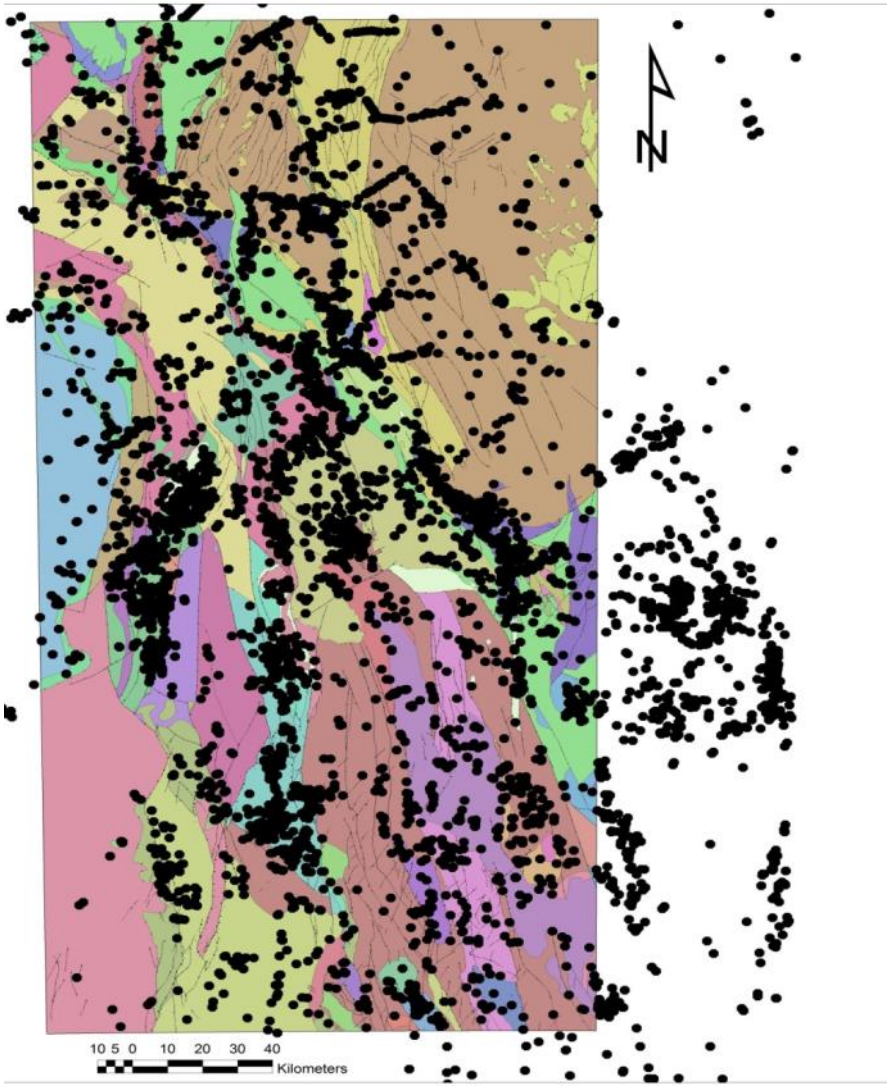
1) Virgin Hills (0-100°C)

2) The Rookery (100-150°C)

3) Manuka (150-200°C)

5) Beloura Tank (250-300°C)

Expanding to a metamorphic map



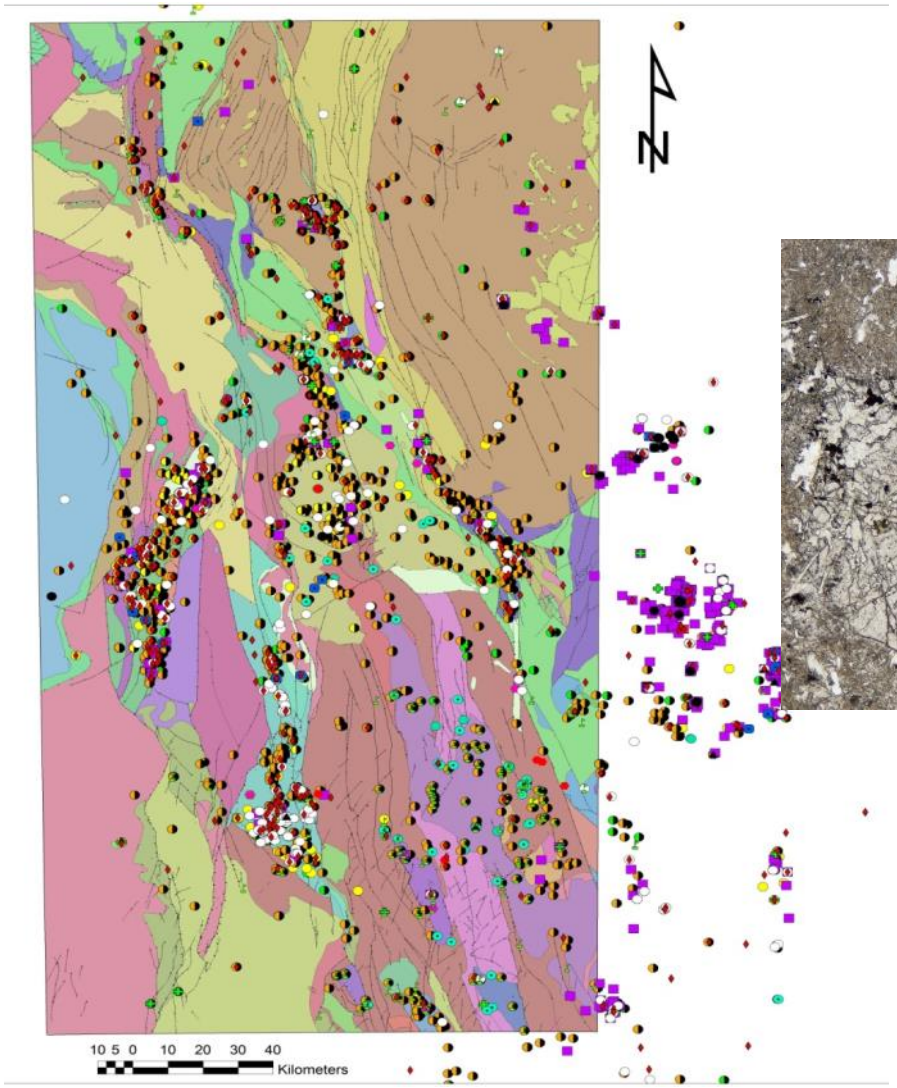
Over 11 000 petrographic observations available.

Can query these to make maps of primary and secondary mineral assemblages, metamorphic textures (e.g. granoblastic, hornfels).

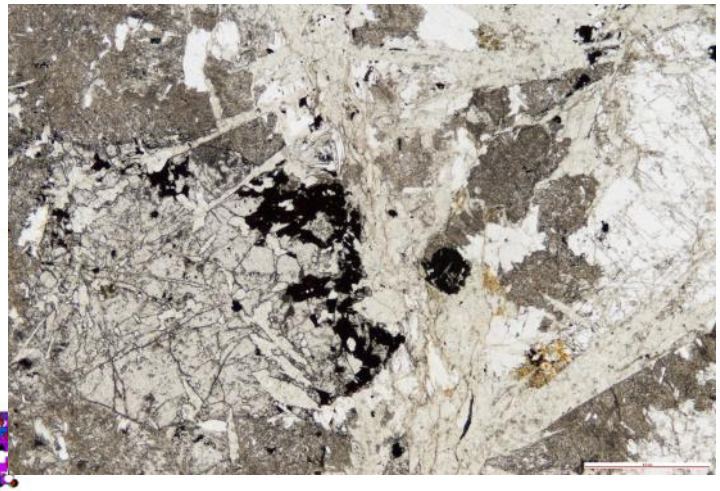
Collate all historical temperature control (CAI, mica crystallinity, mica chemistry, fluid inclusion), field observations and past metamorphic mapping for the area.

