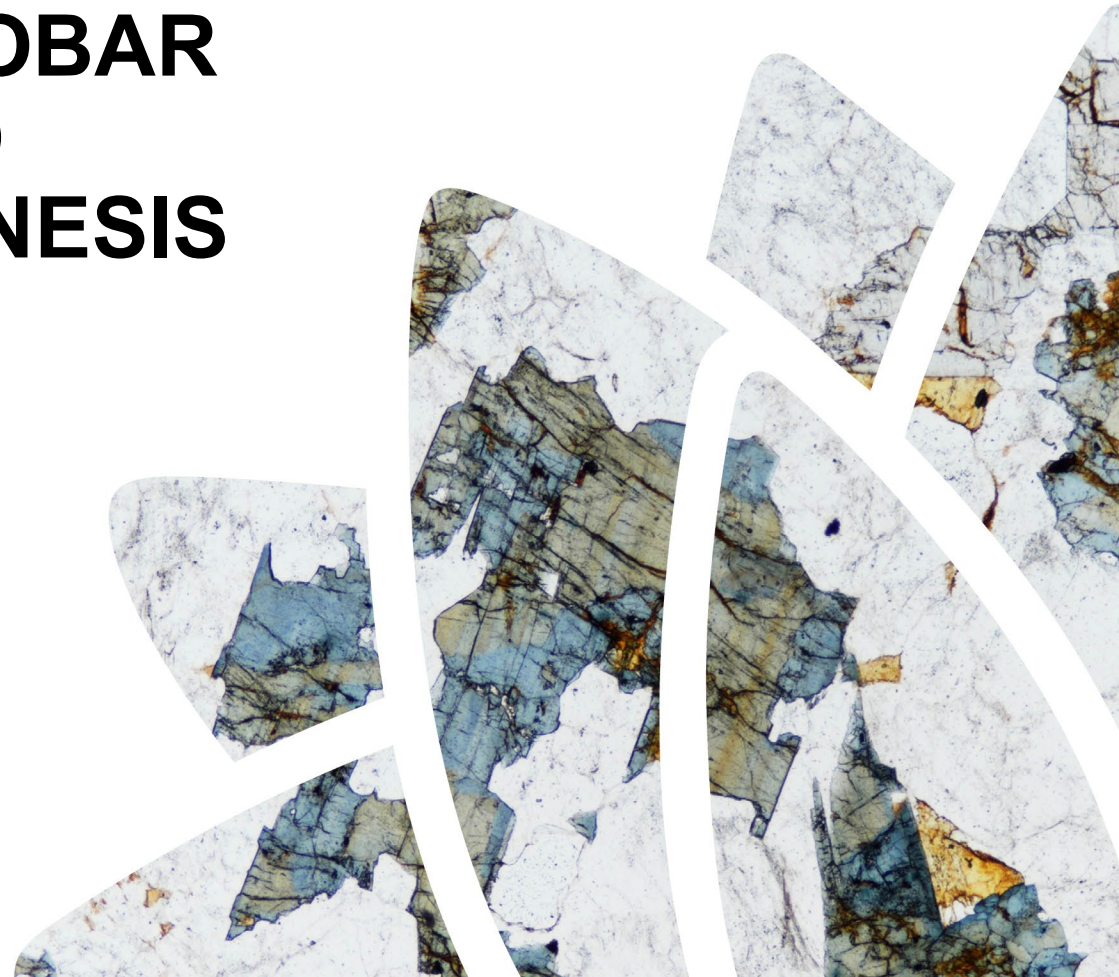
Mining, Exploration & Geoscience

NSW GOVERNMENT

DISTRICT-SCALE CHARACTERISTICS OF MINERALISATION IN THE COBAR SUPERBASIN: ATTEMPTING TO UNDERSTAND TIMING AND GENESIS

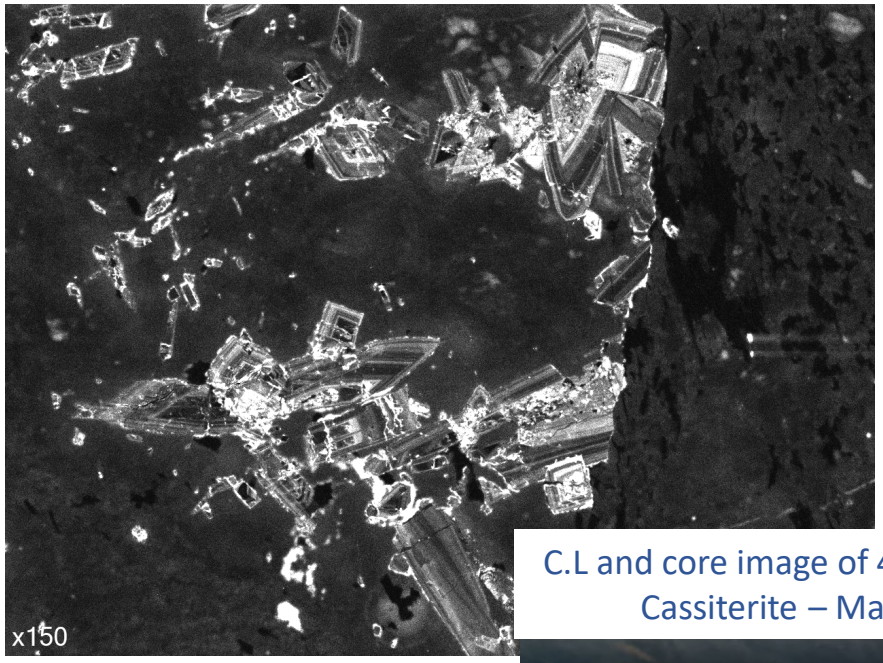
Joel Fitzherbert

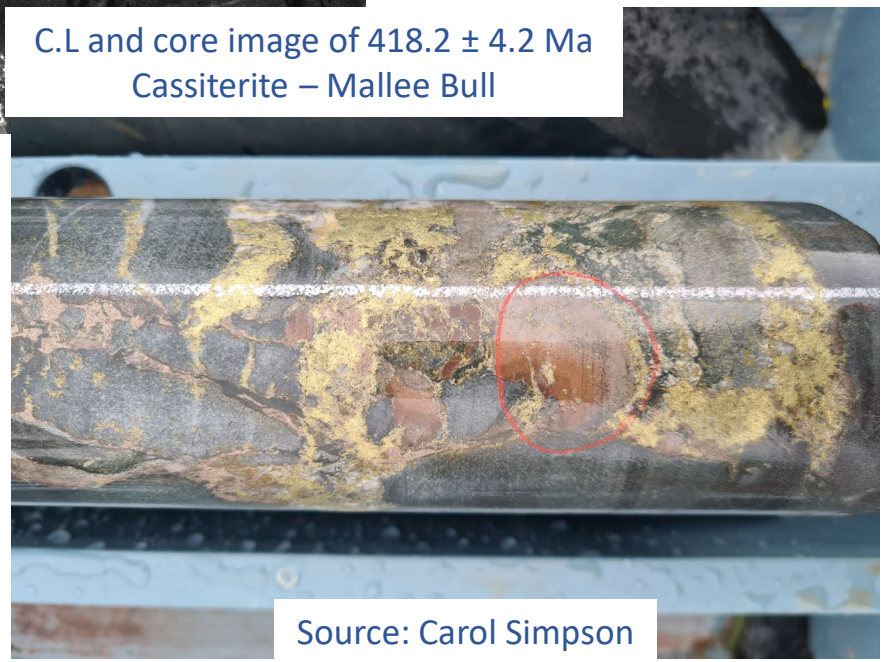
May 2022



District-scale features in this presentation

- **Geochronology**
  - Intrabasin magmatism
  - Structure (faults/foliations)
  - Mineralisation
- **Lead and Sulfur**
  - Spatial variation and relationship to geochronology
- **Models of basin evolution**





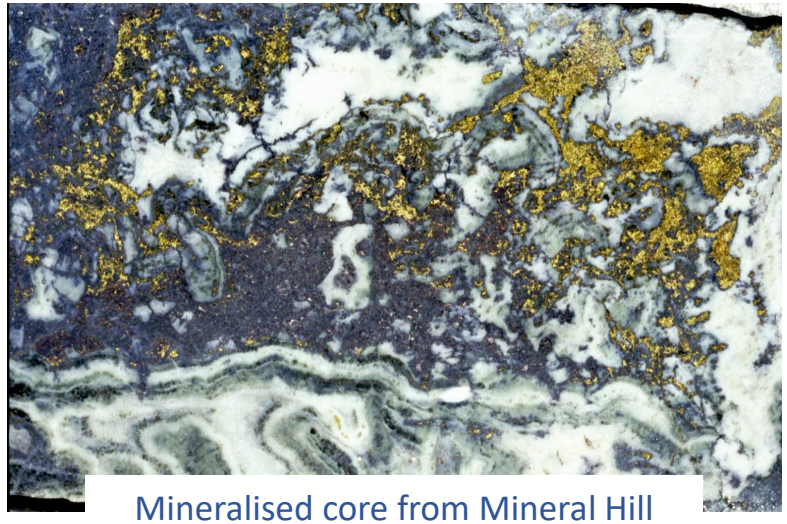
C.L and core image of 418.2 ± 4.2 Ma Cassiterite – Mallee Bull

Source: Carol Simpson

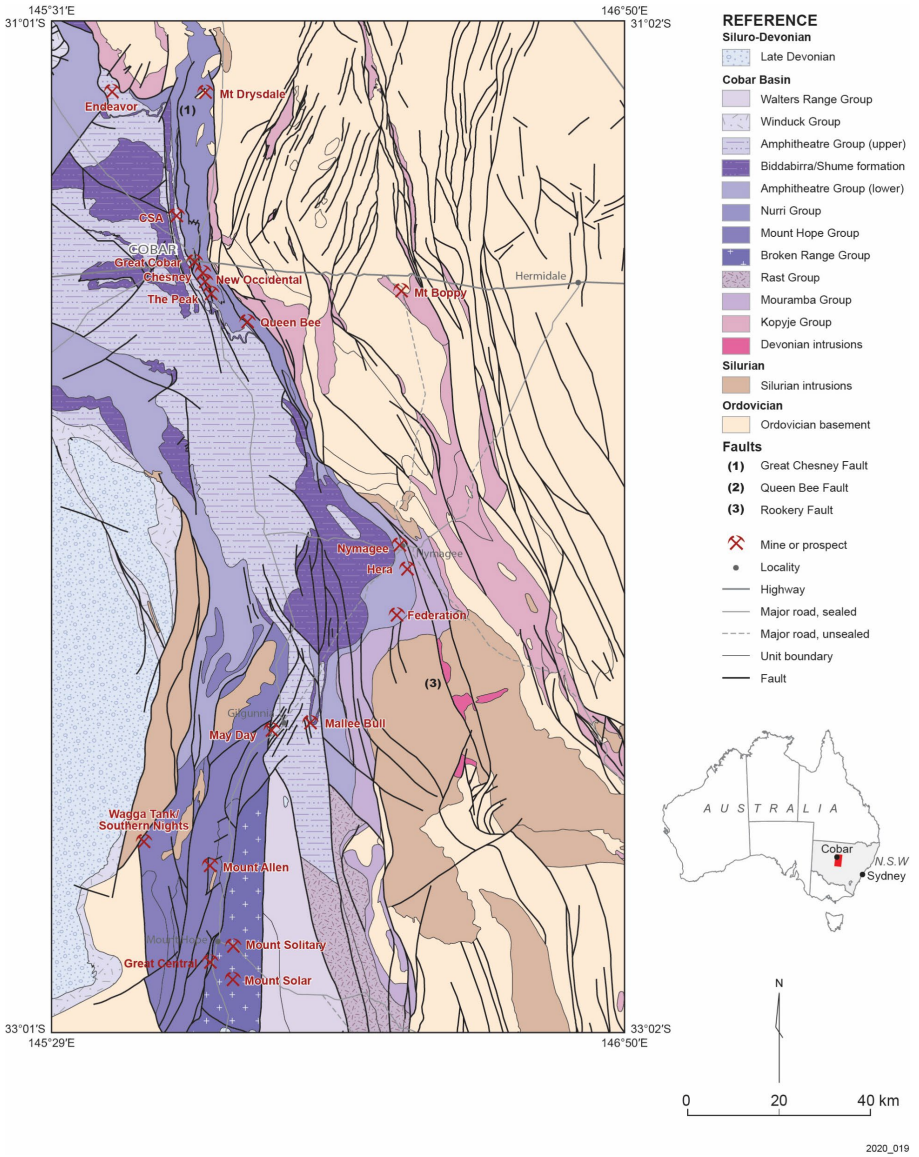
NSW GOVERNMENT

Cobar Superbasin in a slide

- Extension and stratigraphy
  - 420-405 Ma transtension
    - Rapid basin deepening
    - Volcanism underlying and interfingering with deepening turbiditic sequences
    - Blanketed by amagmatic turbiditic sequences
- Compression and deformation
  - 400-380 Ma transpression
  - Basin inversion
- Mineralisation (Cu-Au-Pb-Zn-Ag)
  - Enigmatic genesis
    - VMS, IR, orogenic base metal-Au, skarn etc....



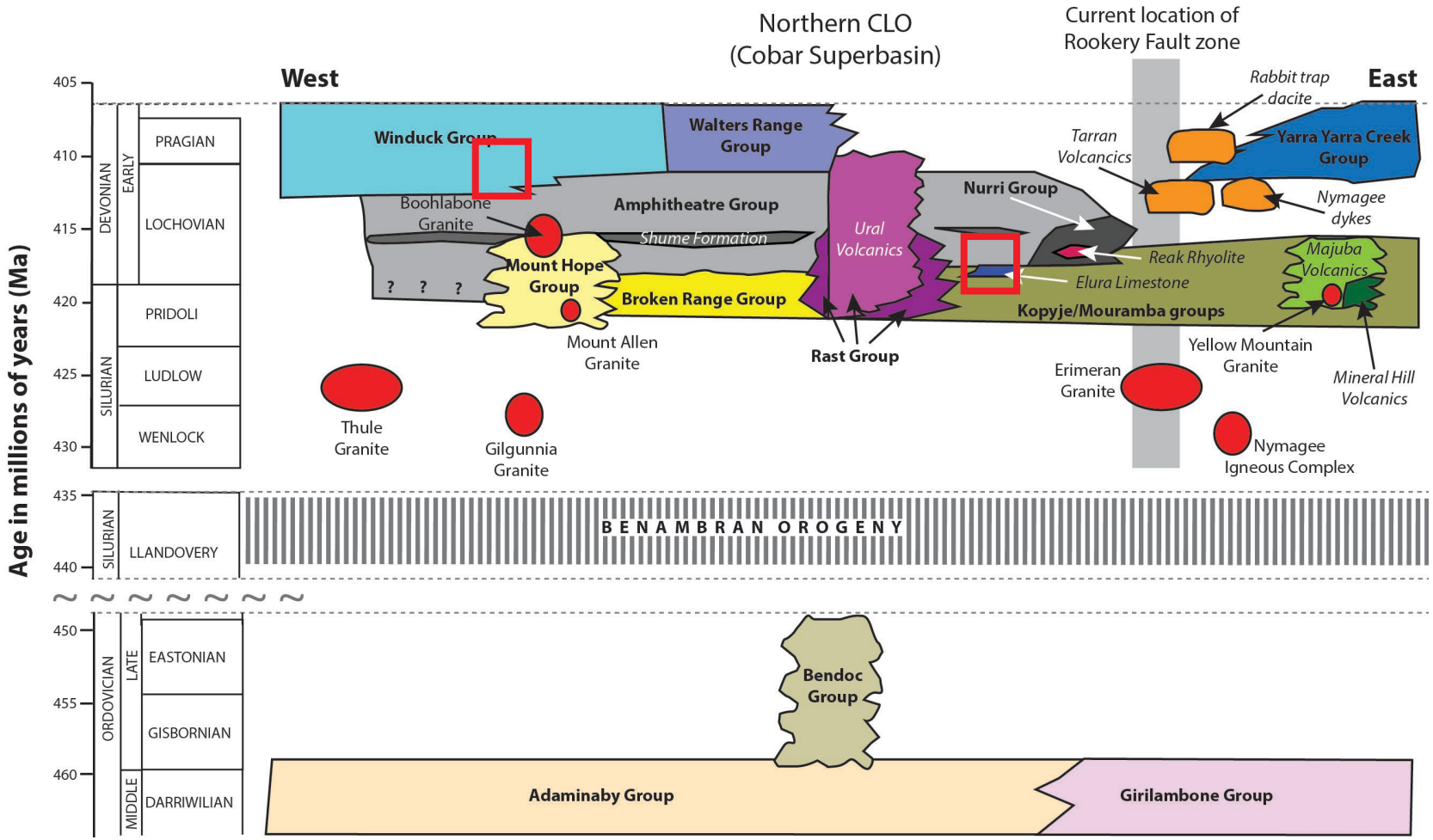
Mineralised core from Mineral Hill



NSW GOVERNMENT

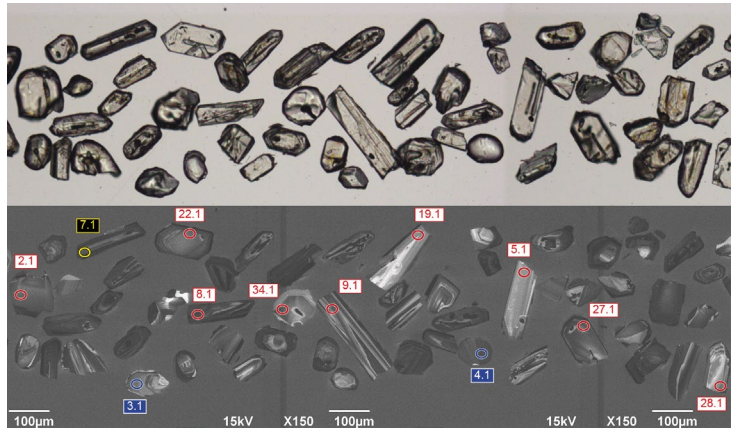
Cobar Superbasin time-space

- **Cobar Superbasin**
  - Intrabasin Magmatism between 423-409 Ma
  - Sediment deposition 420-405 Ma
    - Elura Limestone - Lochkovian
    - Booth Limestone (Winduck Group) - Pragian
- **Basement**
  - Ordovician turbidite
    - Girilambone Group (east)
      - Includes mafic volcanic/intrusive
    - Adaminaby/Bendoc Groups (west)
  - Silurian granite

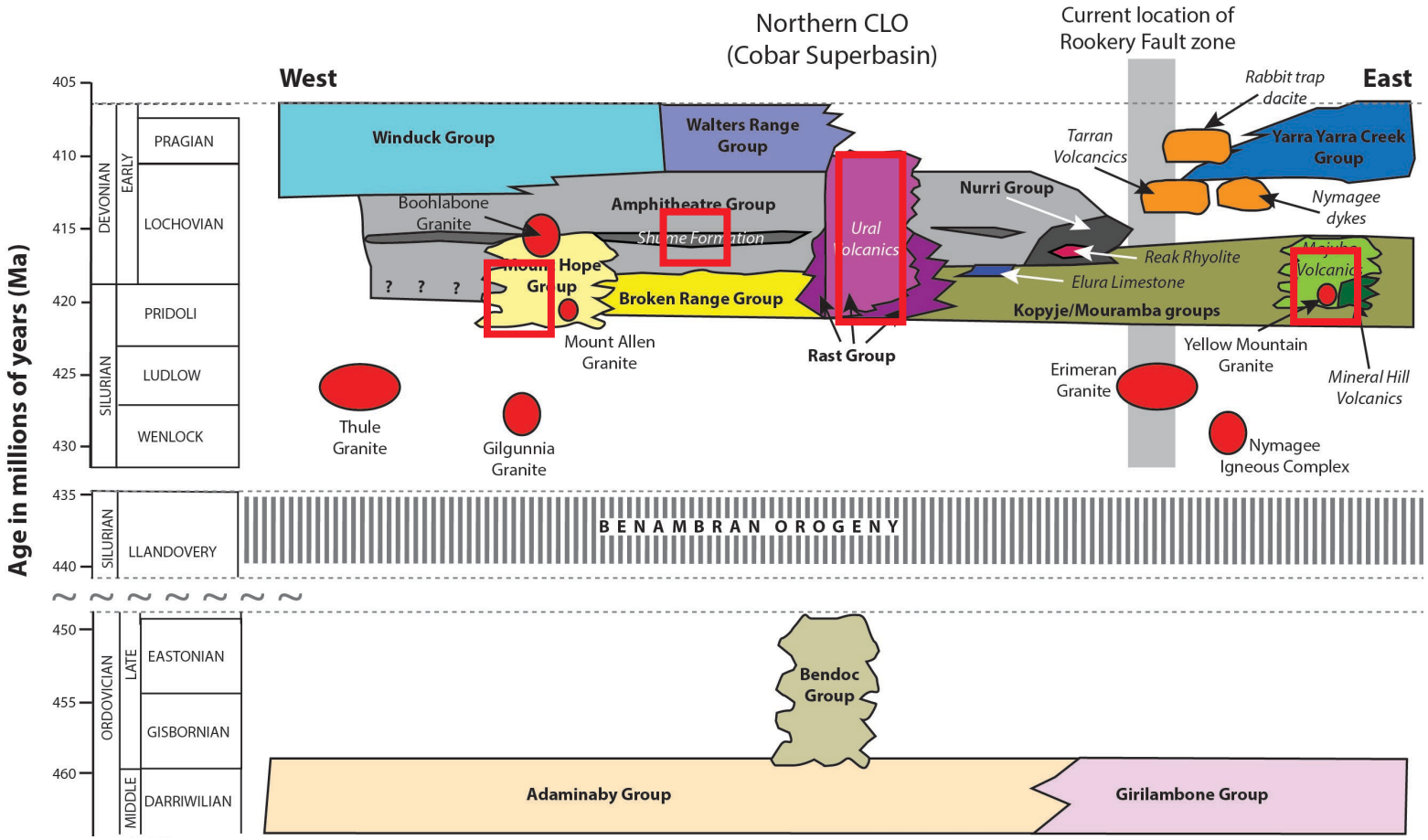


Magmatic geochronology

- **Magmatism**
  - Between 423-409 Ma
  - Majority between 422-417 Ma
  - S & A-type dominant in the west
  - I +/- A-type dominant in the east
    - Predominantly Canbelego-Mineral Hill Belt
  - Stratigraphy compressed in time
  - Almost every syn-depositional volcanic is 420 Ma, hard to resolve