Secondary information also obtained from over 15 000 field observations

Building a metamorphic map



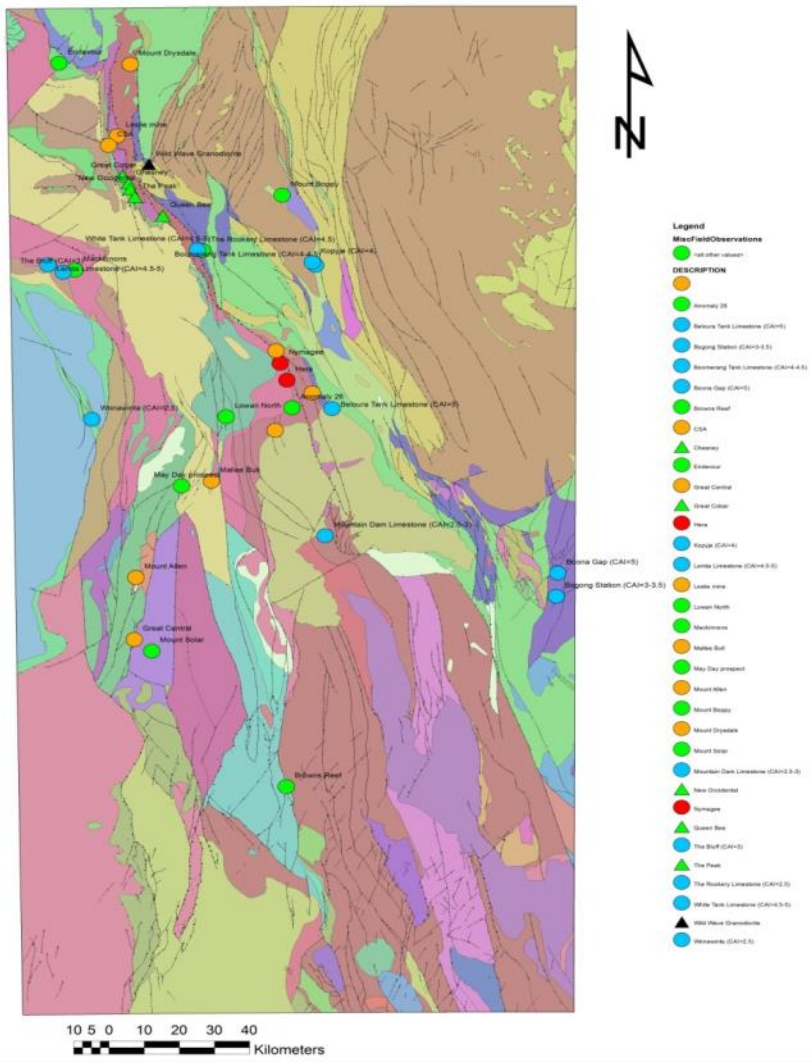
Color coded points highlighting distinctive secondary minerals.



Garnet-tremolite retrogress to chlorite-sphalerite (Nymagee Cu mine)

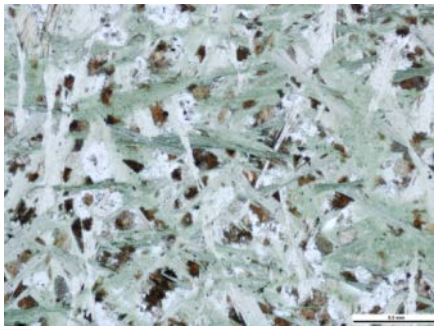
Early carbonate porphyroblasts (Elura Mine)

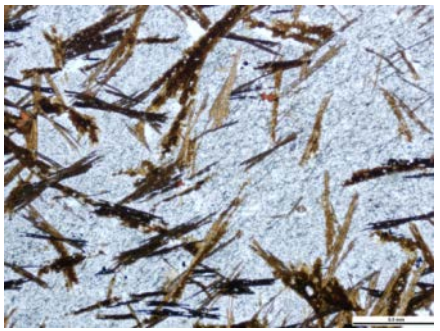
Building a metamorphic map



New petrographic and hyperspectral work conducted on selected prospects and deposits, (e.g. Nymagee, Hera, Lowan, Mount Allen, Browns Reef, Mallee Bull, May Day, Manuka, Yellow Mountain, Mineral Hill, Great Central, Mount Solar). Reassessment of all historic GSNSW thin sections from many of the other deposits.

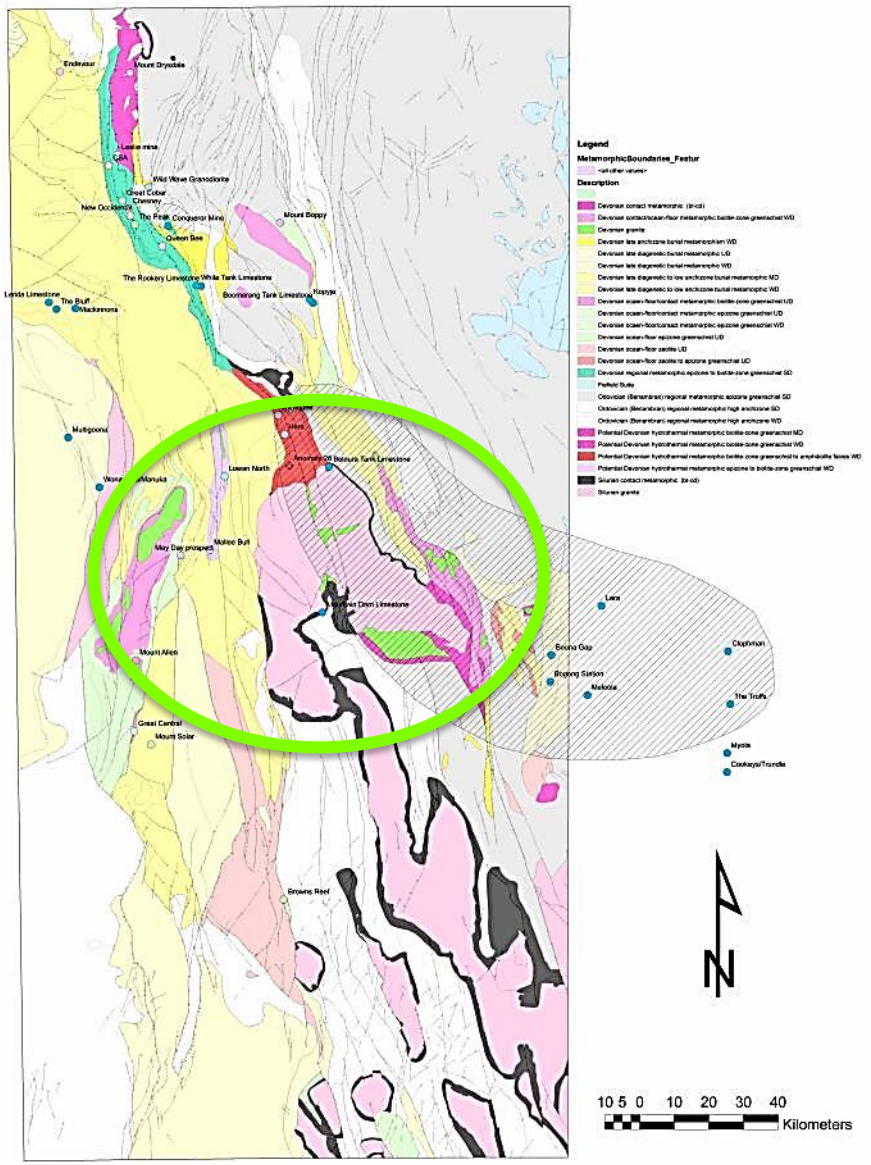
Currently working on core from Cobar mineral field (CSA, Peak and Elura).





Actinolite-biotite-stilpnomelane – Nymagee Cu mine

The metamorphic map



The basin has experienced mostly diagenetic to anchizonal, very low grade metamorphic conditions during burial and inversion (yellow), with the exception of the epizone regional metamorphic high strain zone that hosts the Cobar mineral field (**green**).

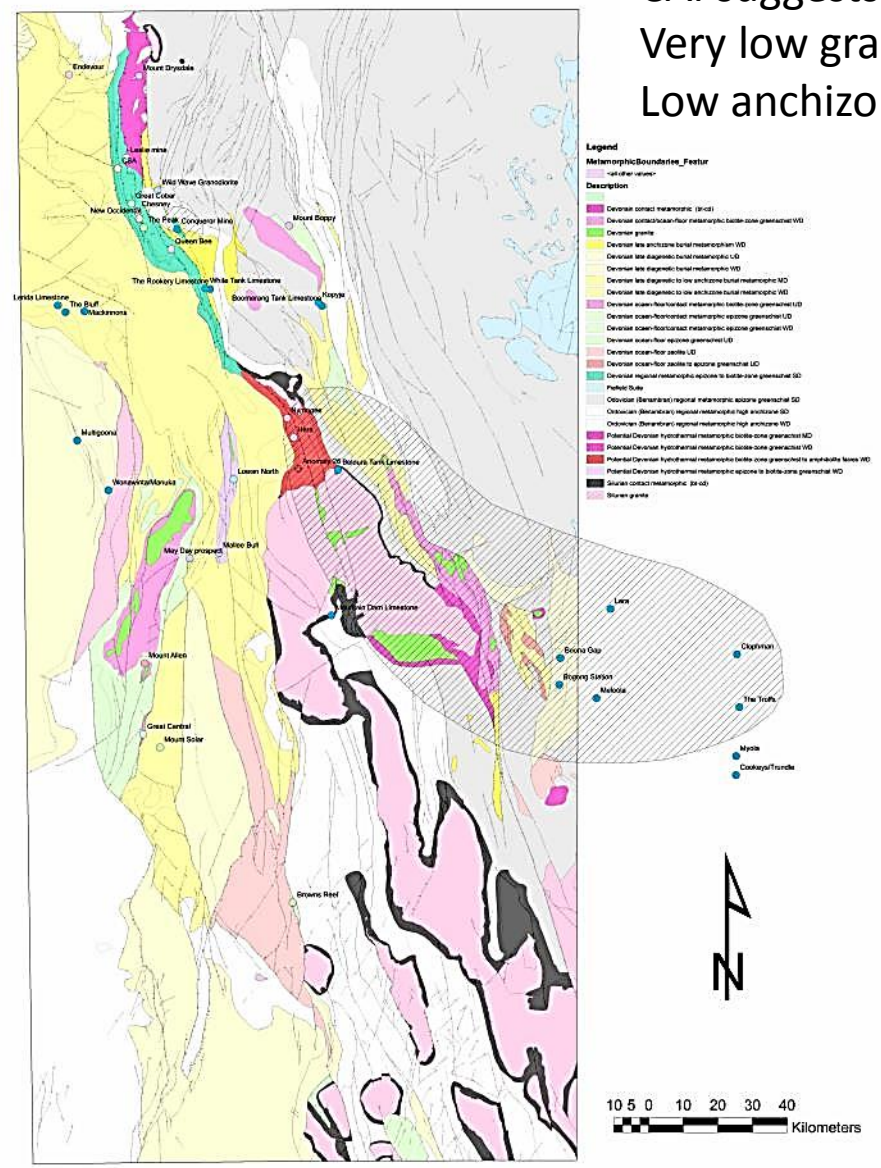
There is a disconnect between the highest grades of overprinting metamorphism and deformation. Highest grade alteration systems (pre-fabric, high-T potassic , calc-potassic to calcsilicate alteration) are actually preserved in lesser deformed sequences (red and deep purple).

Where high hydrothermal grades (350 >400^{o}C; **red** and **deep purple**) have been attained they are extremely localised (except in volcanogenic belts) and there is a strong thermal contrast between the host rocks and the metasomatic mineral associations. e.g. 10's to 100's of meters away have sub greenschist facies (~200^{o}C) basinal rocks. Strongly suggestive of a hot, proximal heat source.

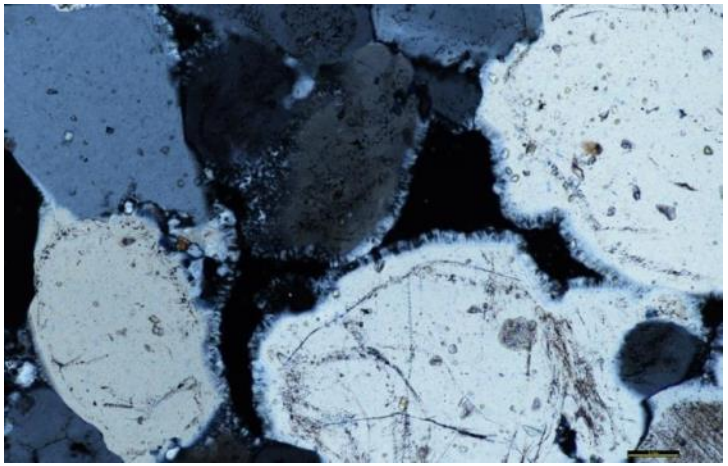
Southern thermal highs very much spatially associated with Devonian intrusions