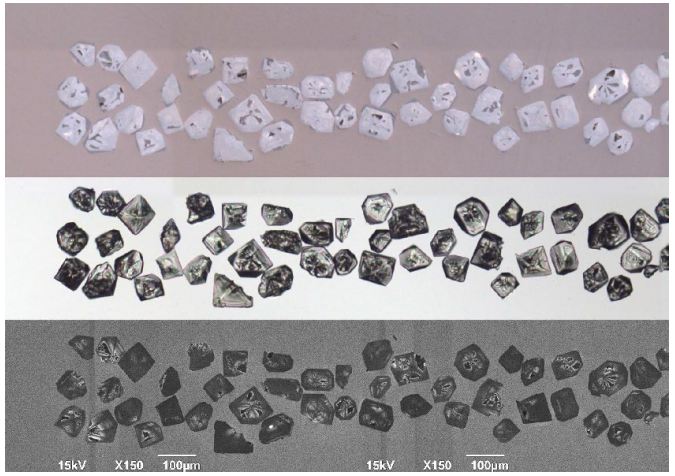


Zircon from 410.8 ± 1.9 Ma Rabbit hill dacite

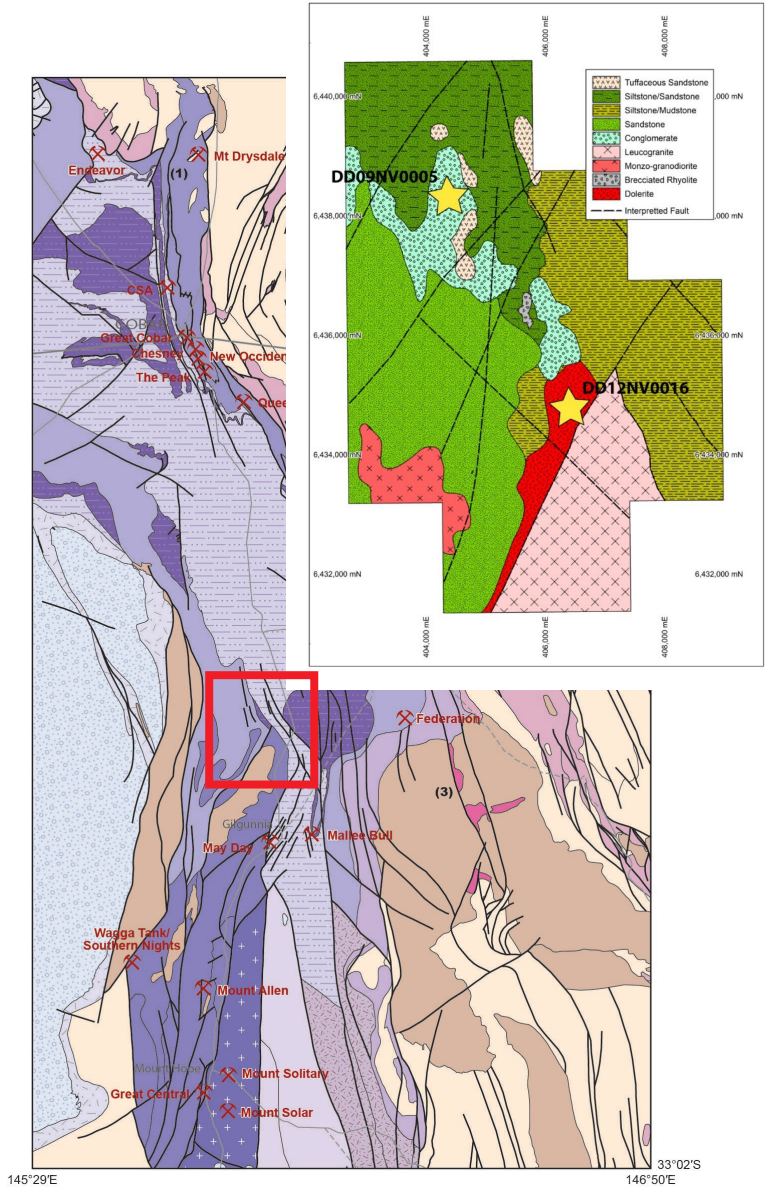


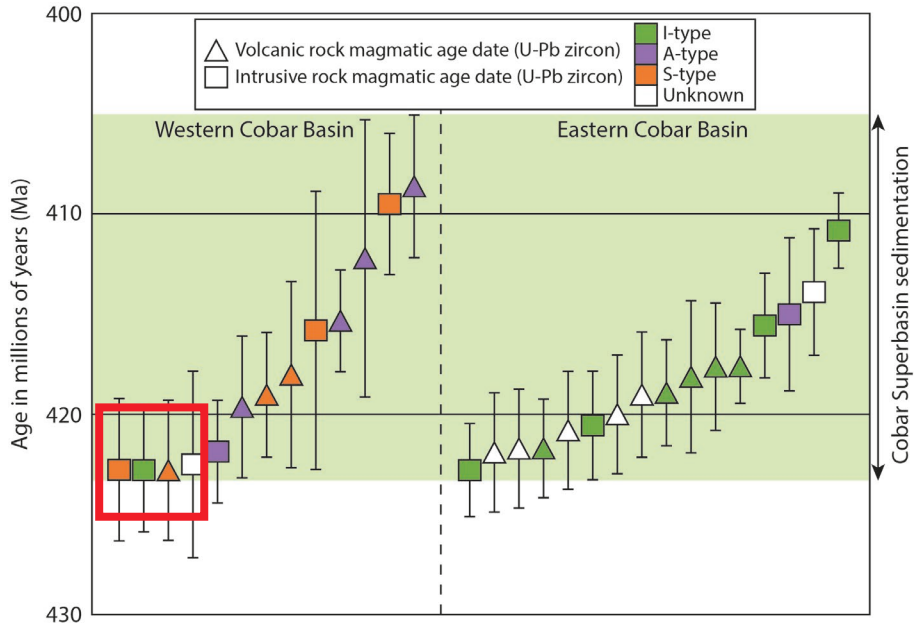
Magmatic geochronology – highlights

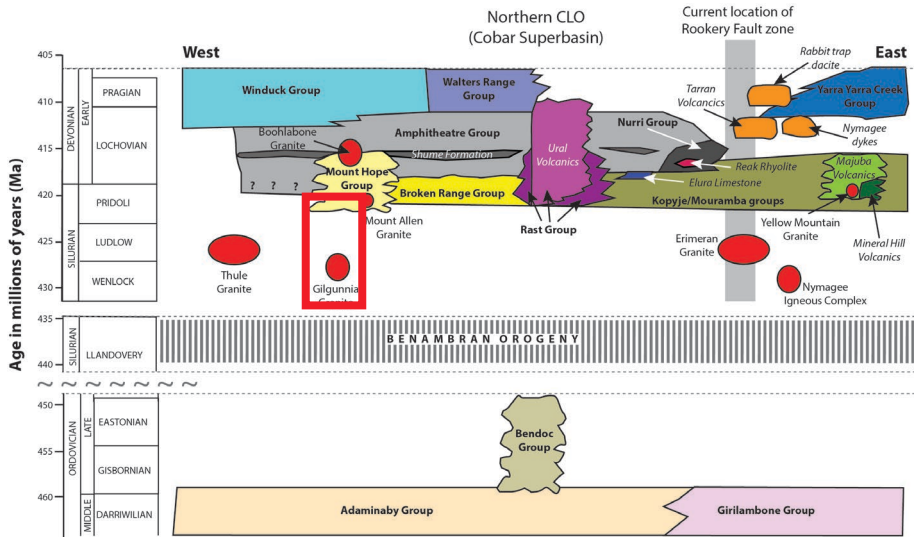
- **Norma vale**
  - Rare mafic magmatism along side S-type Gilgunnia Granite
    - Enigmatic relationships
    - Ages 425-423 Ma
  - Overlain by conglomerate with skarn mineralisation
    - Interpreted as Shume Formation



Zircon from ~423 Ma Norma Vale diorite



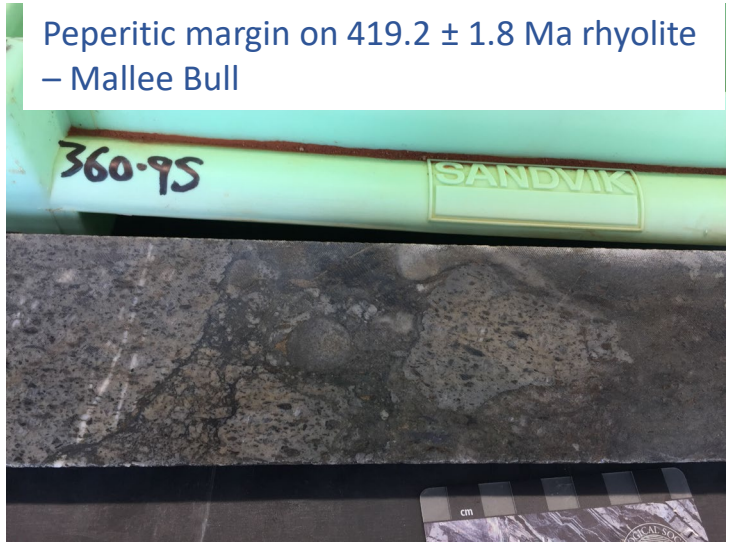




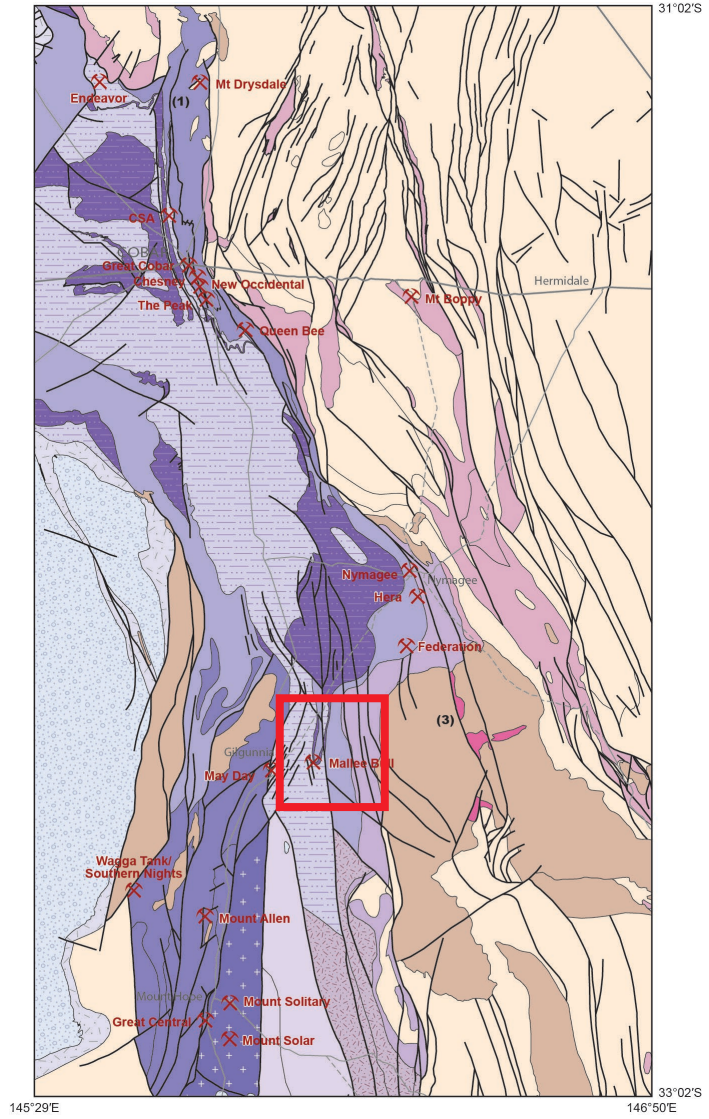
NSW GOVERNMENT

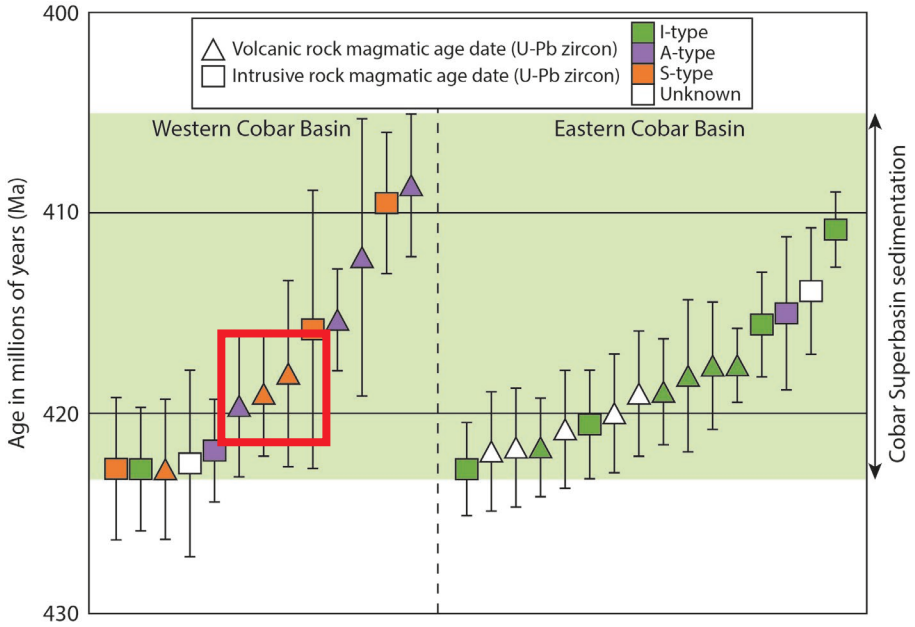
Magmatic geochronology – highlights

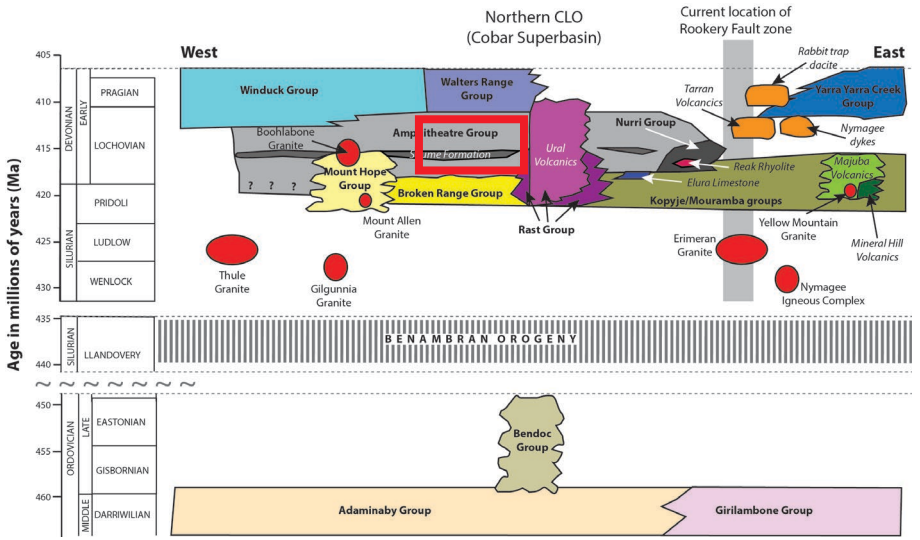
- **Mallee Bull**
  - Rhyolite bodies, domes?
    - Ca. 419 Ma
  - Shume Formation level
  - Little time past, very rapid deepening



Peperitic margin on 419.2 ± 1.8 Ma rhyolite – Mallee Bull



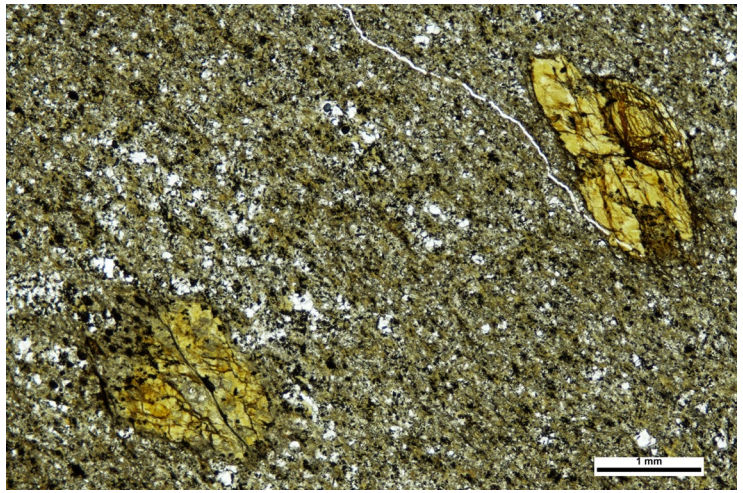




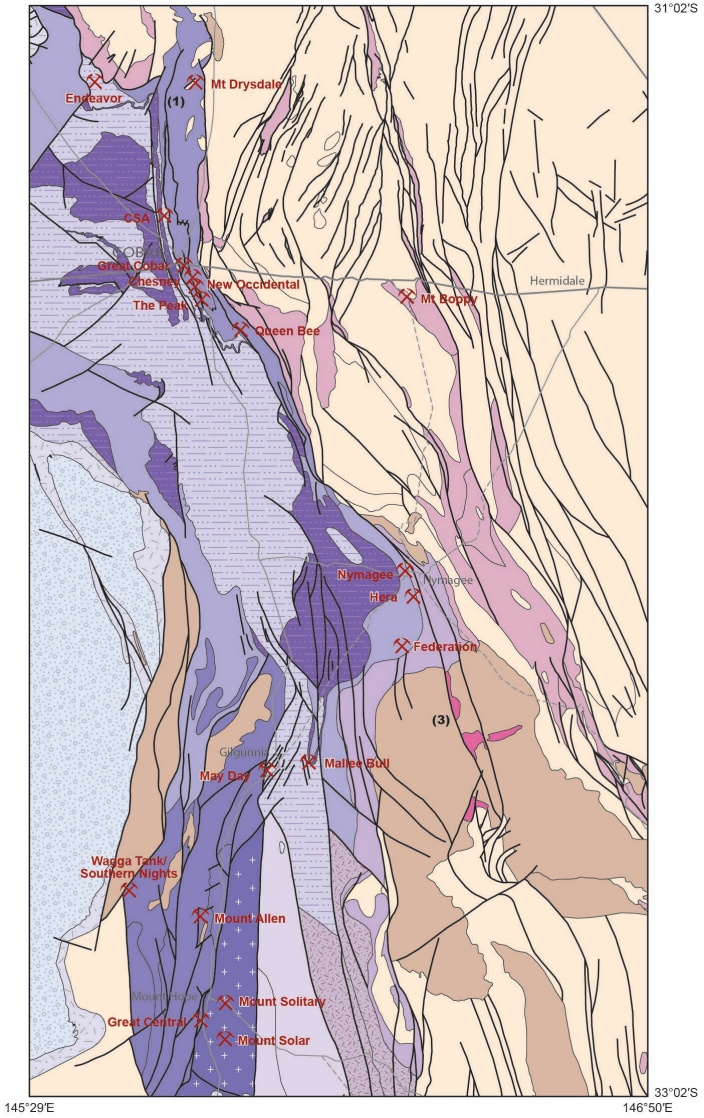
NSW GOVERNMENT

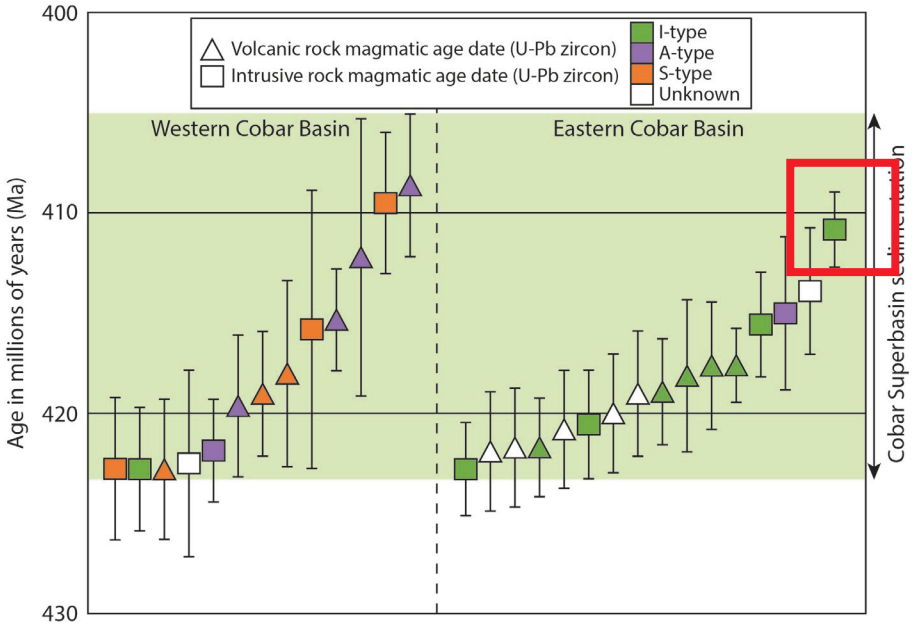
Magmatic geochronology – highlights

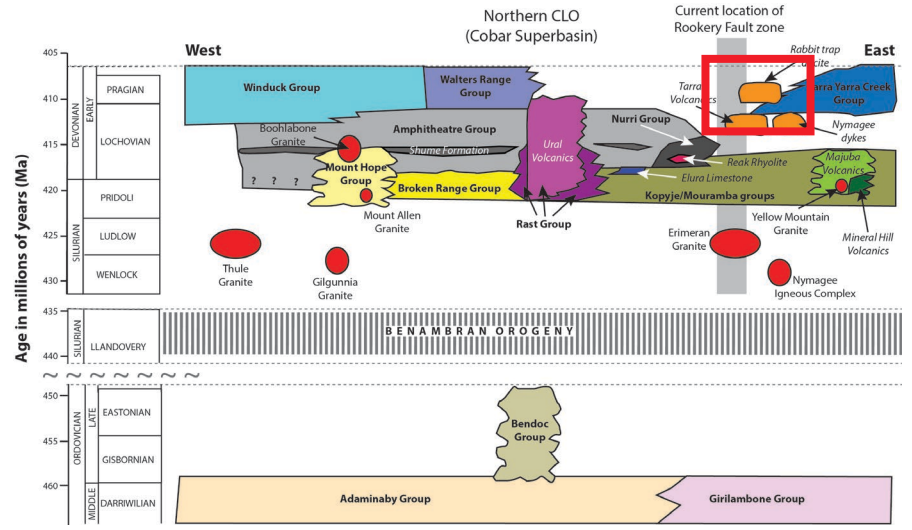
- **Rabbit Hill – last hope!**
  - Hornblende phyric I-type
    - Ca. 411 Ma in Meryula Formation
  - Youngest expression of magmatism



Euhedral hornblende phenocrysts in the 410.8 ± 1.9 Ma Rabbit Hill dacite



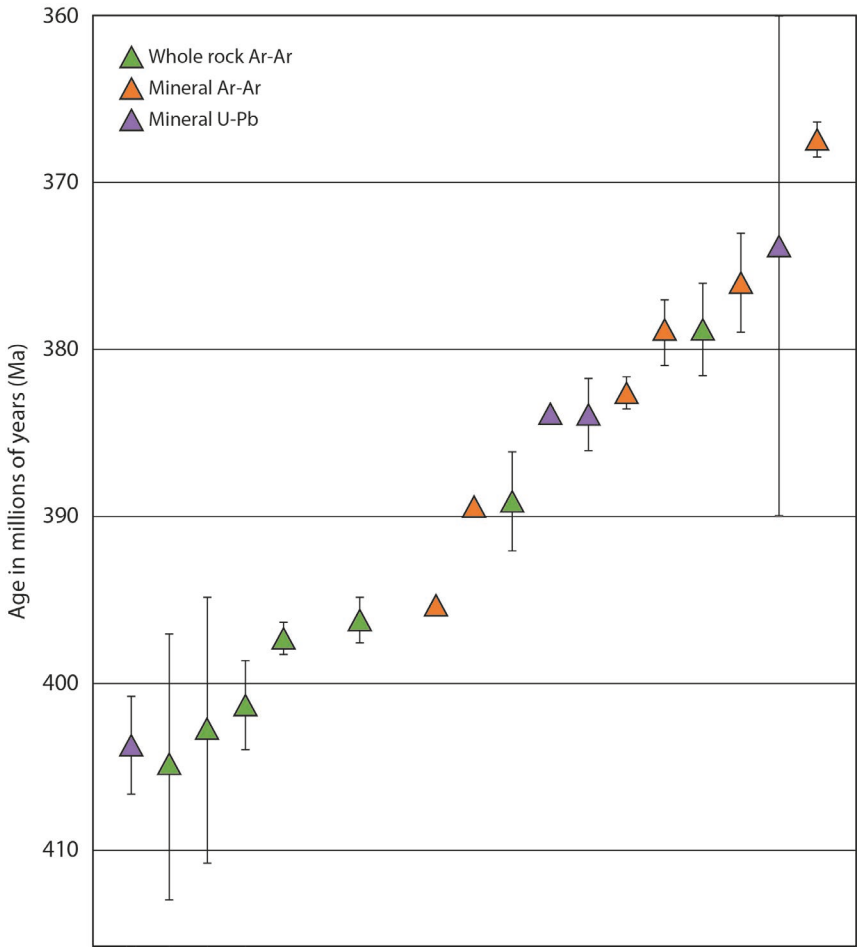


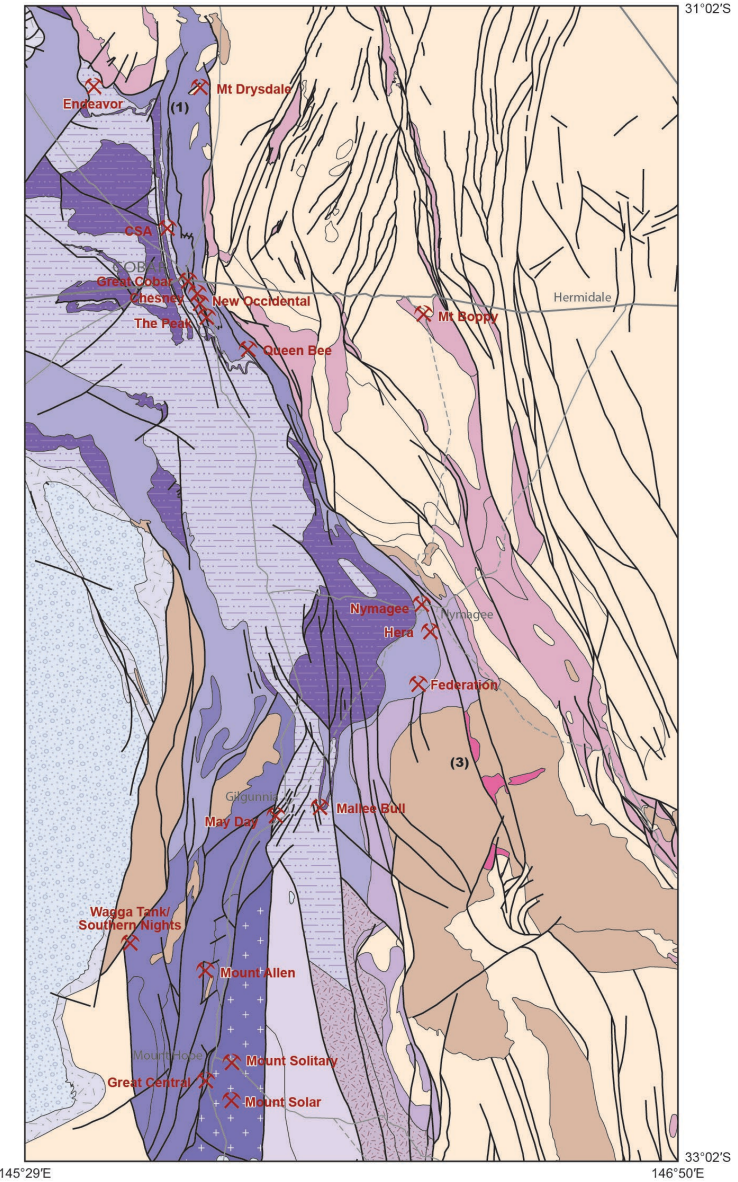


Deformation geochronology

- **Deformation**
  - Faults and foliations not directly associated with mineralisation
  - Ages span 405-367 Ma

Deformed massive sulfide – Hera

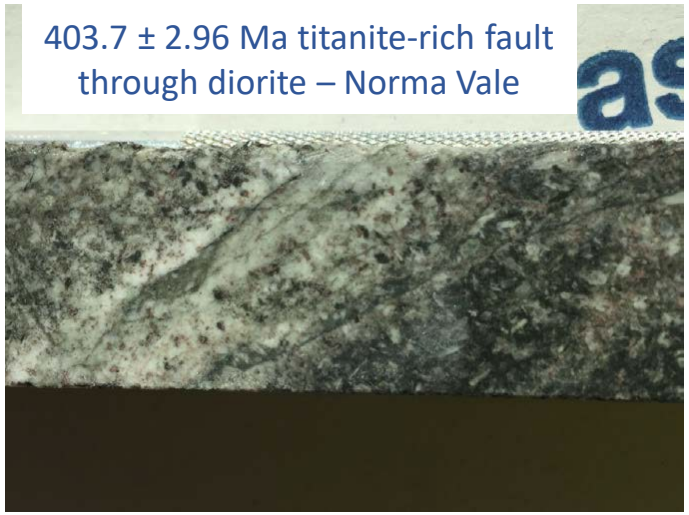


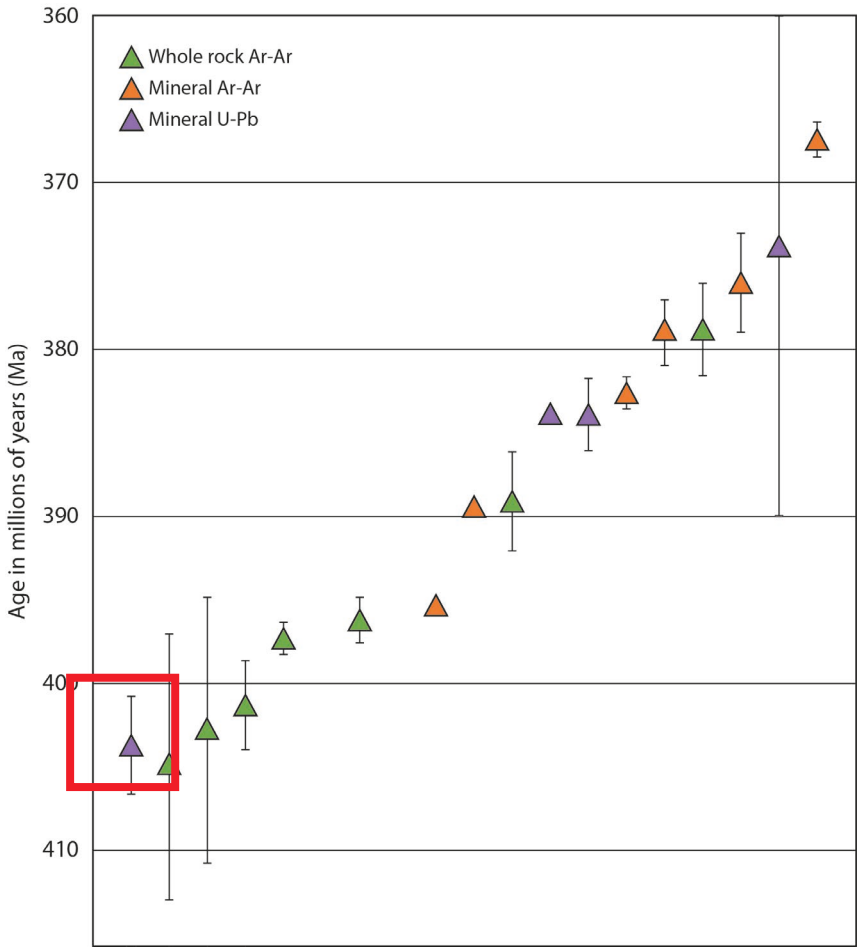


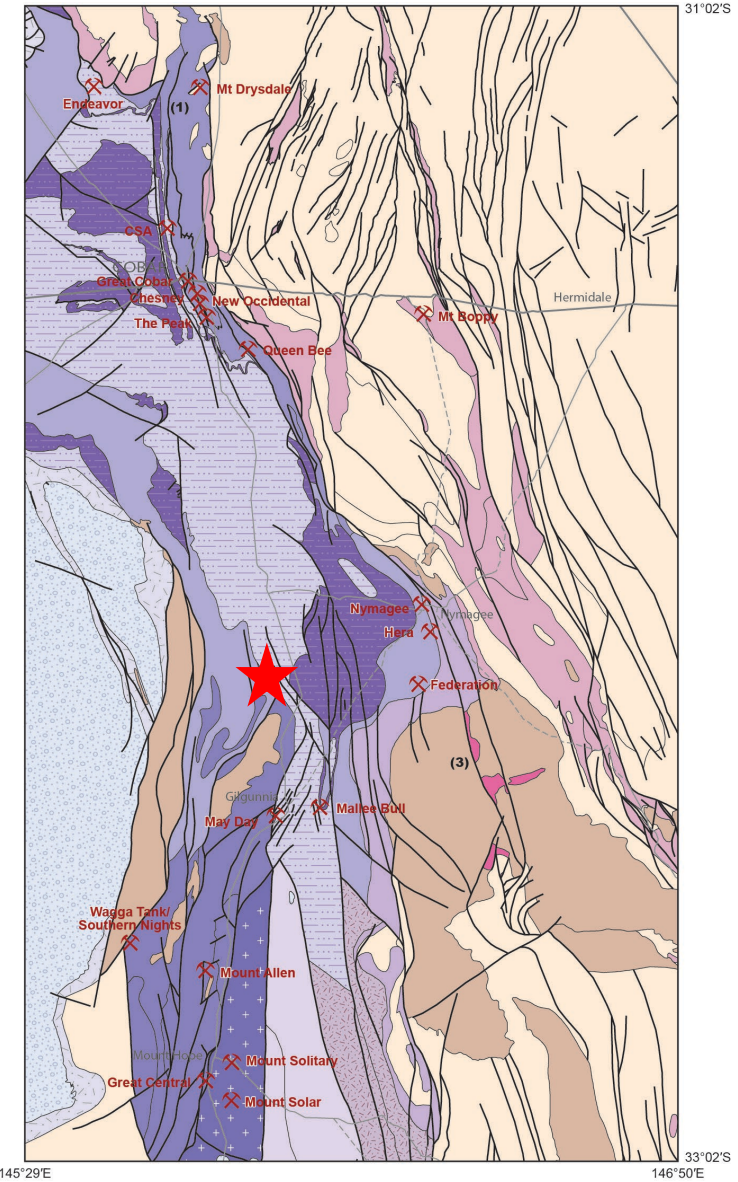
NSW GOVERNMENT

Deformation geochronology

- **Deformation – Norma Vale**
  - Siliceous titanite-rich faults through diorite
  - Northern extension of Bootheragandra Fault system?
  - ~404 Ma hydrothermal activity on faults



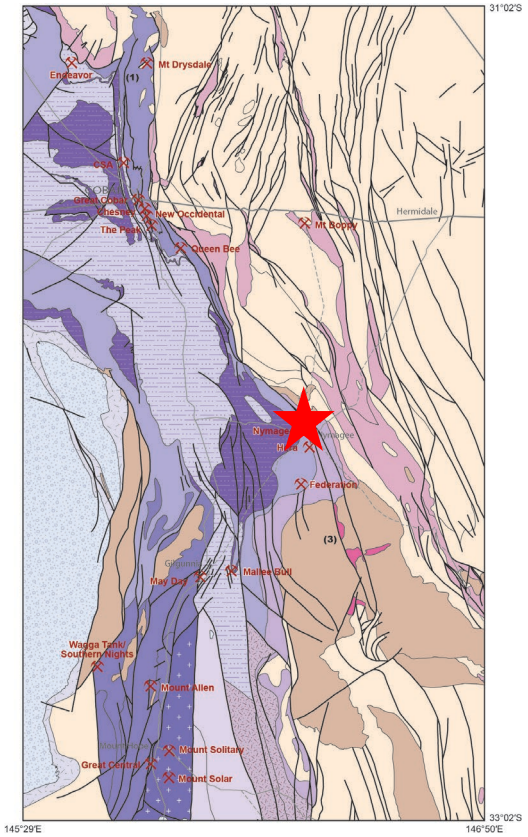


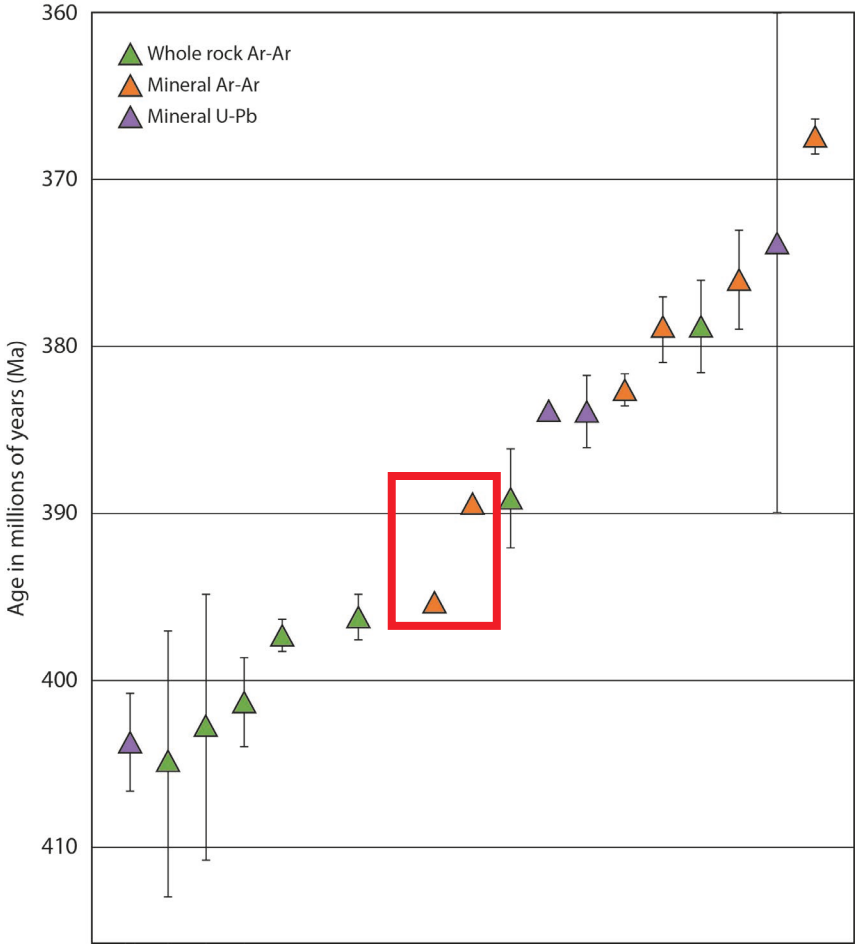


NSW GOVERNMENT

Deformation geochronology

- **Deformation – foliation (Ar-Ar)**
  - Biotite foliation enveloping massive sulfide lenses
    - Hera, Nymagee & CSA mines
    - 396-390 Ma