Burial metamorphosed basin rocks…

CAI suggests
Very low grade
Low anchizone

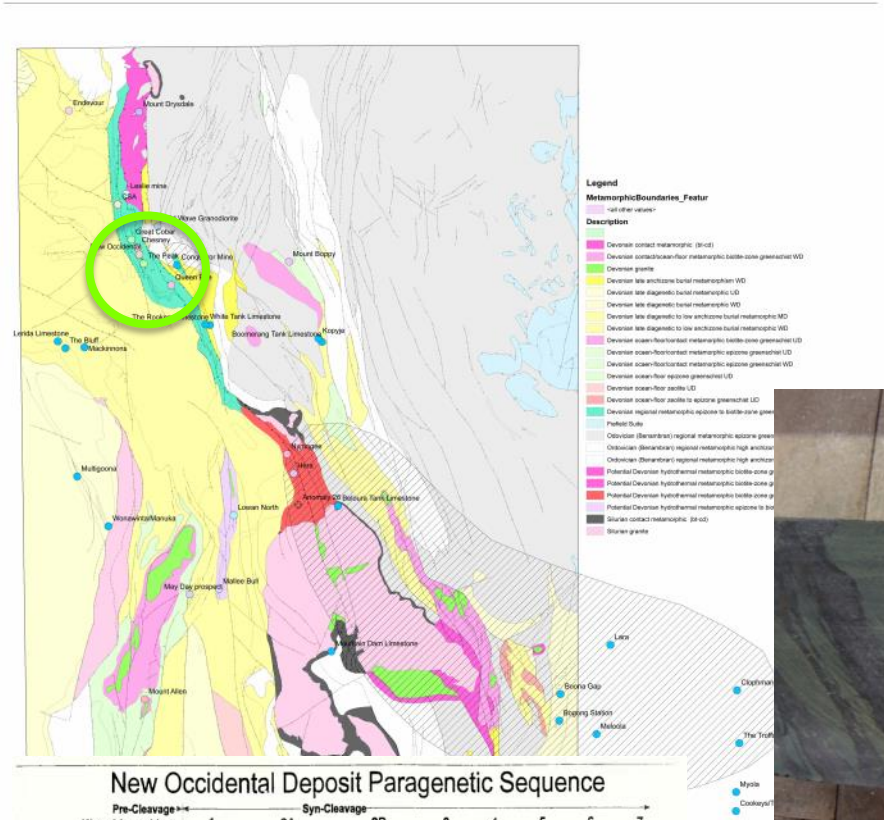


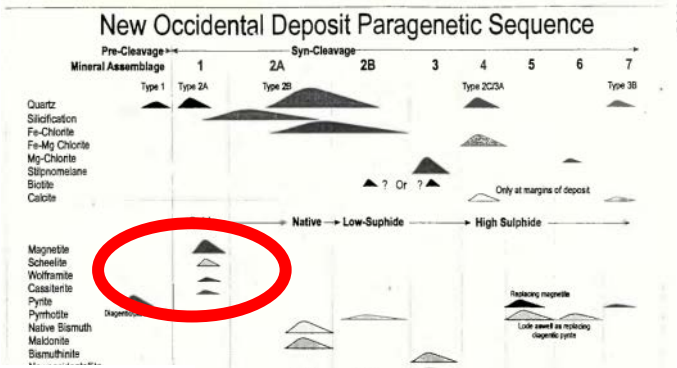
Detrital biotite and muscovite are very well preserved and the effects of deformation are weak. Amphitheatre Group.

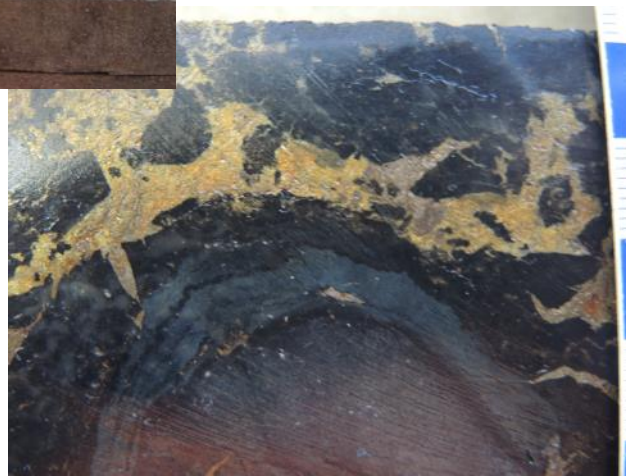


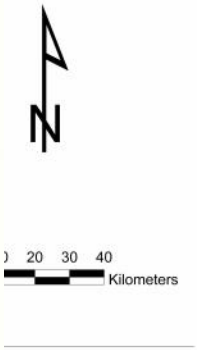
Some sandstones preserve diagenetic textures.

Epizone regional metamorphism









- Example:
- Cobar mineral field
  - Great Cobar
  - Currently examining Hylogged core from CSA, Peak and Elura… **work in progress**.

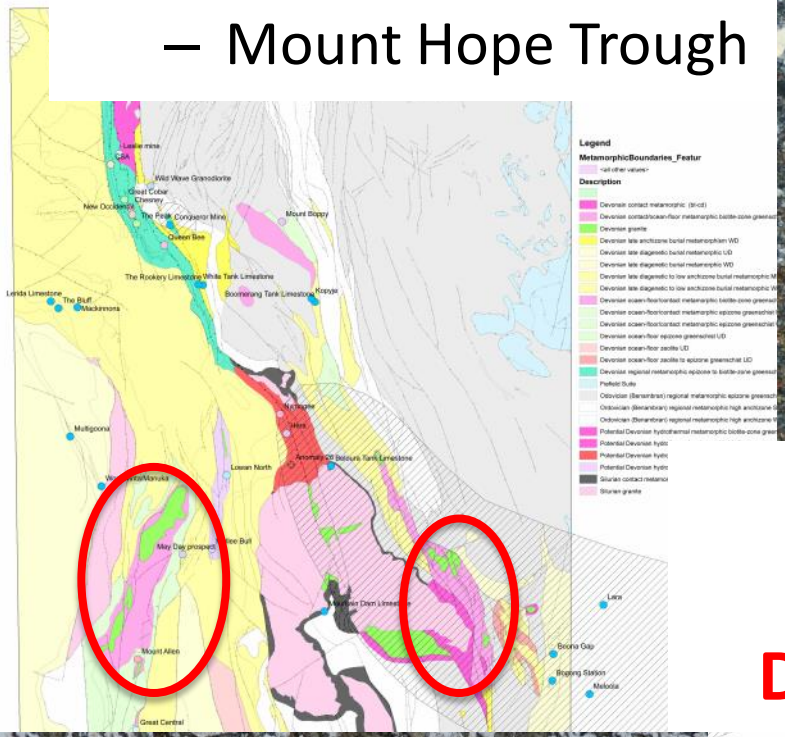
Syn-orogenic mineralisation and greenschist facies regional metamorphism

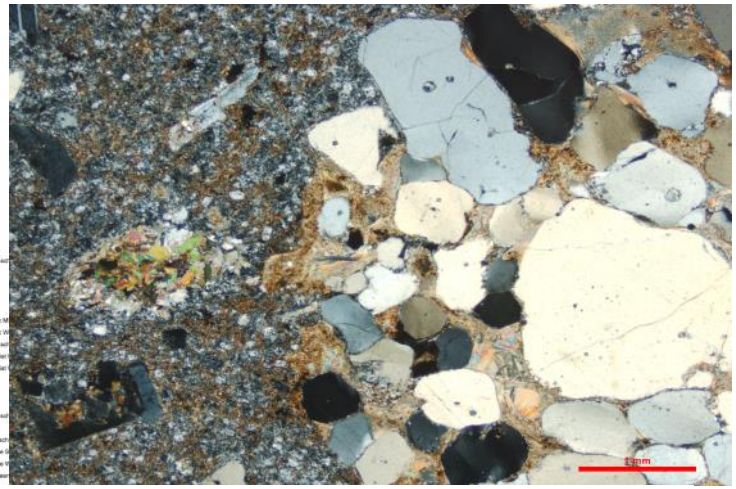
Pre- to early-syn deformation magnetite-biotite veining, with overprinting Chalcopyrite-pyrrhotite-rich mineralisation