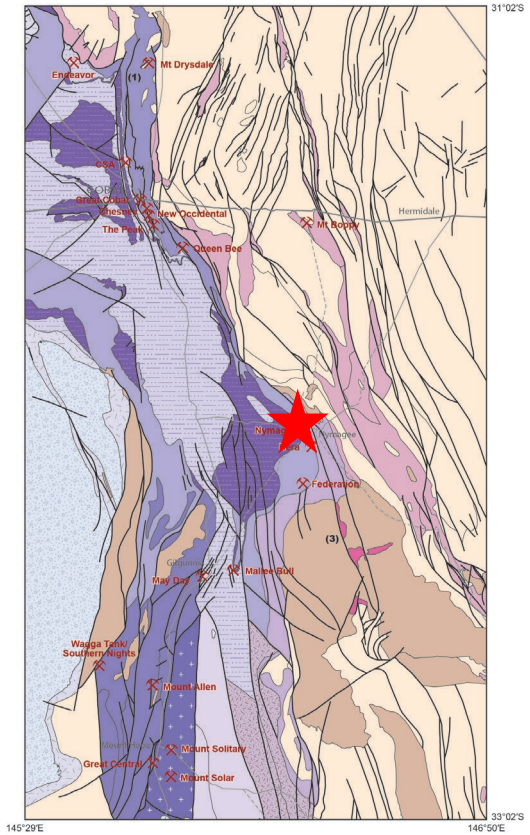


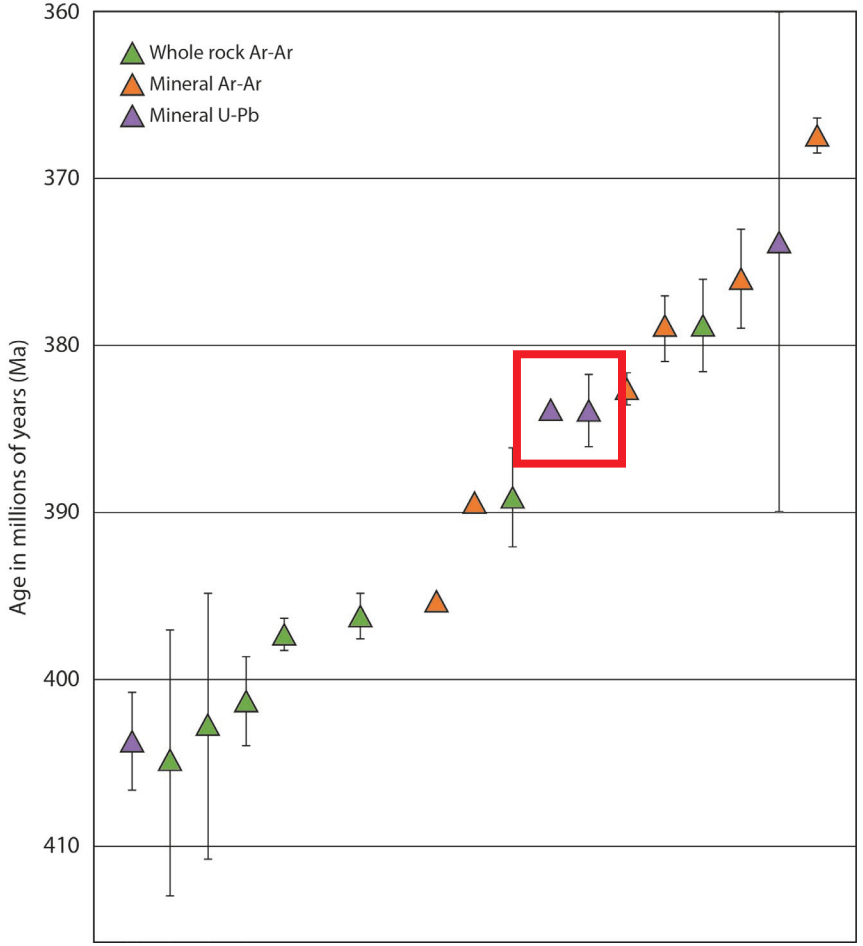


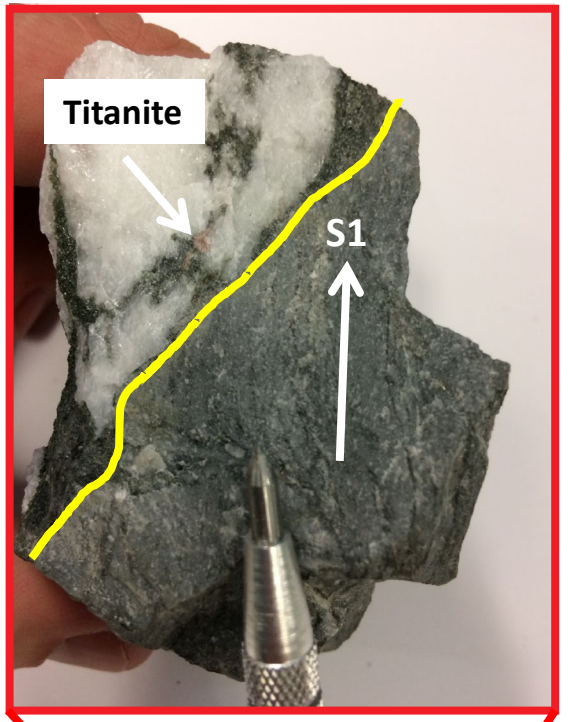
390.03 ± 0.23 Ma Biotite foliation enveloping massive sulfide lode – Hera

Deformation geochronology

- **Deformation – Brittle faults (U-Pb)**
  - Unmineralised brittle faults that terminate ore lenses
    - Hera & CSA mines
    - 383 Ma





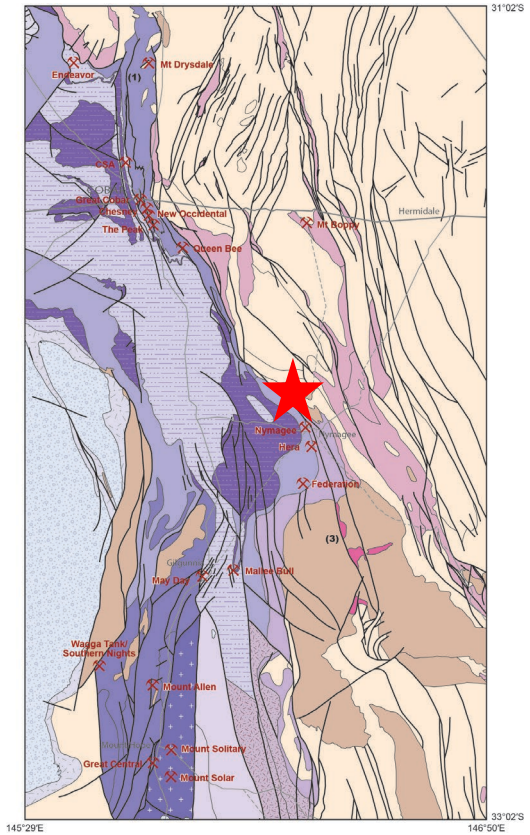


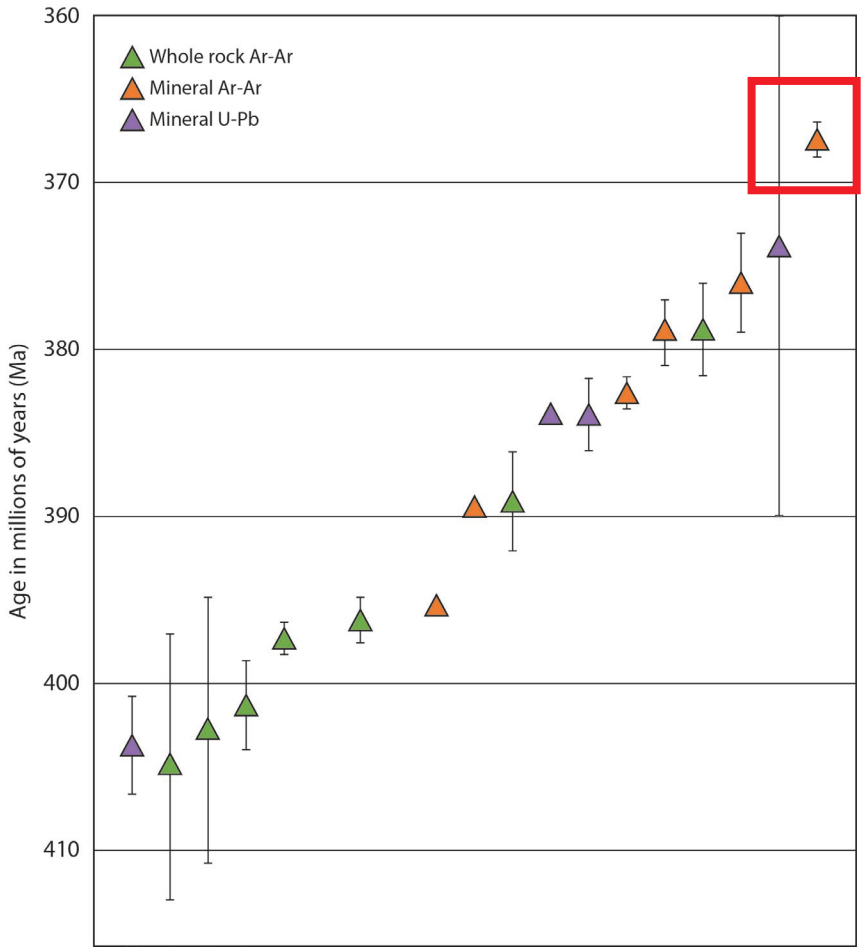
Unmineralised 383.98 ± 0.43 Ma titanite-rich fault – Hera

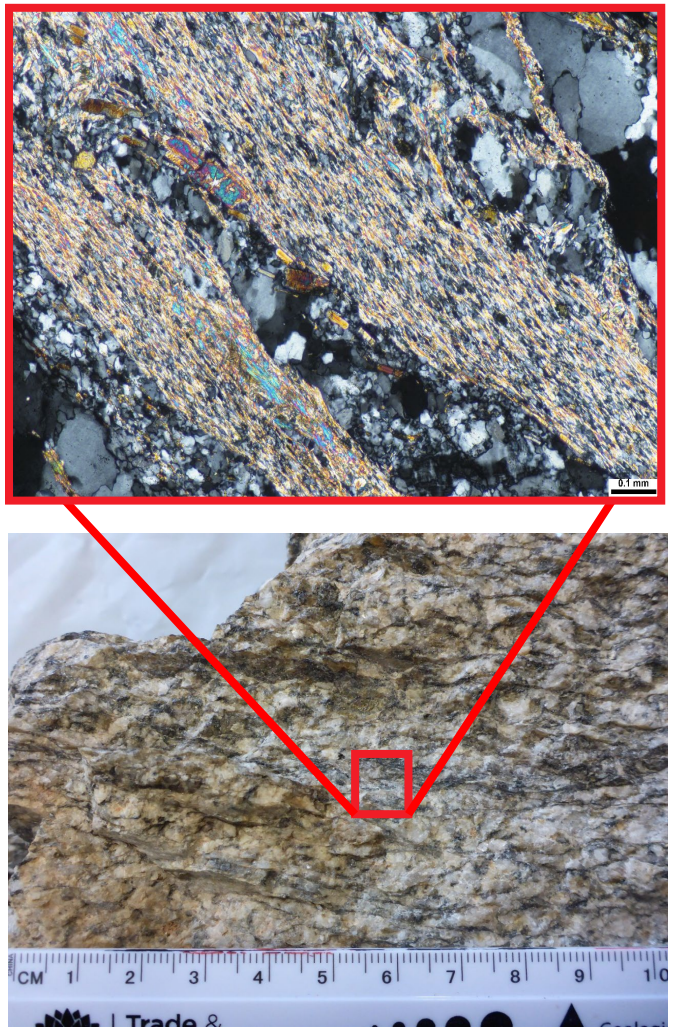
NSW GOVERNMENT

Deformation geochronology

- **Deformation – sericitic shears**
  - Unmineralised shear zone
    - Splay off Rookery Fault
  - Nymagee Igneous Complex
    - 368 Ma





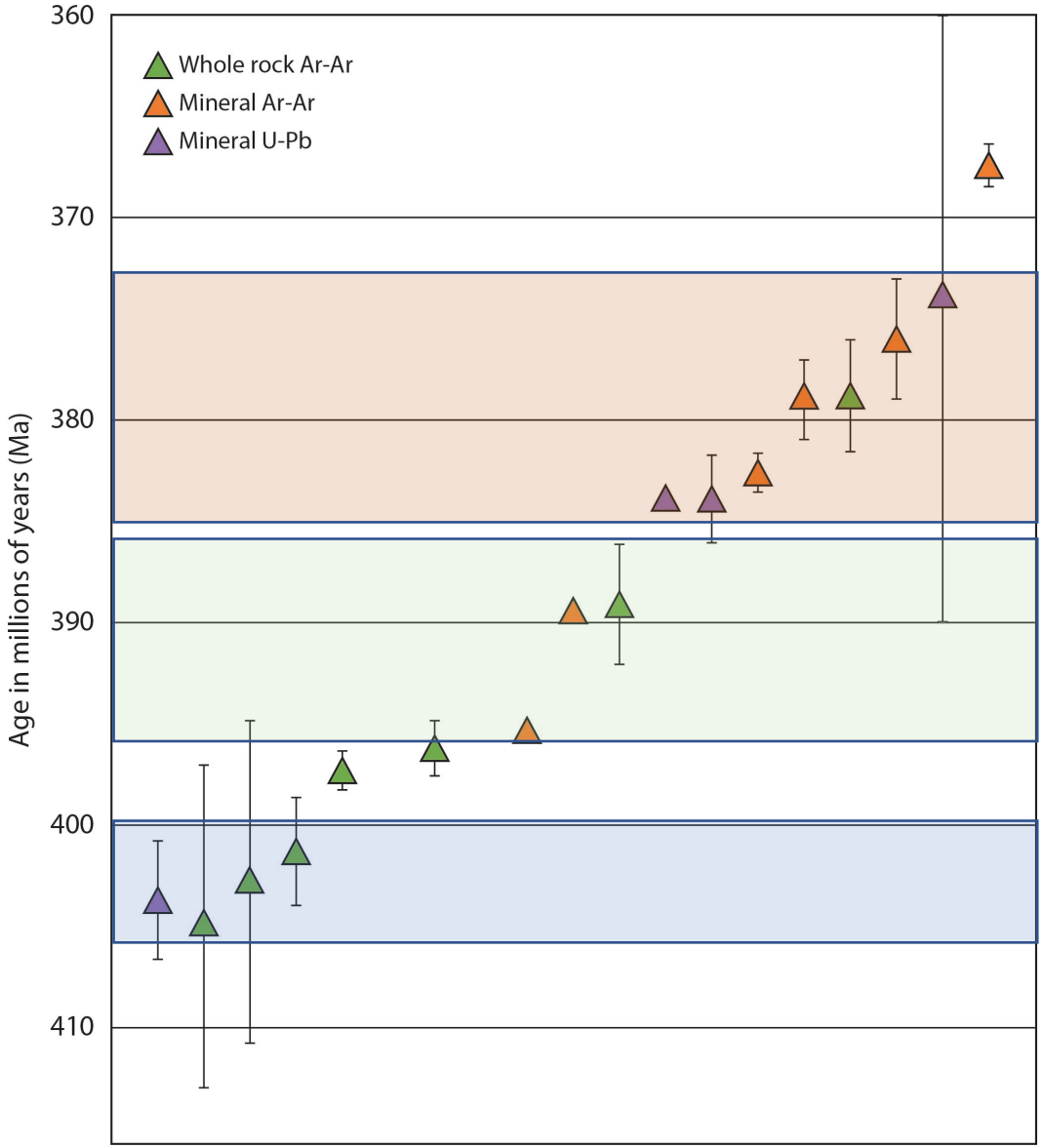


367.43 ± 1.09 Ma sericite shears
– Nymagee Igneous Complex

NSW GOVERNMENT

Deformation geochronology - summary

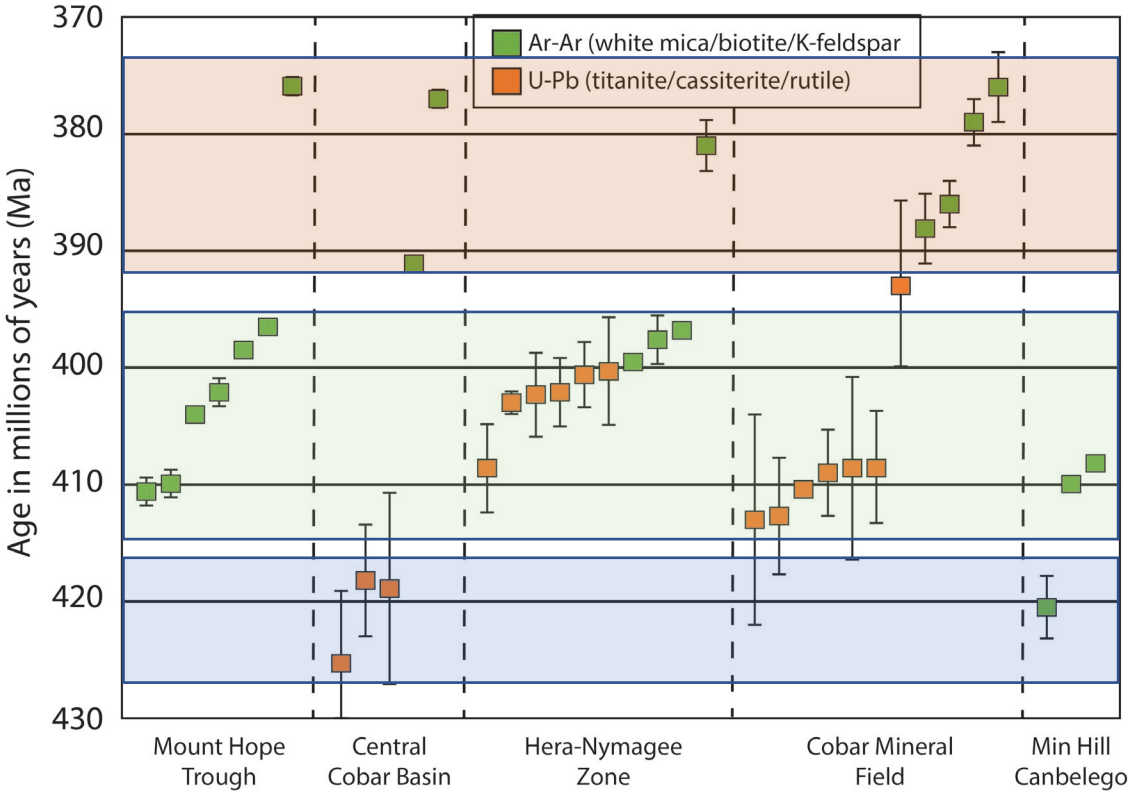
- **Outside of mineralisation**
- Hydrothermal activity on faults
  - 405-400 Ma
- Foliation formation and inversion
  - 395-385 Ma
- Localised faulting
  - 385-380 Ma
- Evidence for continued movement on major faults until 370 Ma

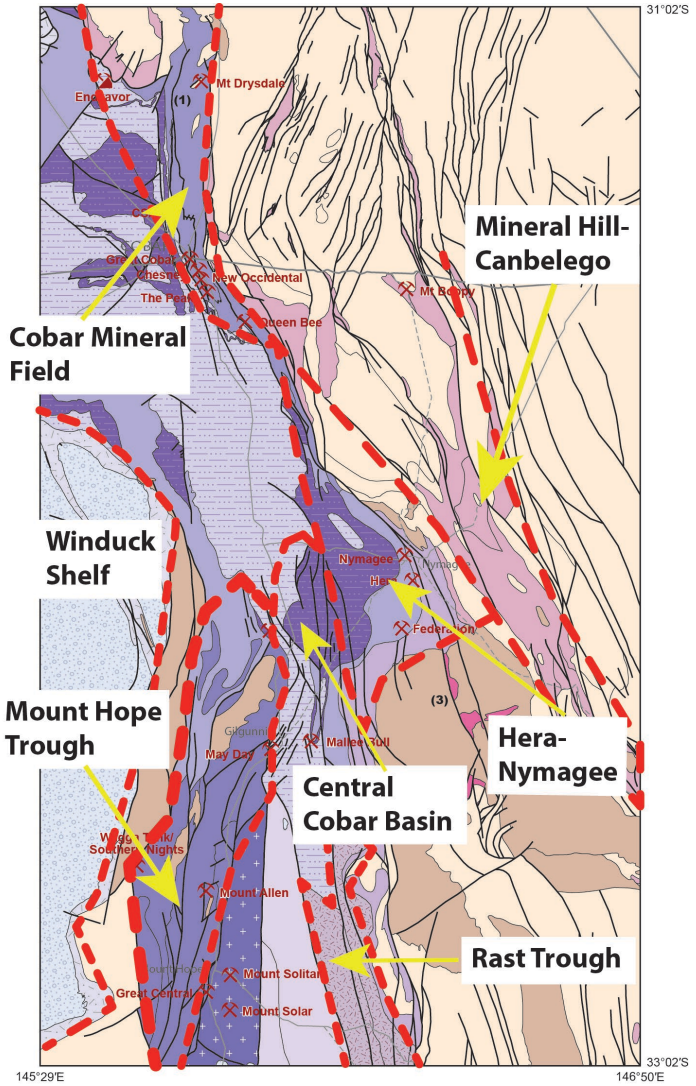


NSW GOVERNMENT

Alteration/gangue – geochronology

- **Alteration/gangue**
  - Simplest way to look at it is 3 phases recorded
    - ~420 Ma, ~410-395 Ma and ~390-375 Ma

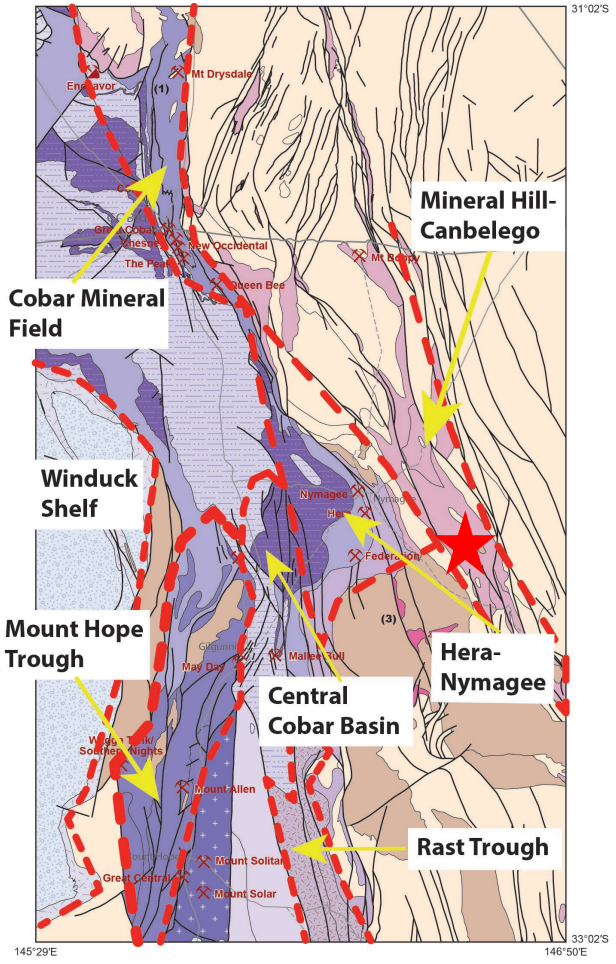


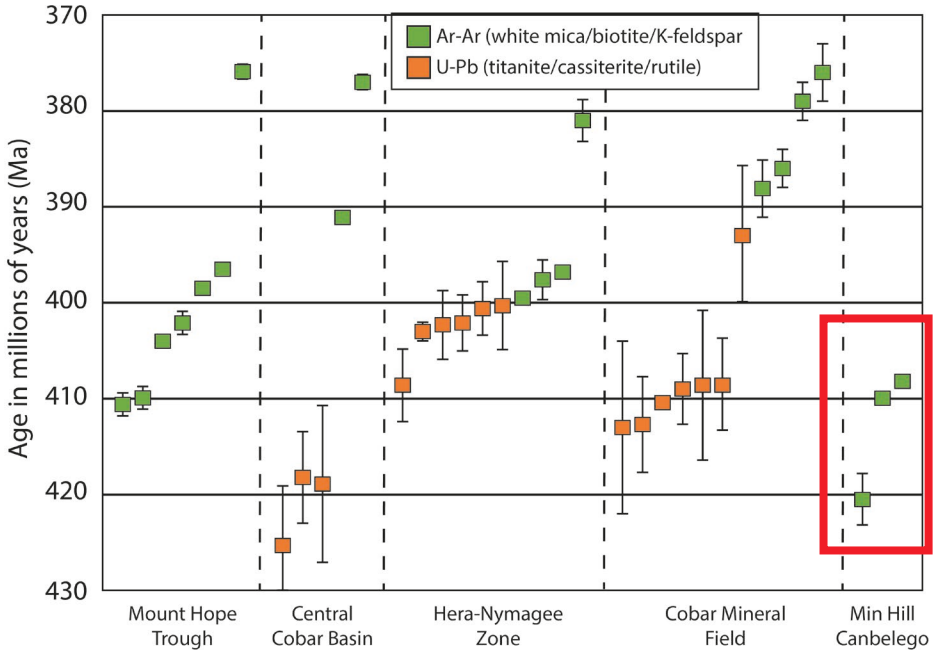


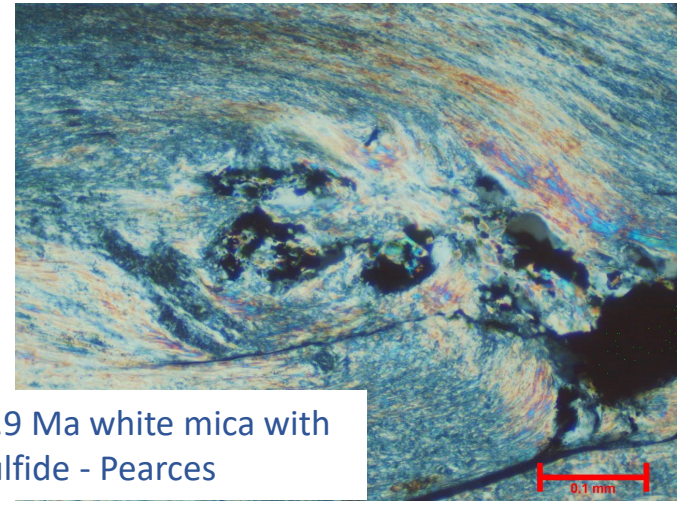
Mineralisation geochronology – traverse

- **Mineralisation – Mineral Hill-Canbelego**
  - 420 and 410 Ma so far
  - Mineral Hill, Pipe Line Ridge Yellow Mountain
    - Rift to sag phase basin
    - Fits the epithermal genesis

White mica-rich alteration – Pearces



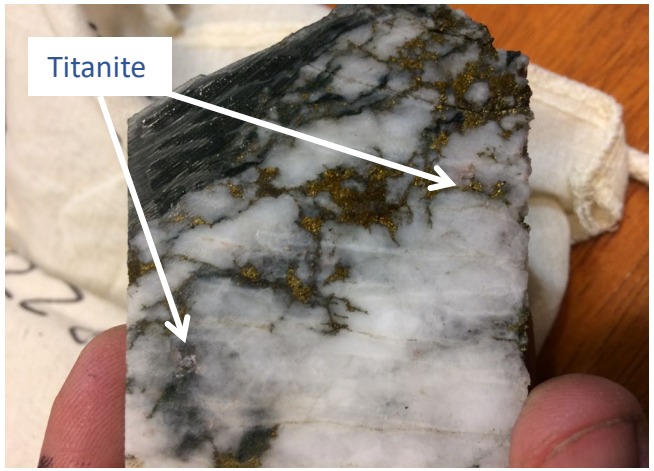




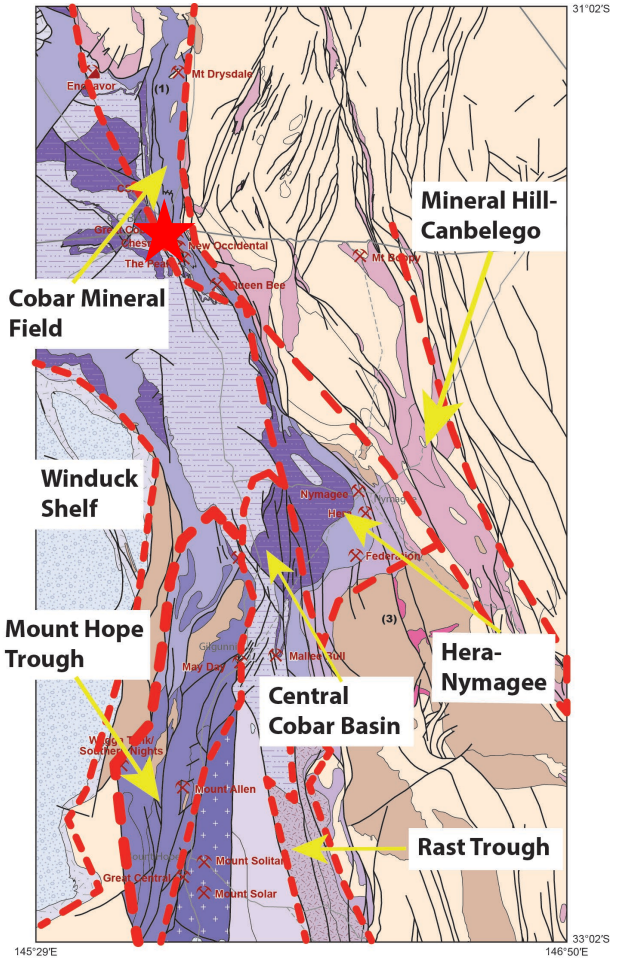
420 .5± 2.9 Ma white mica with sulfide - Pearces

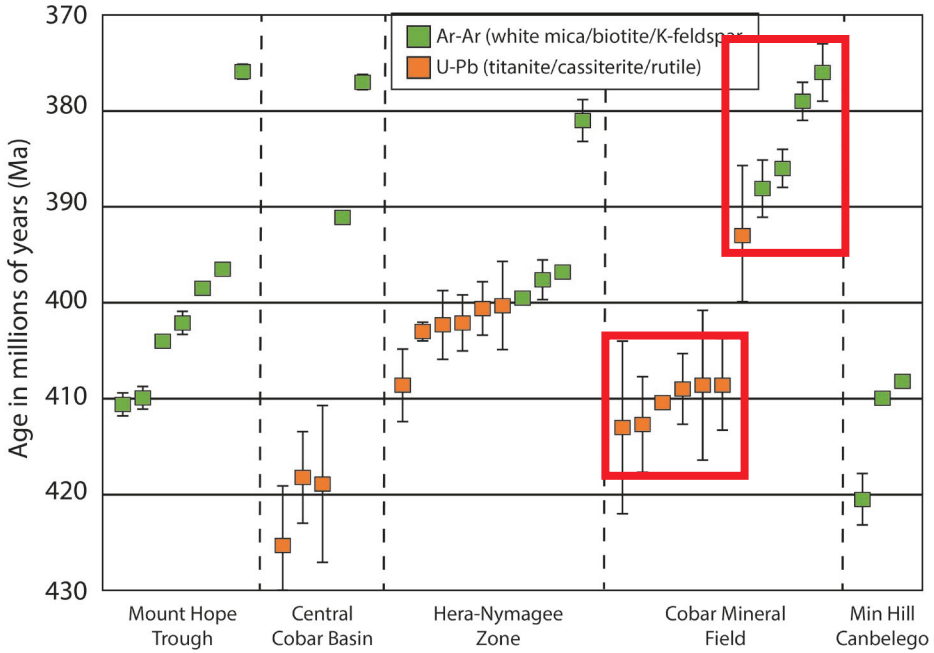
Mineralisation geochronology – traverse

- **Mineralisation – Cobar Mineral Field**
- Ca. 410 Ma - Peak mines (Cu-Au) and CSA (Cu)
  - Epigenetic, structural control
  - Sag phase fault movement?
  - Suggest magmatic flavour
- 390-375 Ma - Endeavour and CSA (Pb-Zn)
  - Basin inversion orebodies

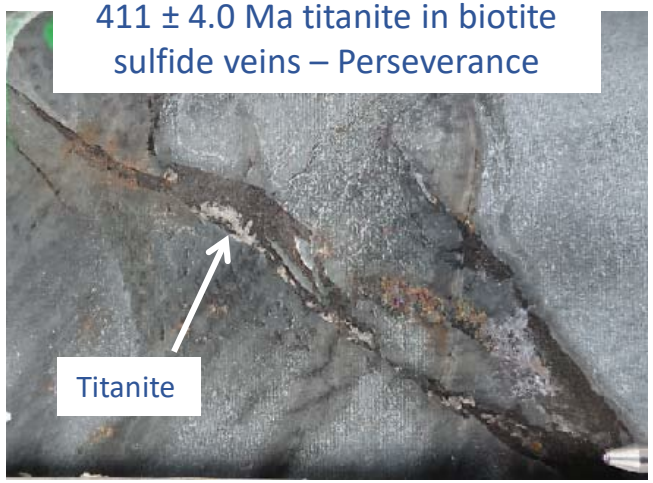


408.6 ± 4.7 Ma titanite in deformed mineralised veins – CSA





411 ± 4.0 Ma titanite in biotite sulfide veins – Perseverance

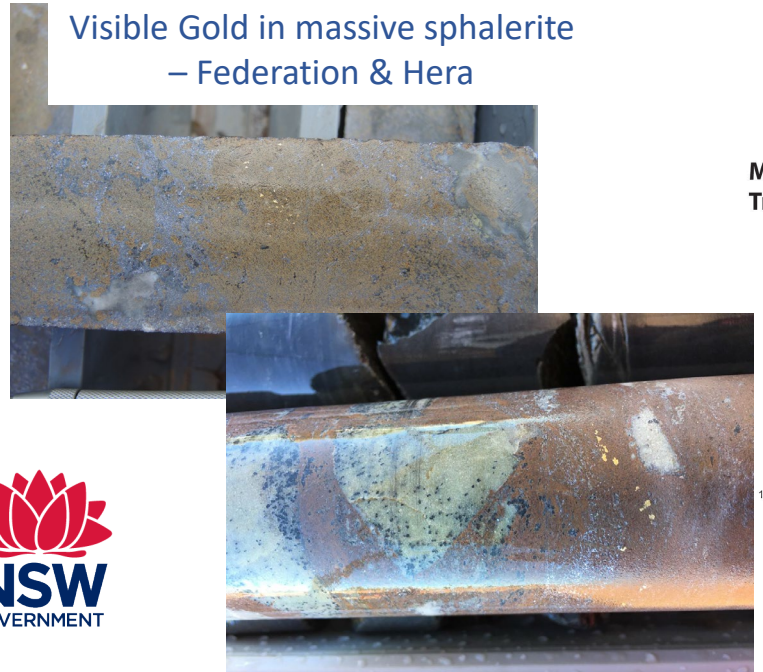


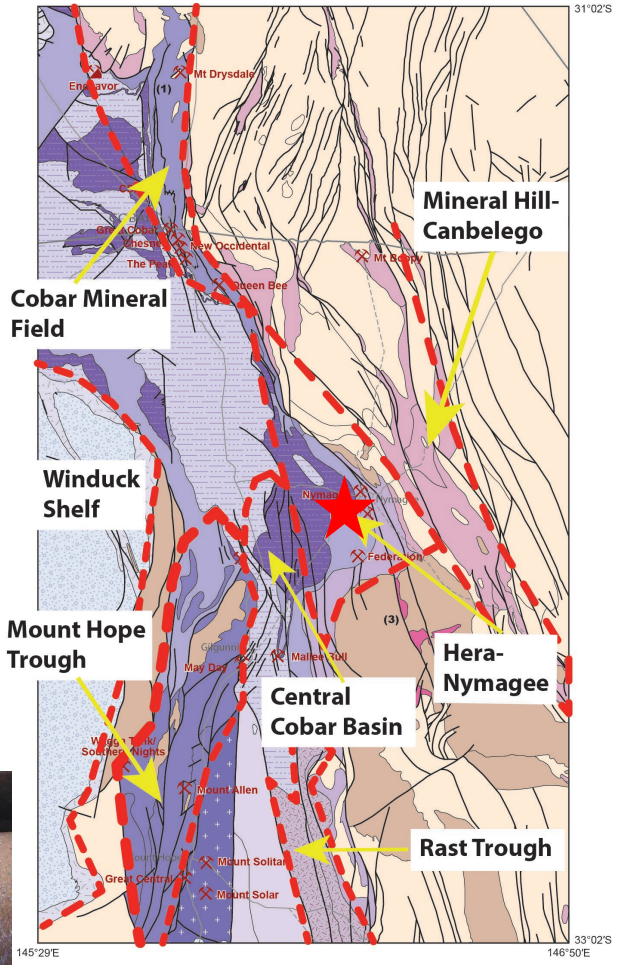
NSW GOVERNMENT

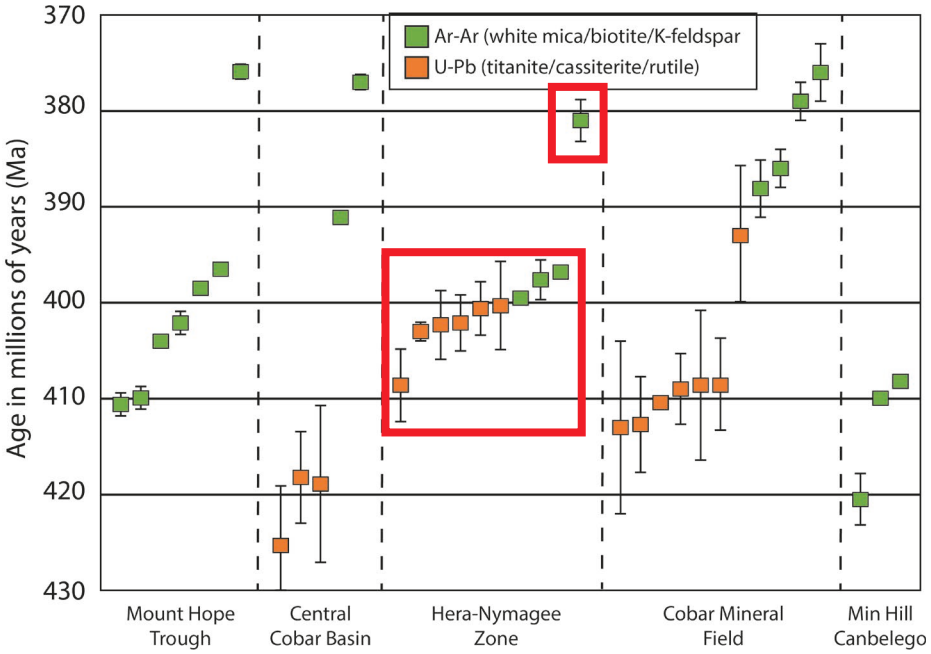
Mineralisation geochronology – traverse

- **Mineralisation – Hera-Nymagee Zone**
- Ca. 408 Ma (Federation) to 404-395 Ma (Hera/Nymagee)
- Some evidence of ca. 380 Ma consistent with faulting of orebody at Hera
- Hera distal skarn – magmatic flavour suggested

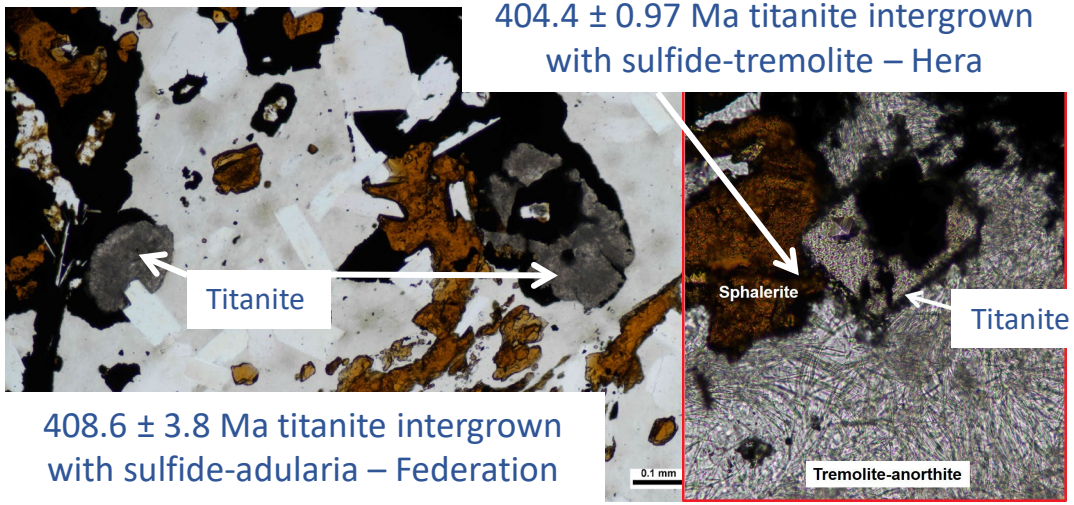
Visible Gold in massive sphalerite – Federation & Hera







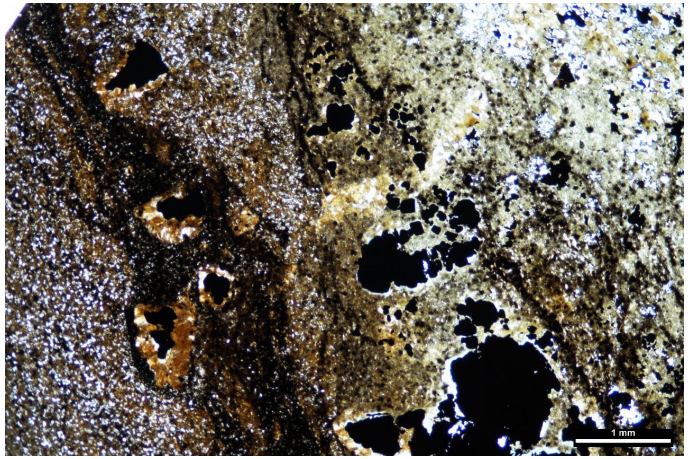
404.4 ± 0.97 Ma titanite intergrown with sulfide-tremolite – Hera