Stegman (2000)

Syn-rift ocean floor/contact metamorphism

- Example:
  - Mount Hope Trough

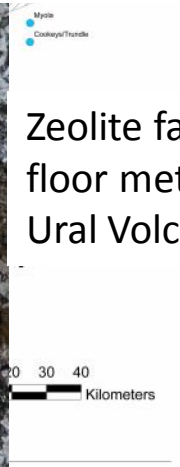




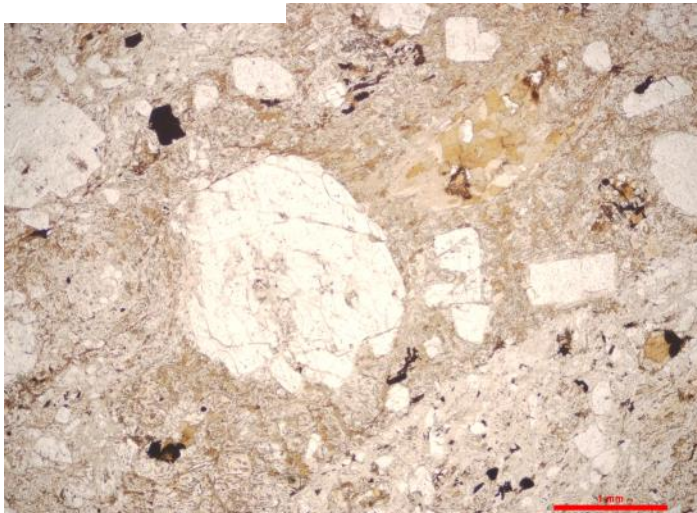
Biotite zone contact metamorphosed rhyolite with quartz sandstone clast. Mount Halfway Volcanics.

Biotite zone - association with Devonian intrusives

ocean floor
osed rhyolite.
canics.



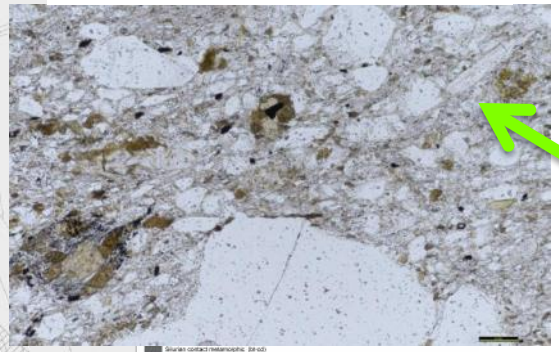
Zeolite facies ocean floor metamorphism. Ural Volcanics.



High-T hydrothermal metamorphism

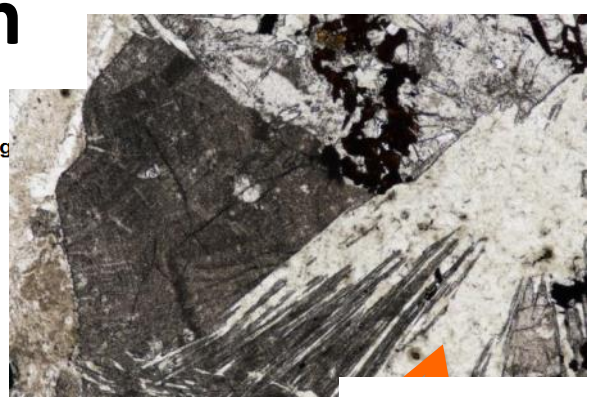
Example: Southeastern Cobar Basin Nymagee-Hera

~200°C ıed deformed, detrital biotite



~350°C

Biotite porphyroblasts enveloped by chlorite foliation. Nymagee mine



Skarn-like Garnet-tremolite. Nymage mine

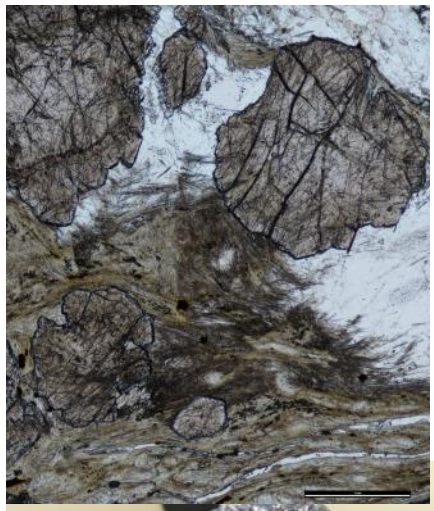
~400°C

High-T hydrothermal metamorphism

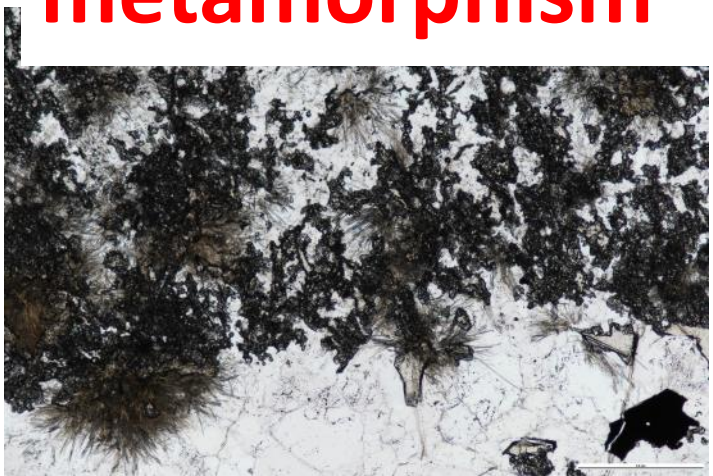
In and around mineralisation - Hera

Skarn-like calcsilicate alteration (garnet-tremolite-zoisite).

Very similar to Nymagee ~200°C thermal contrast between host basin sequences and high-T hydrothermal metamorphism