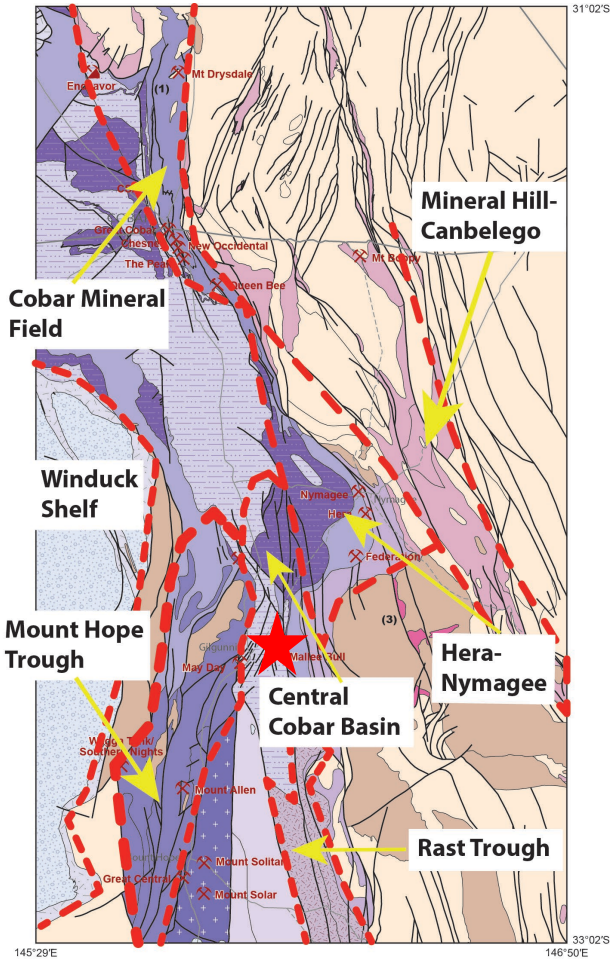
408.6 ± 3.8 Ma titanite intergrown with sulfide-adularia – Federation

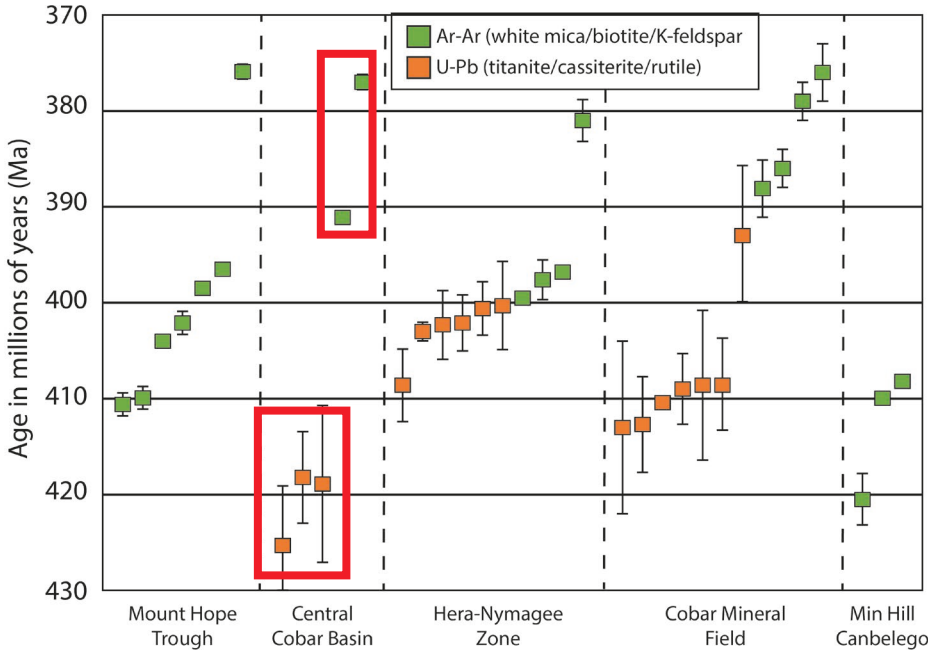
Mineralisation geochronology – traverse

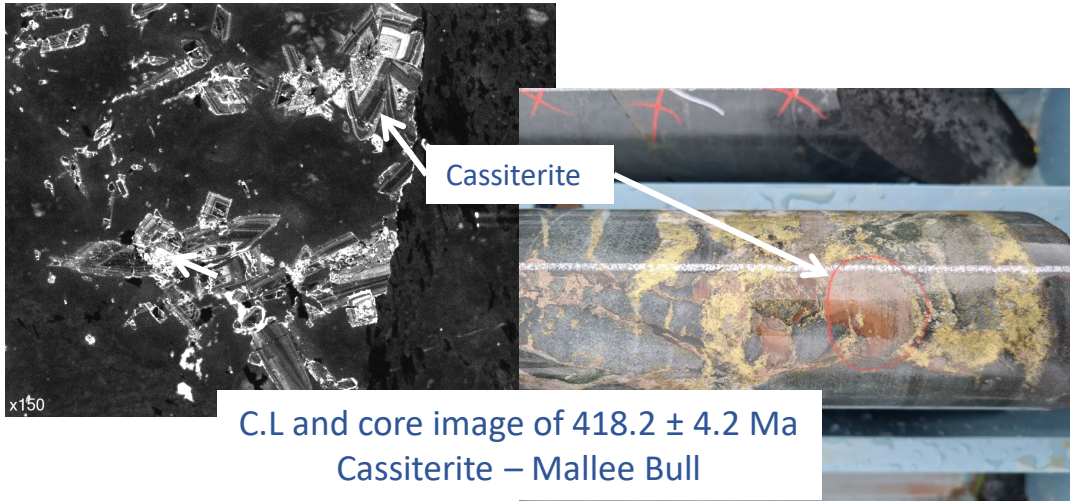
- **Mineralisation – Central Cobar Basin**
- Ca. 419 Ma and 390-380 Ma – Mallee Bull
- At least Sn = same timing as magmatism
- Biotite = clear evidence of inversion related hydrothermal activity and ore



Photomicrograph of 391.1 ± 0.6 Ma Biotite selvage on pyrrhotite vein – Mallee Bull





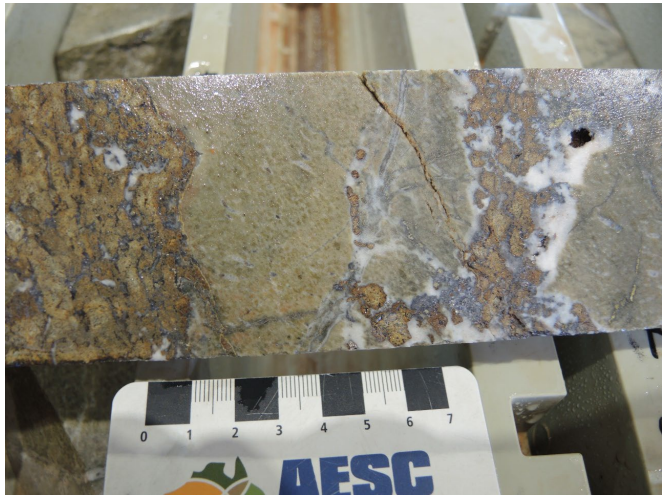


C.L and core image of 418.2 ± 4.2 Ma Cassiterite – Mallee Bull

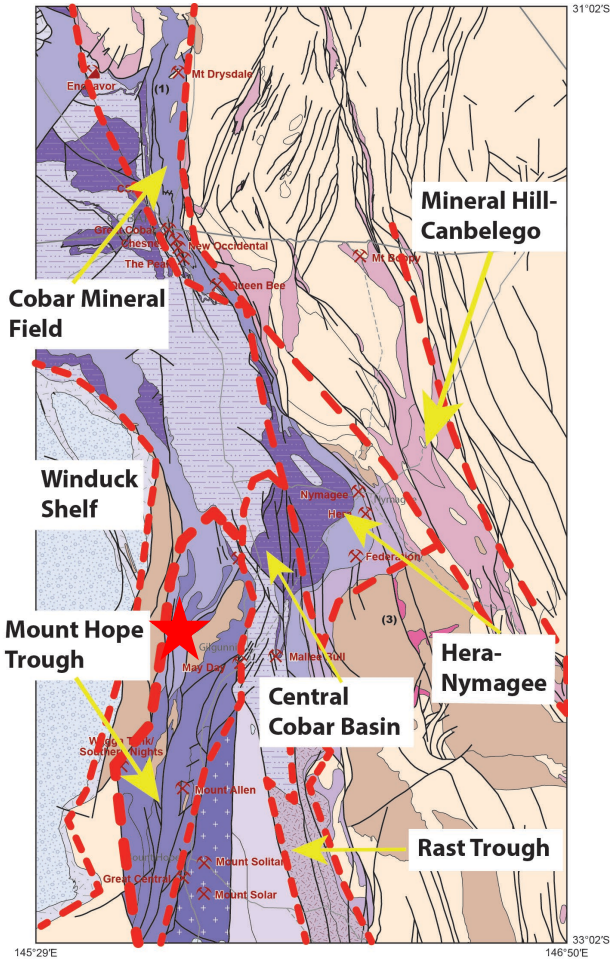
NSW GOVERNMENT

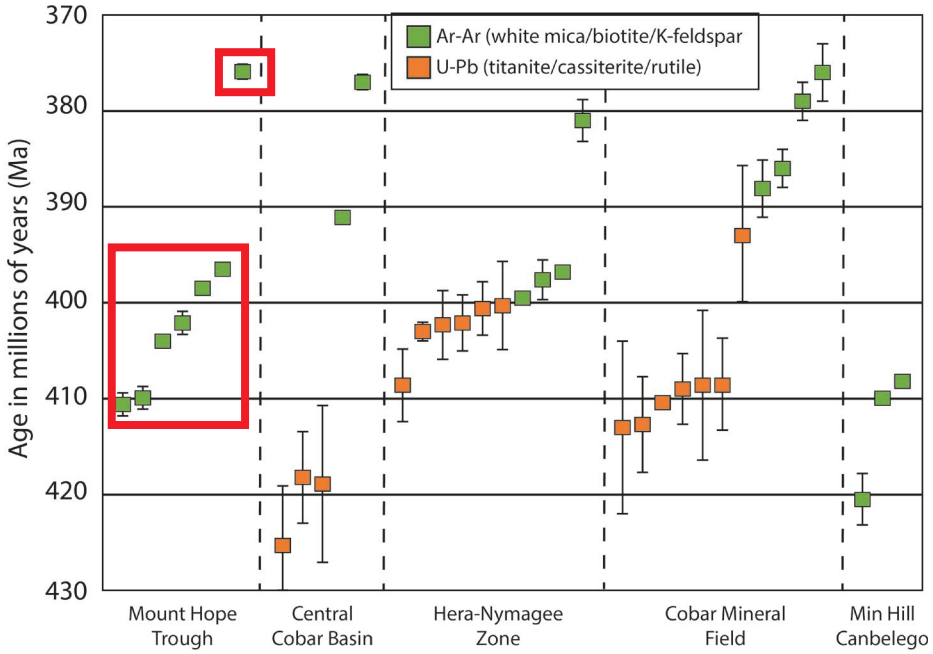
Mineralisation geochronology – traverse

- **Mineralisation – Mount Hope Trough**
- 410-398 Ma– Southern Nights-Wagga Tank
  - Consistent with Hera-Cobar fields
- Ca. 376 Ma adularia - Blue Mountain
  - Consistent with basin inversion

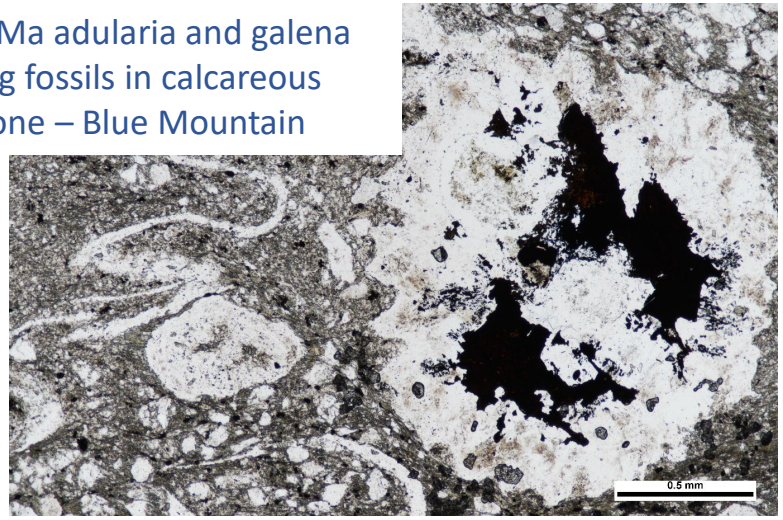


409.9 ± 1.21 and 398.5 ± 0.6 Ma adularia and sericite alteration in mineralised aphyric vesicular rhyolite – Southern Nights





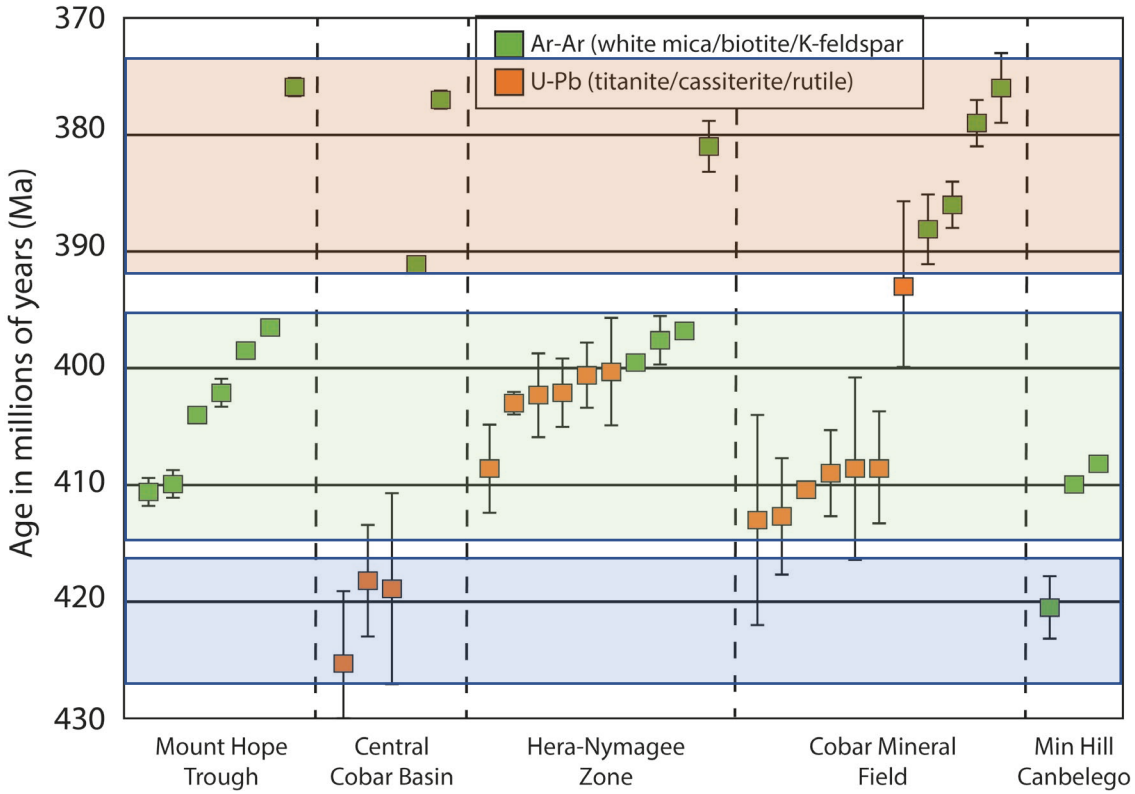
376 ± 0.8 Ma adularia and galena replacing fossils in calcareous mudstone – Blue Mountain

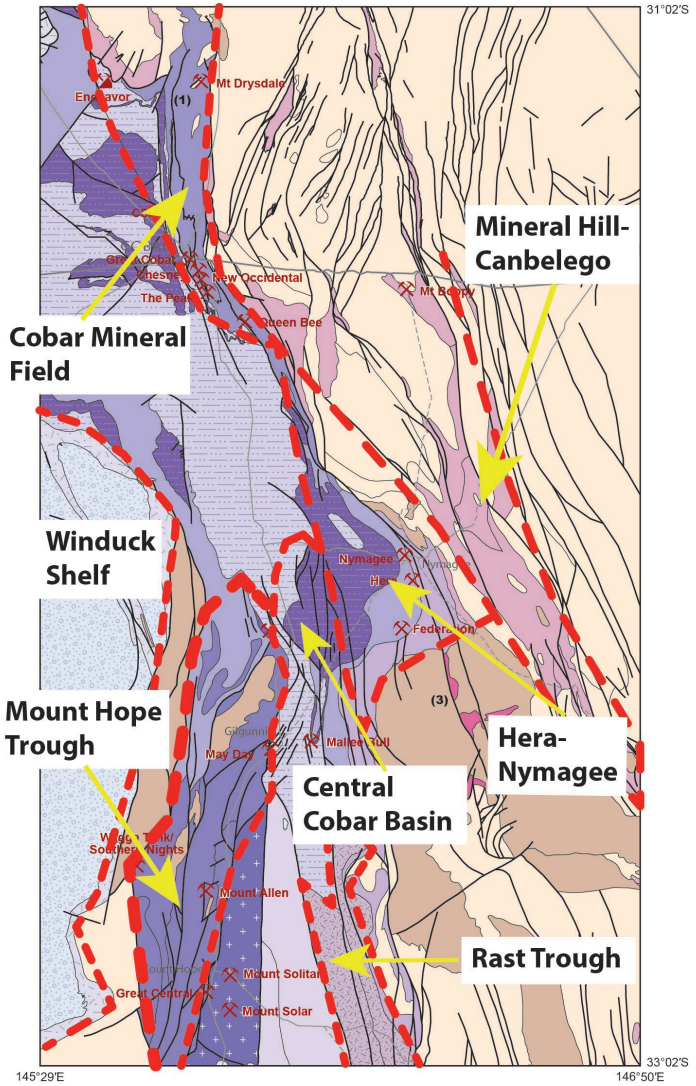


NSW GOVERNMENT

Alteration/gangue – geochronology summary

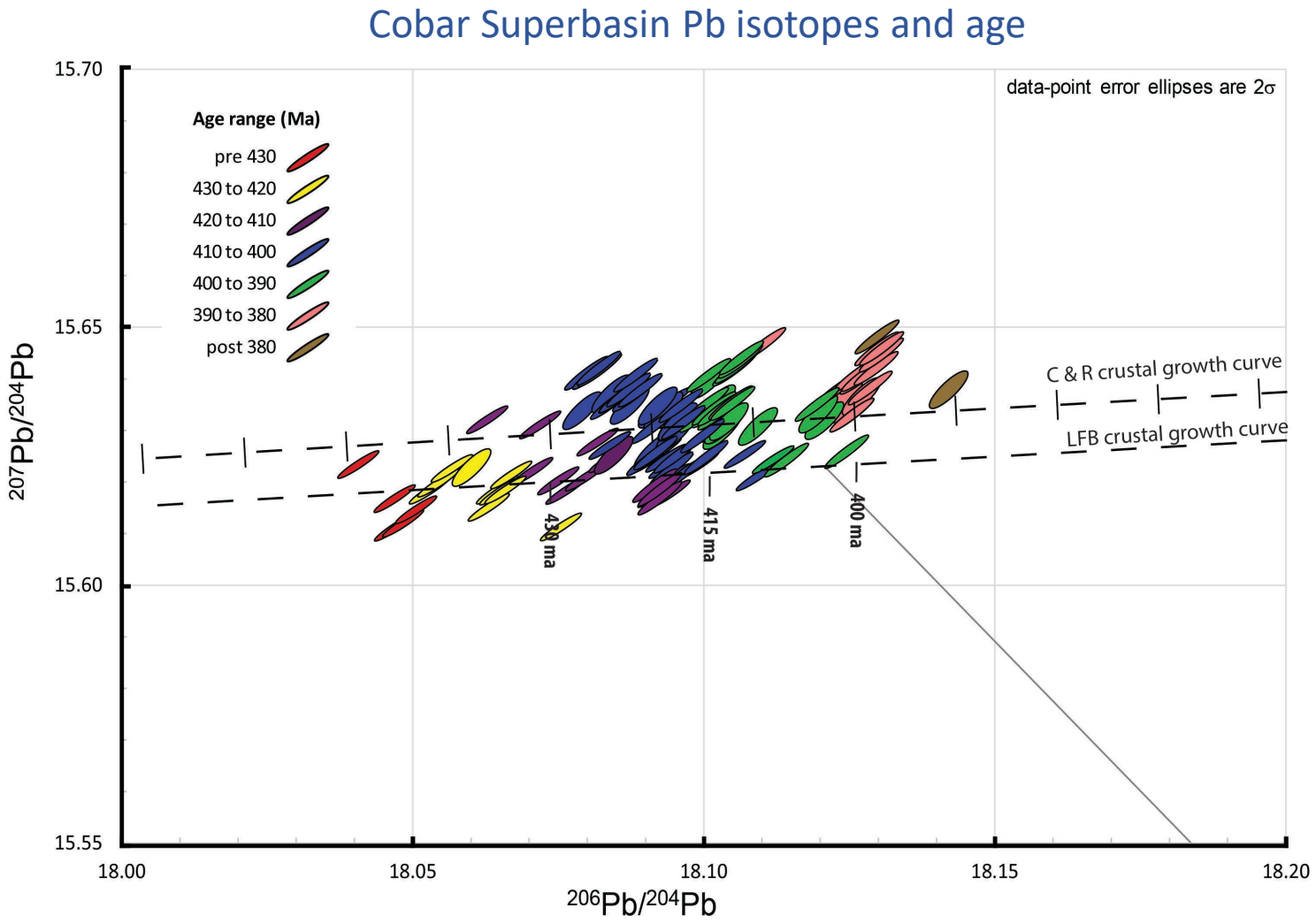
- **Alteration/gangue**
  - Simplest way to look at it is 3 phases recorded
    - ~420 Ma, ~410-395 Ma and ~390-375 Ma
  - Different zones preserve different events and often multiple





Pb isotopes

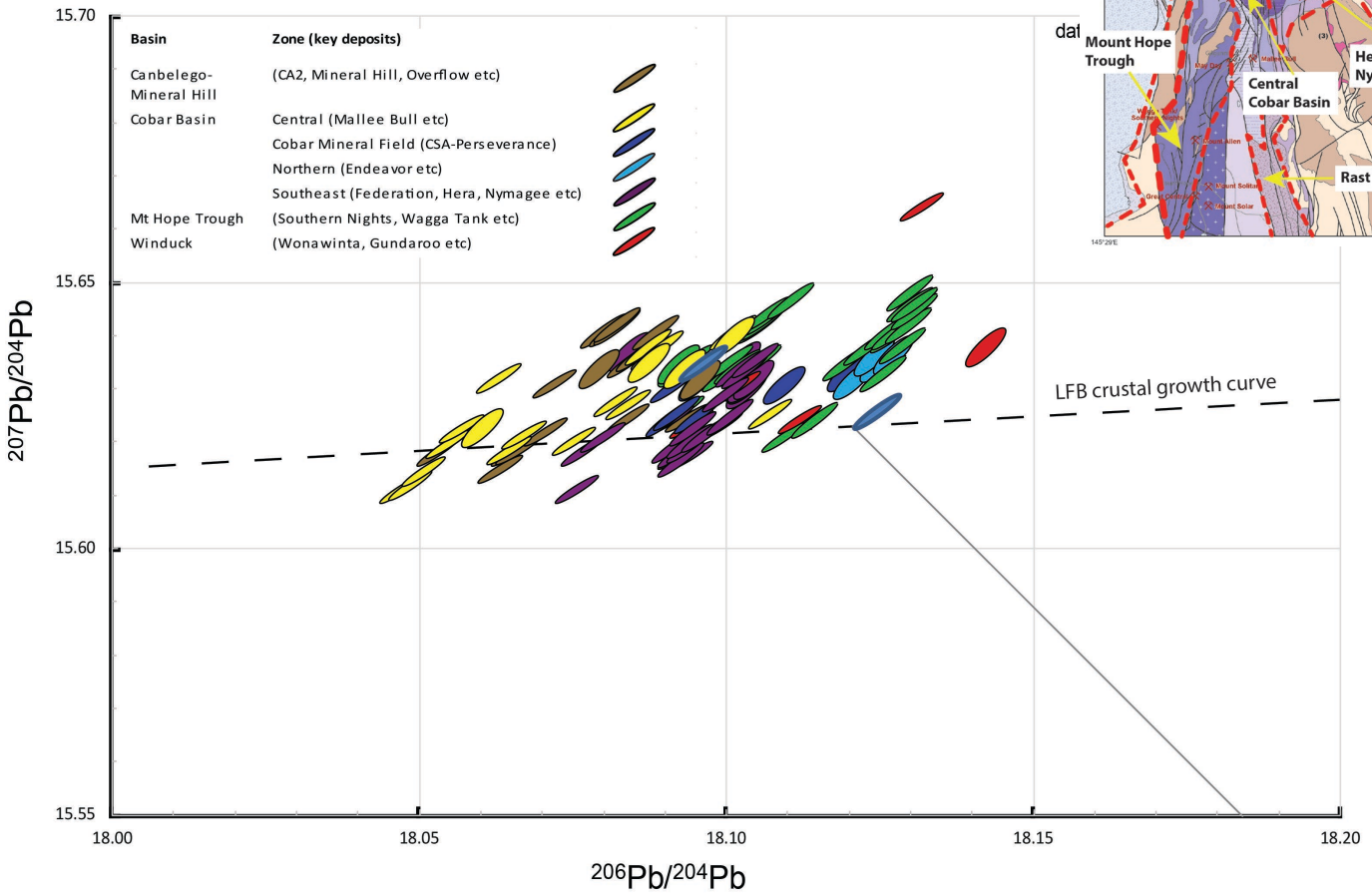
- ^{204}Pb (common Pb), ^{207}Pb, ^{206}Pb (stable radiogenic decay products of U and Th)
- Look at ratios of common/radiogenic Pb can give idea of source (e.g. crust/mantle) and model age
  - Pb reservoir is a mix of minerals
  - U(Th) within those minerals will continue to decay until the point that Pb is extracted
- Galena only in Cobar – High Pb
  - Once Pb is bound in Galena there is insufficient U-Th to change the initial Pb ratios
  - Frozen Pb-isotope ratio of galena formation/mineralisation in reservoir
- In the context of Cobar:
  - Pb is crustal
  - Calculated Pb model ages vary between 440-370 Ma
    - Consistent with our range for geochronology

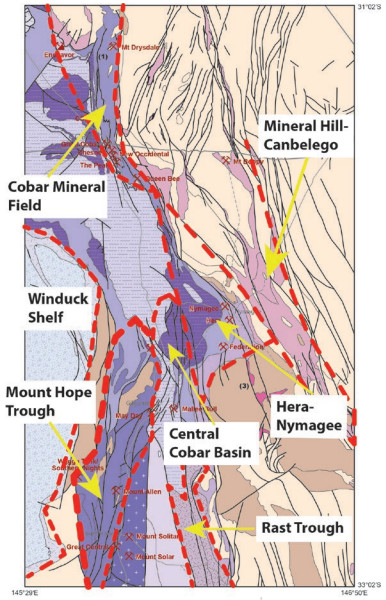


Pb isotopes – model age spatially

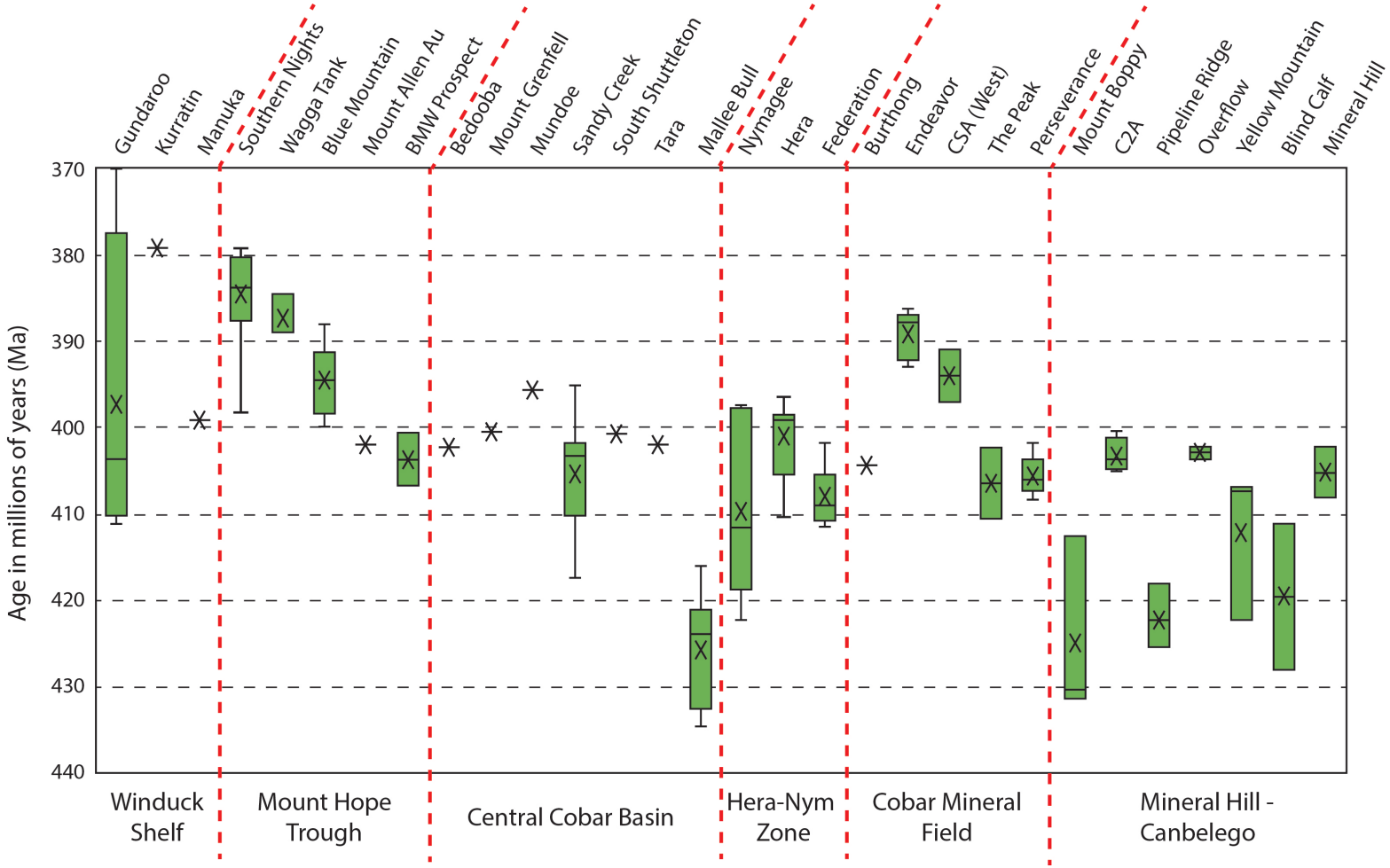
- Pb isotopes in galena record a time evolution, but also…
- Model age varies spatially across the Cobar Basin
- Canbelego-Mineral Hill and Mallee Bull
  - Oldest Pb model ages
- Nymagee-Hera Zone and Cobar Mineral Field
  - Younger Pb mode age
- Endeavor, CSA (Pb) Mount Hope Trough
  - Younger again

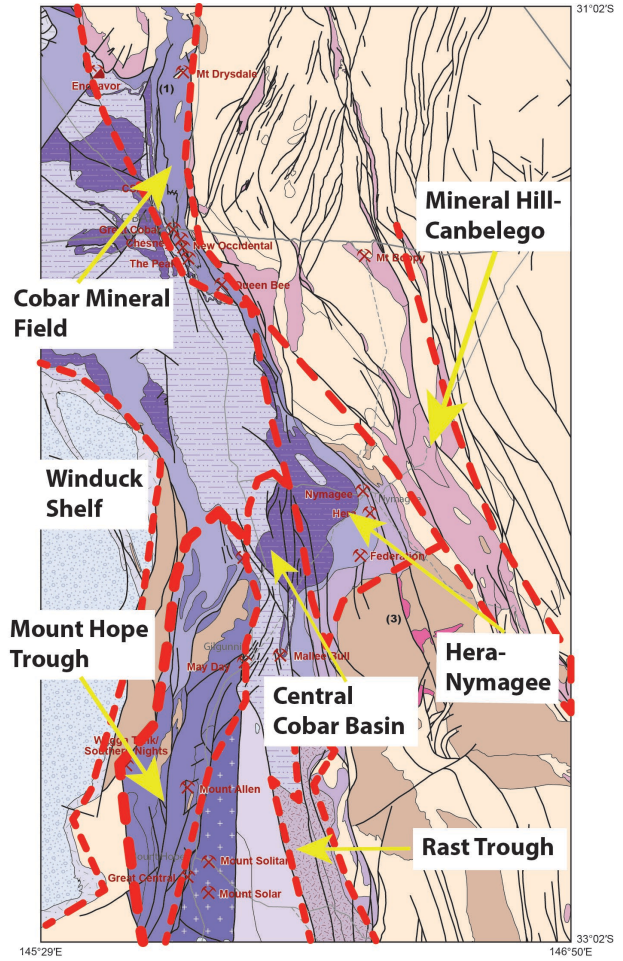
Cobar Superbasin Pb isotopes spatially





Pb isotopes – model age & metal source

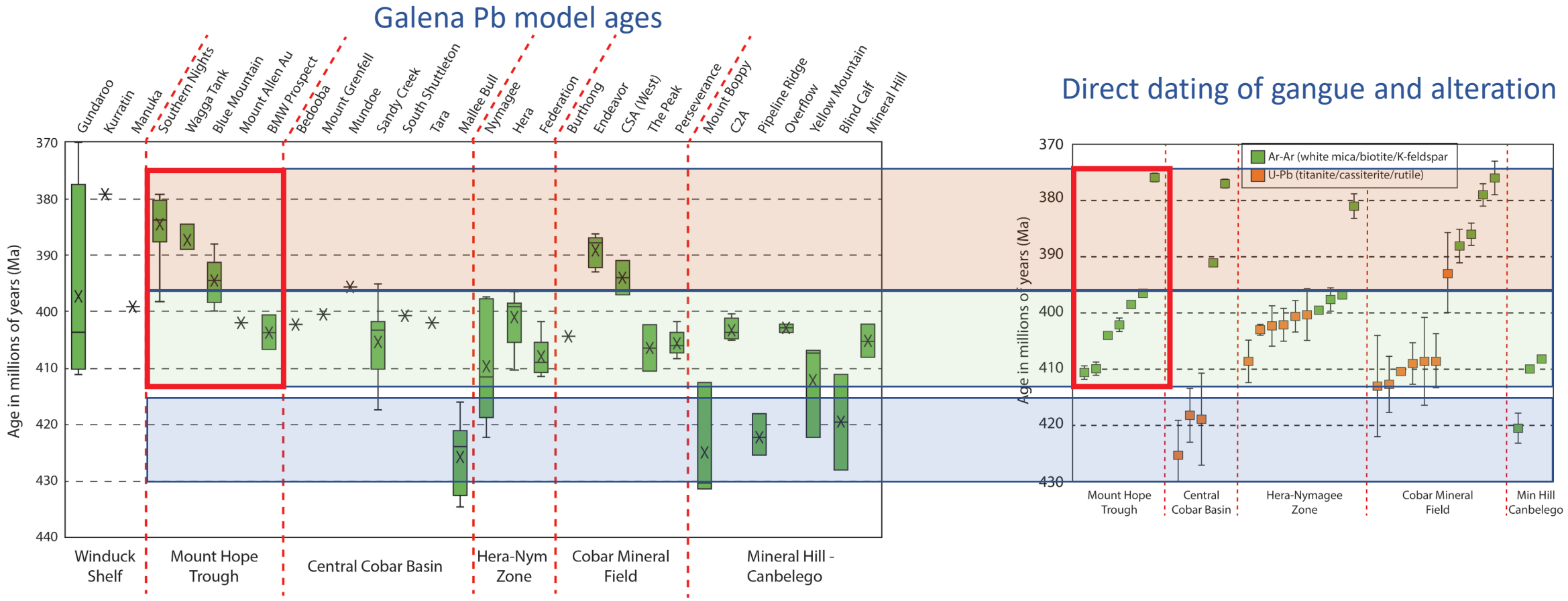




Box and whisker plot of Cobar Superbasin Pb model ages spatially

NSW GOVERNMENT

Pb model age versus geochronology

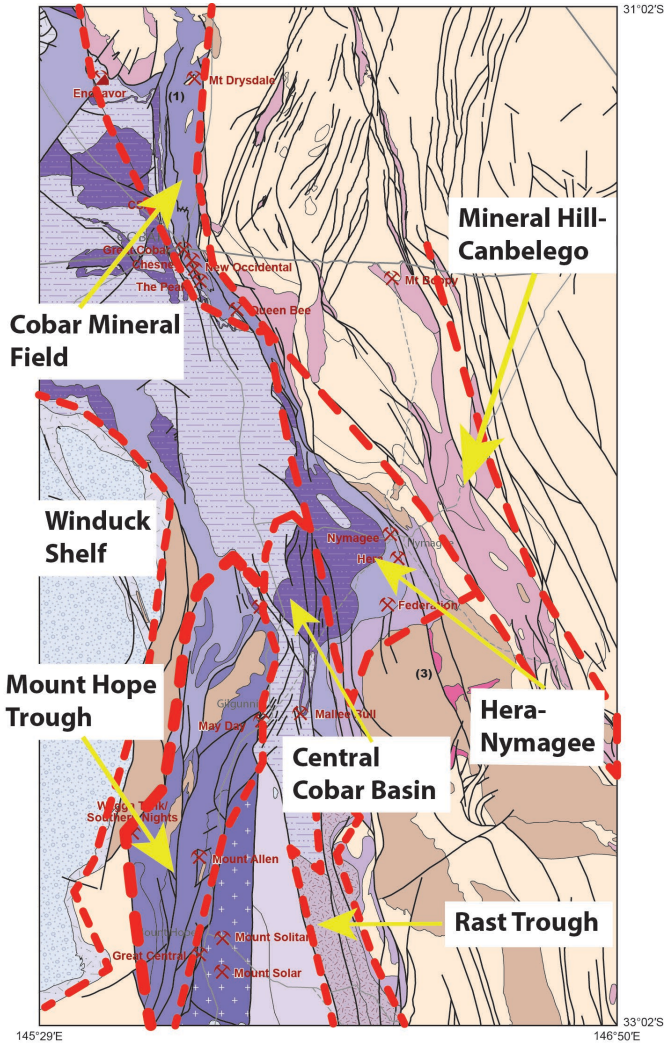


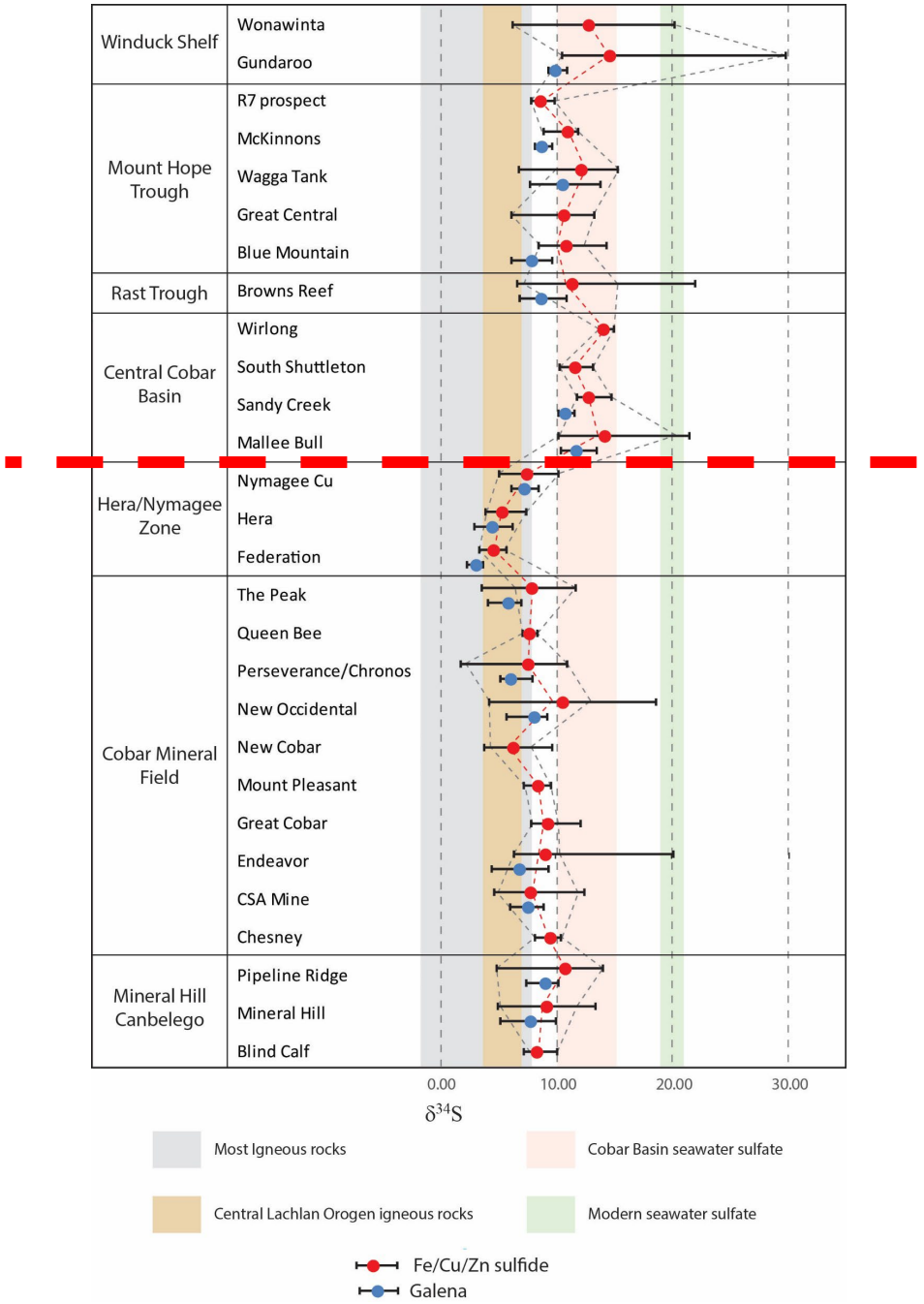
- Ages for Pb-mineralisation mostly mirror gangue mineral geochronology
- 3 phases ~420 Ma, 412-396 M and 390-380 Ma. Can piggy-back.
- Mount Hope mismatch, maybe we have only sampled Galena B in the back pack?