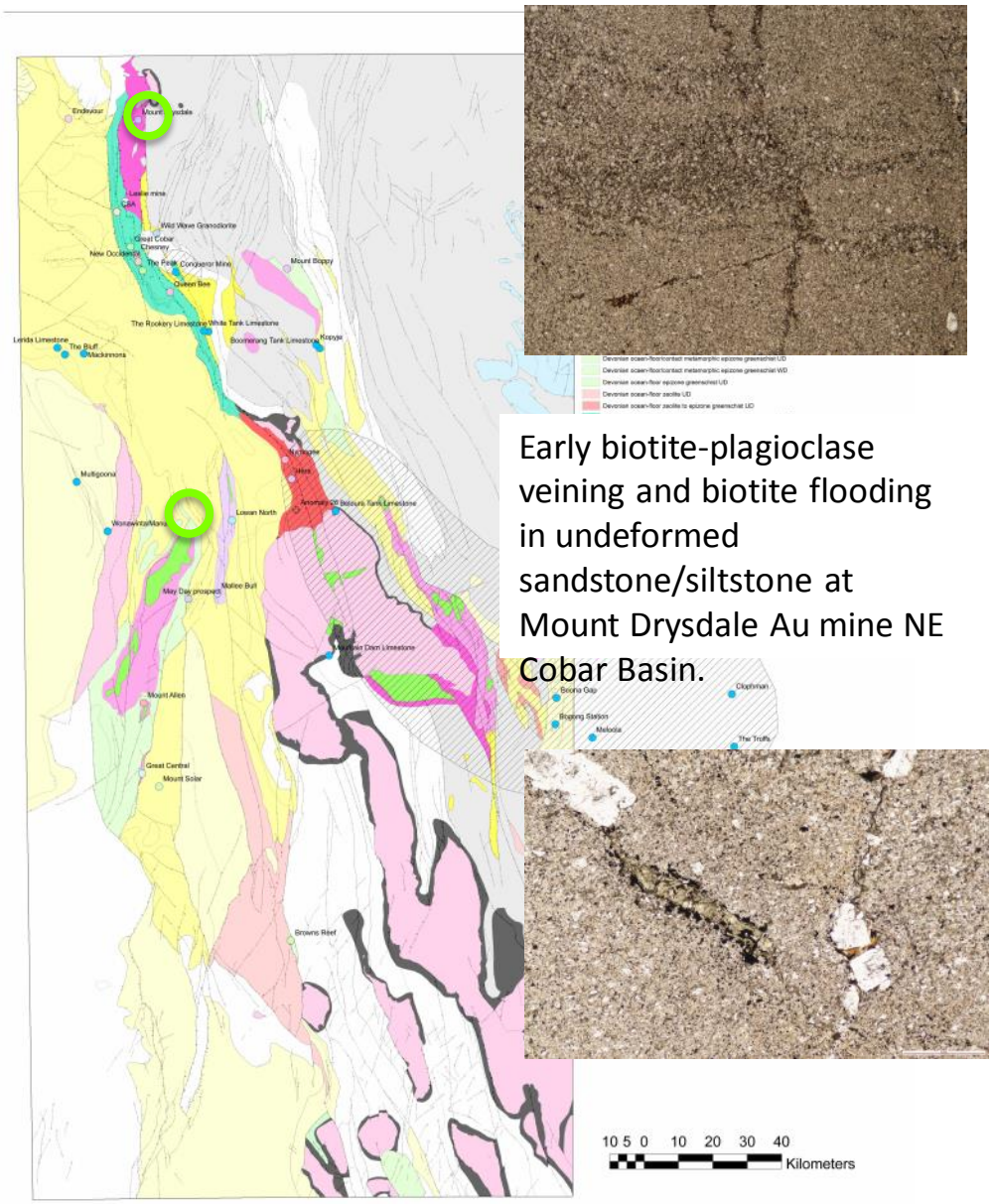


Garnet-rich veins from Hera, along with abundant garnet with sulfide. (courtesy of Adam McKinnon, Aurelia)



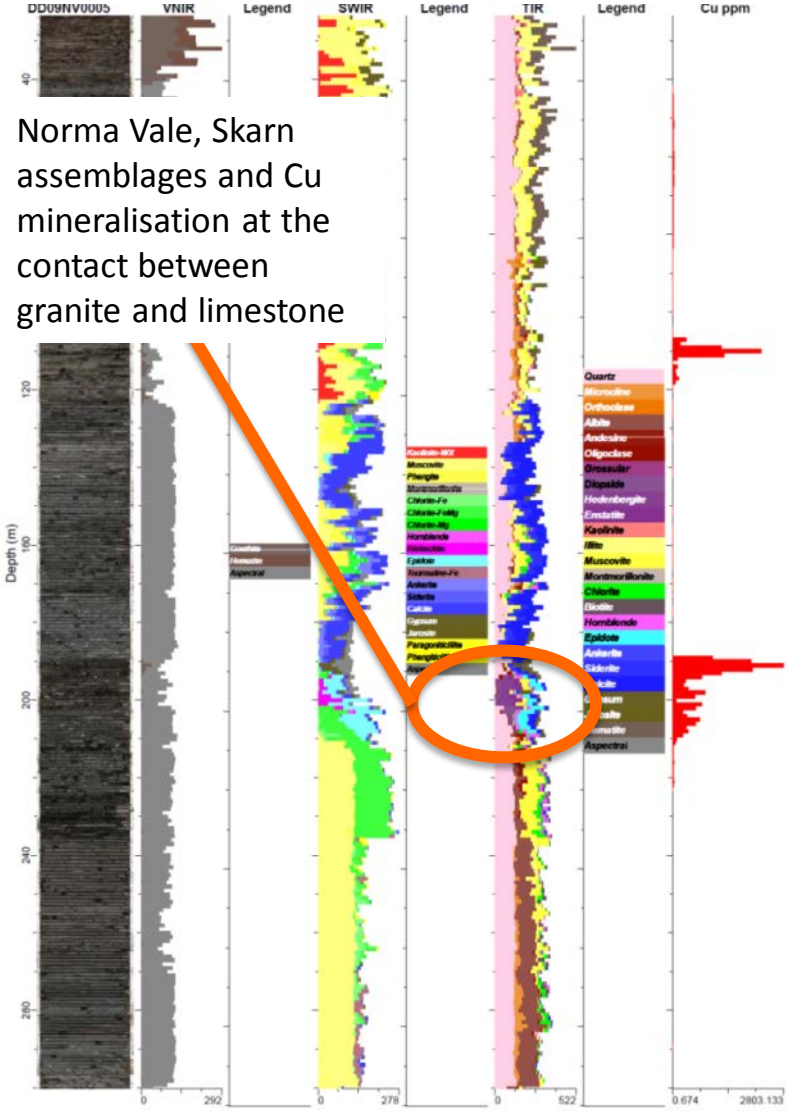
High-T associations early, subsequently deformed

Do we see the same elsewhere?



Early biotite-plagioclase veining and biotite flooding in undeformed sandstone/siltstone at Mount Drysdale Au mine NE Cobar Basin.

Norma Vale, Skarn assemblages and Cu mineralisation at the contact between granite and limestone



High-T hydrothermal alteration: What would we expect?

Syn-rift/magmatic:

Mineralisation/alteration need not have a temporal or spatial relationship with regional metamorphic grade or deformation. To the contrary, alteration systems associated with mineralisation would be expected to predate regional metamorphism and deformation and may have a temporal or possibly spatial relationship to magmatic rocks and basin forming faults.

High thermal contrast may exist between low-grade, host basin lithologies and magmatically heated/derived hydrothermal fluids proximal to a causative magmatic body.