NSW GOVERNMENT

δ34S and fluid source

- Simplest way to look at Sulfur source in Cobar is by comparison with geologically important reference reservoirs
- Simple ratio of S^{34}/S^{32} ($\delta^{34}S$) as parts per thousand (‰)
- Sharp divide between the eastern basin and the central and western basin
- Eastern basin = mix between Cobar Basin seawater sulfate and Central Lachlan igneous $\delta^{34}S$
  - Hera – Nymagee zone $\delta^{34}S$ = Central Lachlan igneous
- Central and western basin
  - $\delta^{34}S$ closer to Cobar Basin seawater sulfate





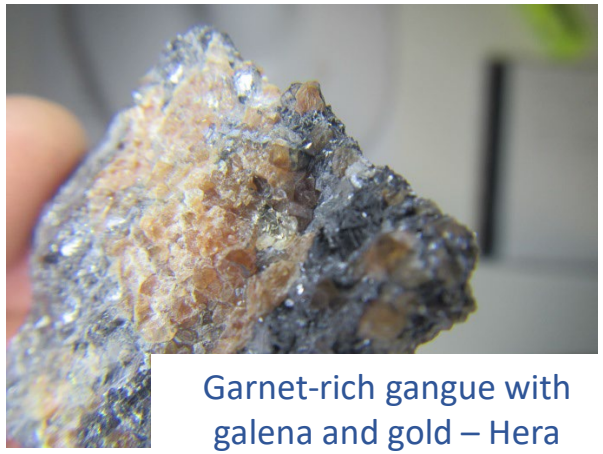
Suggests a magmatic flavour in the east

NSW GOVERNMENT

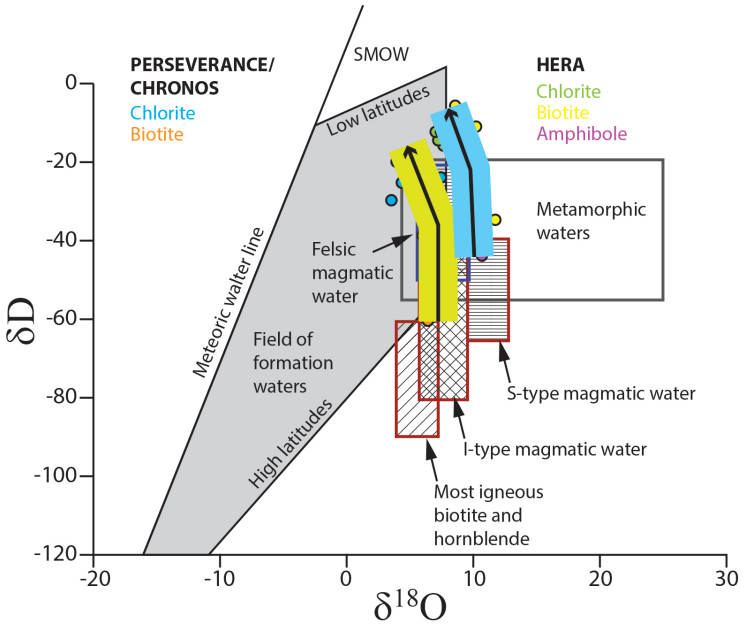
Other evidence for magmatic input

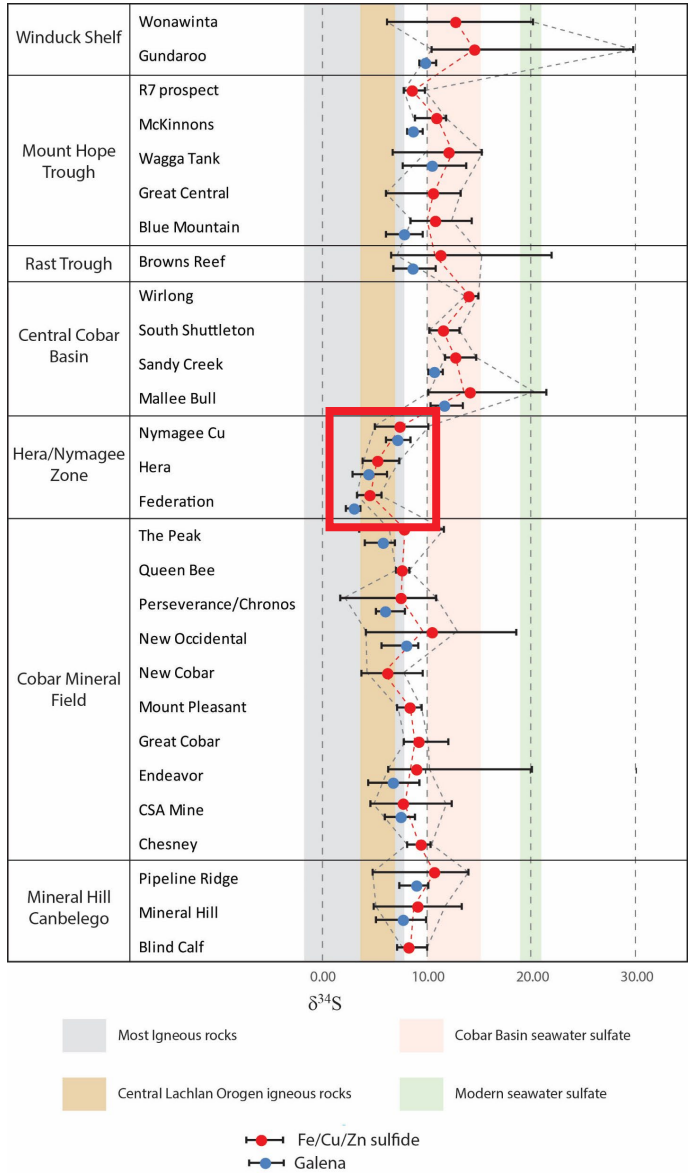
- Hera-Nymagee Zone – $\delta^{34}S$ = akin to Central Lachlan igneous rocks
- Distal skarn association with mineralisation
- O-H isotopes - measured ratios of D_2O/H_2O (δD) and O^{18}/O^{16} ($\delta^{18}O$) for biotite, amphibole and chlorite
- Fluid evolves from a field consistent with I-type/felsic magmatic water (or metamorphic) into the field of formation waters

Garnet-rich gangue – Hera

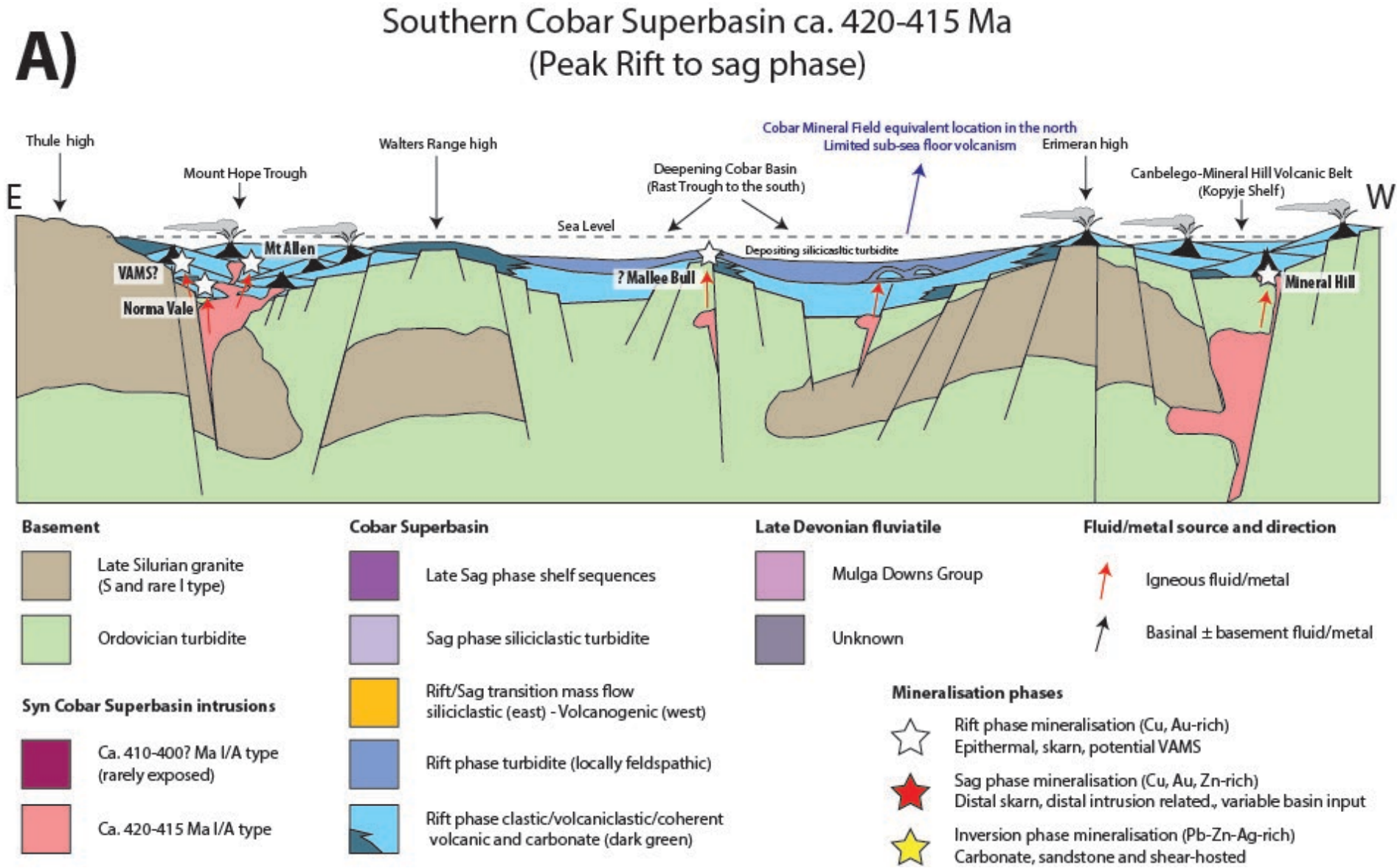


Garnet-rich gangue with galena and gold – Hera



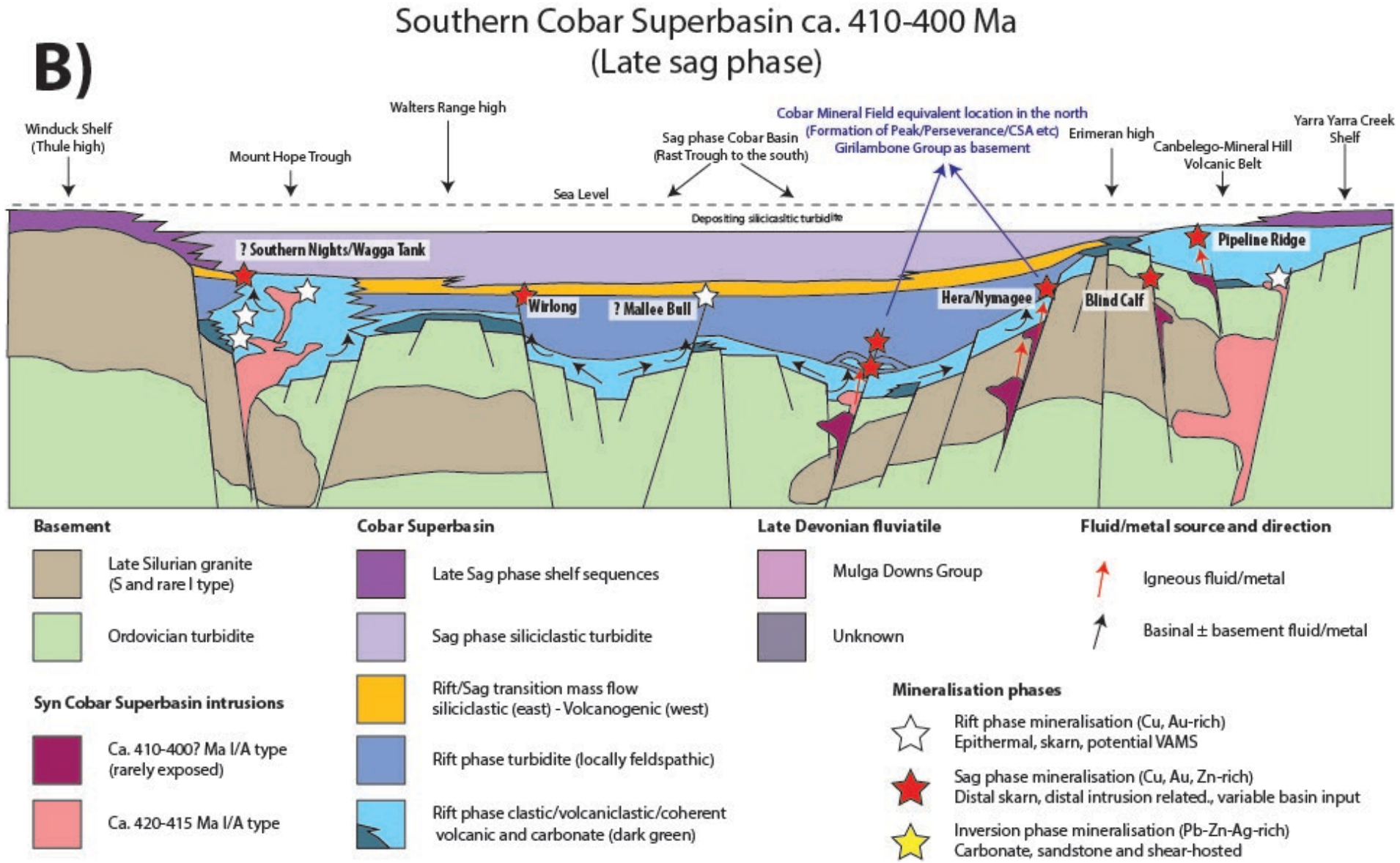


Towards a model



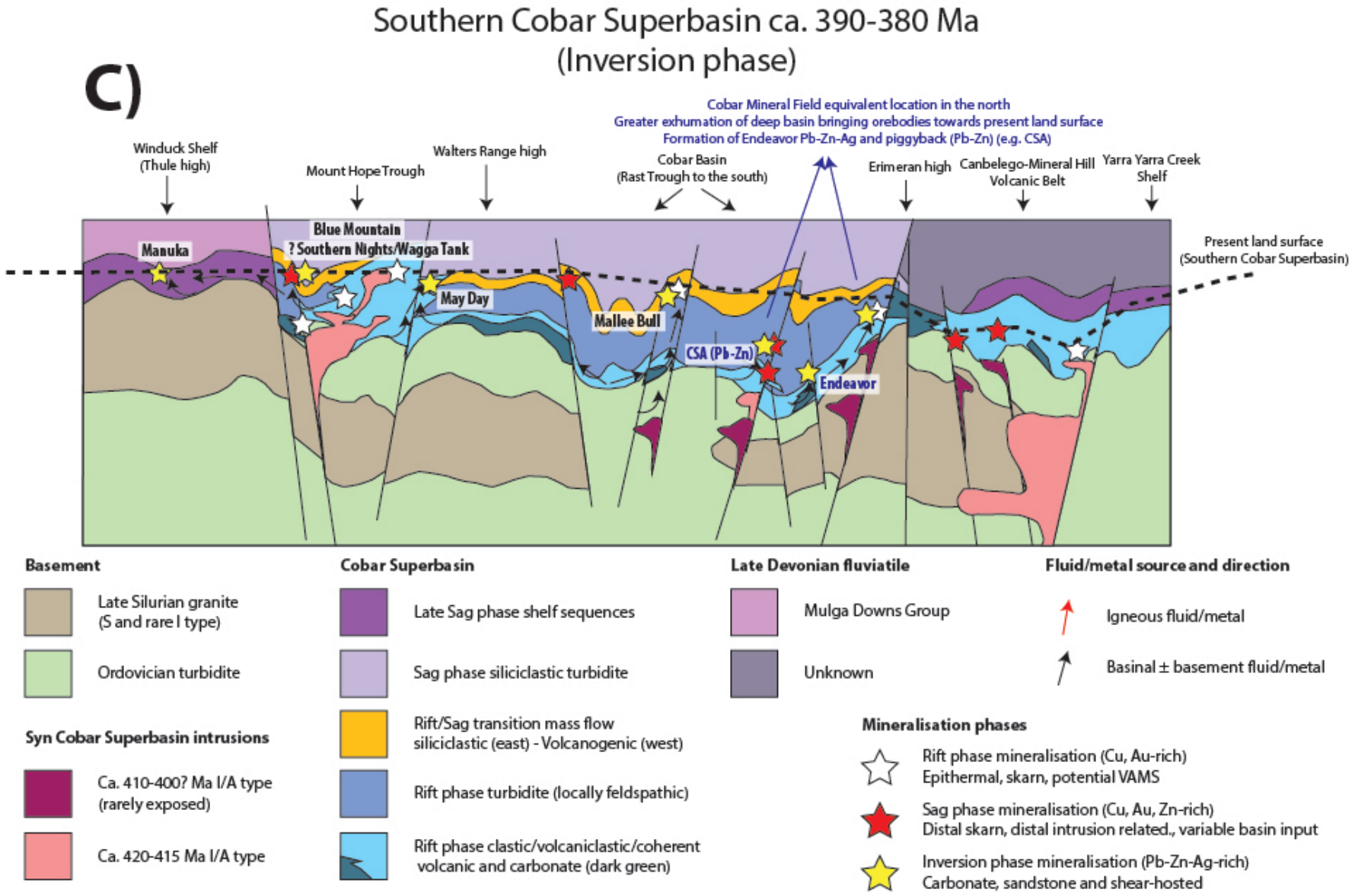
NSW GOVERNMENT

Towards a model



NSW GOVERNMENT

Towards a model

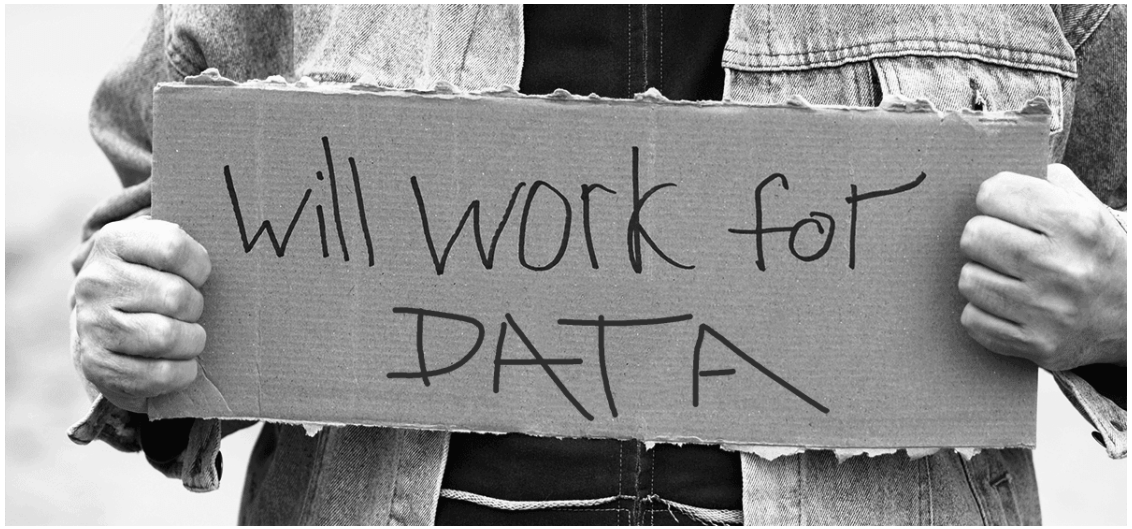


NSW GOVERNMENT

Summary

- Follow the data…
- Magmatism in the Cobar Basin so far recorded from 423-410 Ma
  - I – type dominant in the east and S-A – type dominant in the west
- Evidence for faulting and hydrothermal activity from ca. 405 Ma
- Foliation development most likely ca. 390 Ma
- Renewed faulting from 385-370 Ma

The impact of new data on knowledge is always positive



Source: https://www.shellypalmer.com/2016/05/rich-data-poor-data-data-rich-data-poor-data-middle-class-not/

- Mineralisation in three pashes using two data sources – direct dating of gangue and Pb-Pb isotopes of galena
  - Ca. 420 Ma coinciding with rift volcanism – Cu-Au-Pb-Zn-Ag(Sn) – Likely more to be revealed
  - 410-400 Ma epigenetic mineralisation along major fault systems – Magmatic flavour Cu-Au-Zn-Pb-Ag – Tail end of magmatism
    - We know we have faults active at this time.
  - 390-380 Ma epigenetic mineralisation. Amagmatic dominantly Pb-Zn-Ag
    - Basin derived during inversion between 390-380 Ma. Can be piggyback bodies
  - Mismatch between Pb and Ar-Ar dating in the western basin may represent:
    - Incomplete sampling of the system. i.e. we haven't found the old Pb yet – New Pb isotope from laminated sulfide horizons
    - Older plateaus in the Ar-Ar may reflect host feldspar – New SHRIMP dating to be done at Southern Nights

NSW GOVERNMENT

Joel Fitzherbert

Joel.Fitzherbert@regoinal.nsw.gov.au

NSW GOVERNMENT