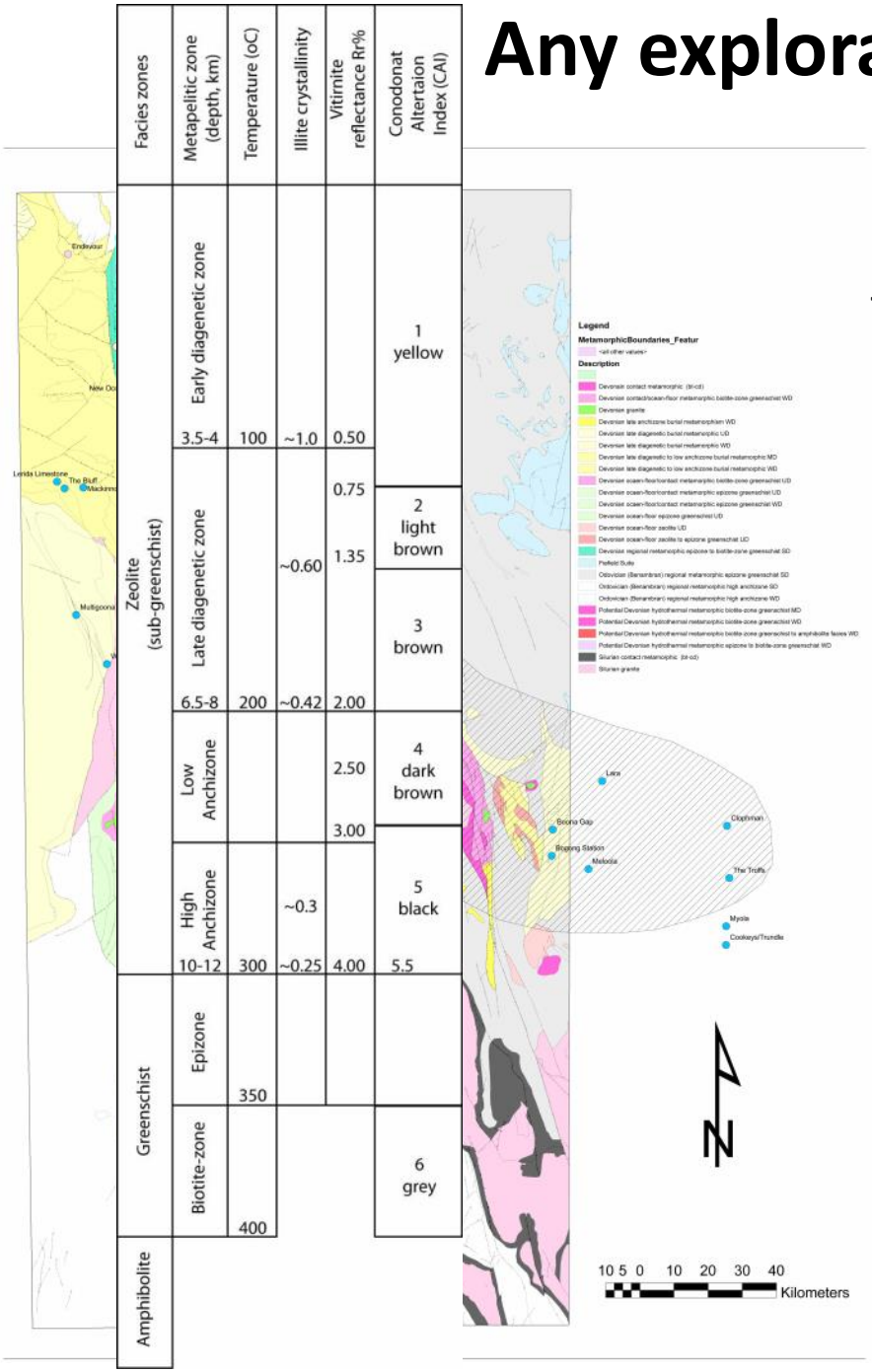
Orogenic (structurally controlled):

Mineralisation/alteration should display a temporal and spatial relationship with deformation and regional metamorphic grade.

Distant dehydration-derived fluids cool during ascent through large rock volumes and thermal contrast between buried basin lithologies and alteration should be limited. Indeed hydrothermal alteration associated with the vast majority of orogenic gold deposits is within 100°C of the peak, often epizone (300±50°C) metamorphic temperatures experienced by the host rock sequences (Grooves et al 1998).

If hot, dehydration-derived hydrothermal fluids from a deeper (amphibolite facies) source is to be invoked then peak (highest-T) hydrothermal alteration would also be expected to occur late in the orogenic cycle at upper crustal levels, allowing time for fluid generation and migration from deeper levels (Grooves et al 1998; Grooves et al 2000; Hagemann & Cassidy 2000; Grooves et al 2003; Goldfarb et al 2005).

Any exploration implications?



Follow the heat near basin forming faults

Thermal highs in very low grade basin rocks associated with mineralisation.

Deposit-scale thermal studies to basin-scale maps:

- New petrography
- CAI

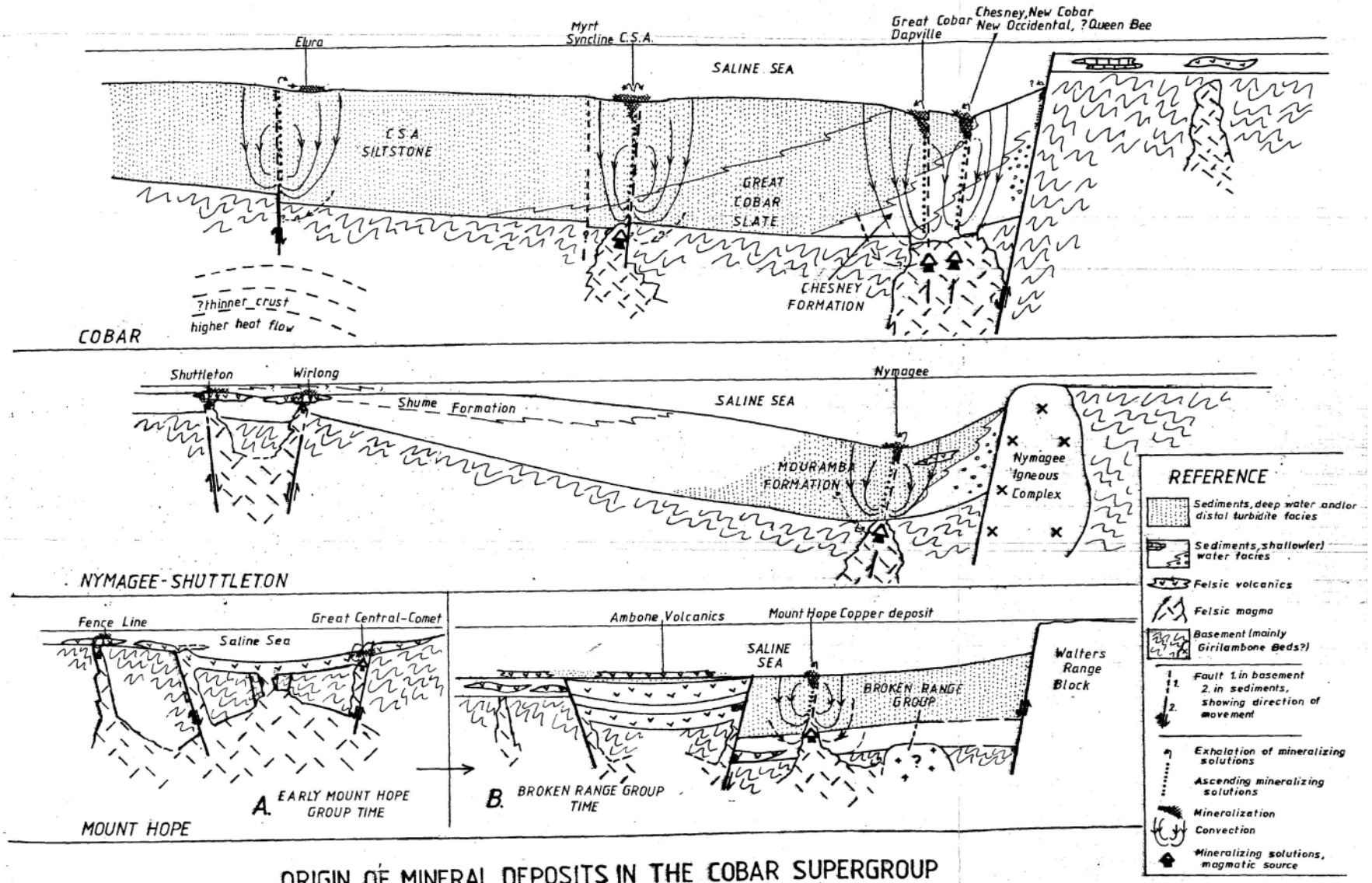
Most effective method for mapping temperature in VLG pelitic rocks is…

Illite or white mica crystallinity

- Kubler Index

For contact metamorphism the crystallinity-defined aureole may be up to 3 times the size of the petrographically defined aureole.

Same for hydrothermal metamorphism?



ORIGIN OF MINERAL DEPOSITS IN THE COBAR SUPERGROUP

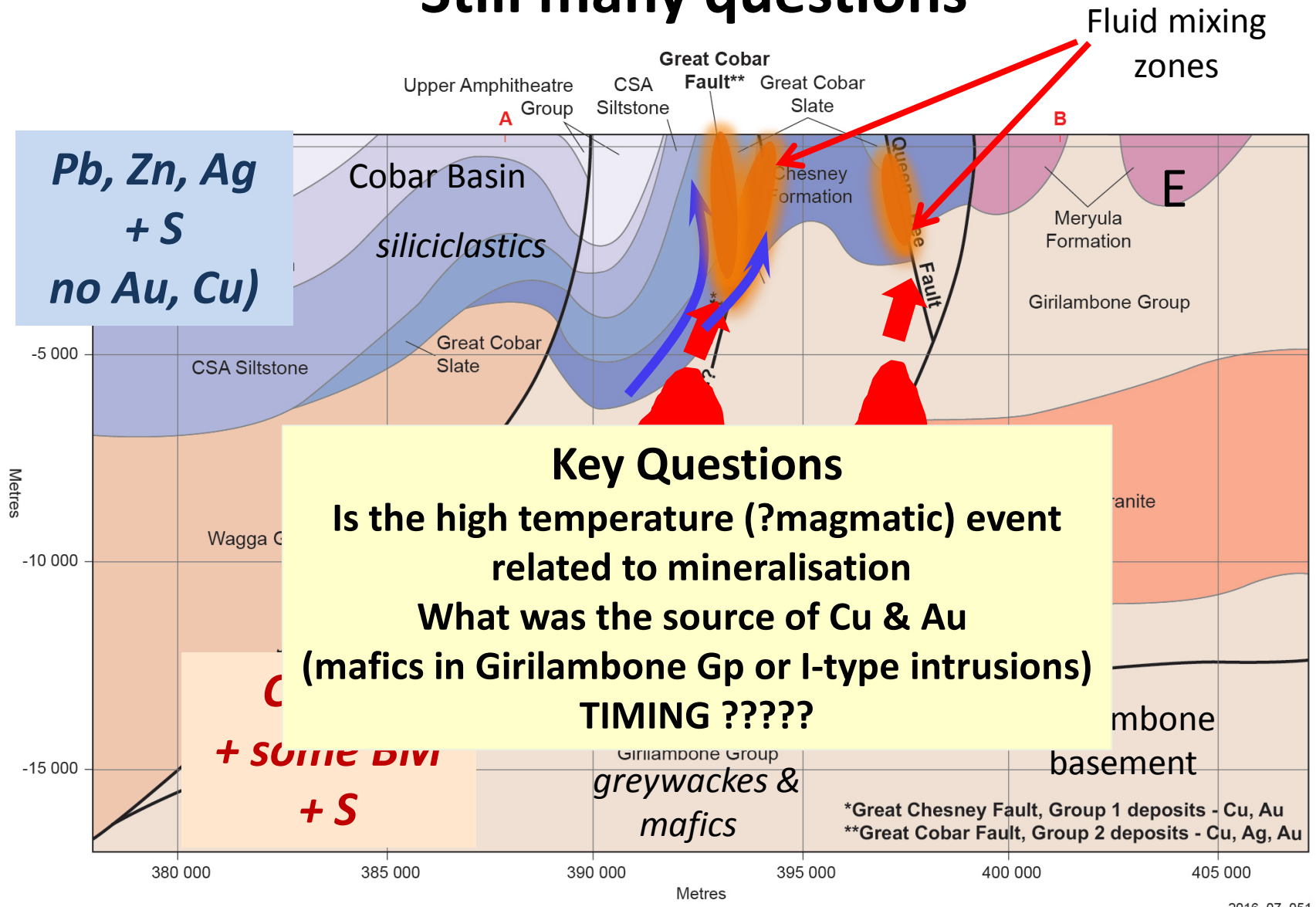
COBAR SYNCLINORIAL ZONE

(HIGHLY DIAGRAMMATIC)

FIGURE 5·1

Suppel DW, 1984 A study of mineral deposits in the Cobar Supergroup, Cobar region, New South Wales. MSc. UNSW (unpubl).

Still many questions



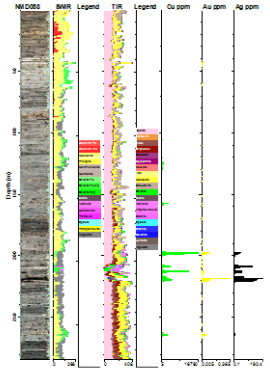
early high T ?magmatic fluid/heat

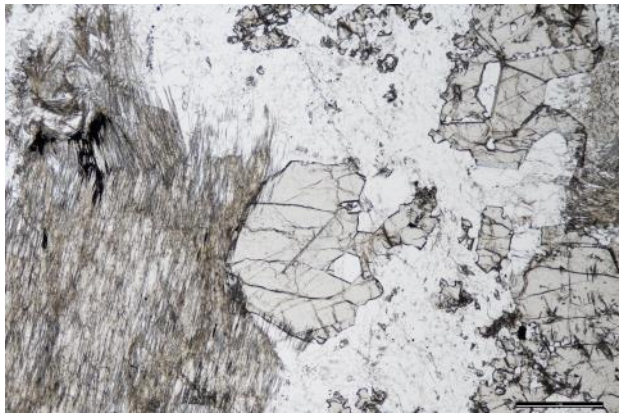
Basinal fluids

Basement fluids

In the Pipeline……

- Petrographic work following up HyLogger scanning .
- Sm-Nd dating of garnet from high-T alteration systems at Nymagee and Hera.
- δO-δD of tremolite in high-T alteration zones from Nymagee and Hera.
- Dating of titanites at Hera.
- *Bi-Act-Gt just reported at Cobar.*
- EMP analysis of minerals.
- Sr, Nd characterisation of fibrous white tourmalines from Hera.





Studies?

BRING OUT YOUR DEAD

Chasing intrusive rocks and alteration minerals to date!

Any limestones?

CBH Resources Limited

Aeris RESOURCES

aurelia METALS Ltd.

newgold Peak Gold Mines Pty. Ltd.

Australian Government
Geoscience Australia

Australian National University

CSA Mine

peel mining LIMITED

MINCOR RESOURCES NL

KBL Mining Limited

AuScope

POLYMETALS MINING LIMITED

INCORPORATING MMG

五礦資源有限公司
MINMETALS RESOURCES LIMITED

KIDMAN RESOURCES

UNIVERSITY OF WOLLONGONG

University of Nevada, Reno

NSW Department of Industry Resources & Energy

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

THE UNIVERSITY OF MELBOURNE

Clancy Exploration

CCR Silver Corporation of Australia

Geological Survey of New South Wales