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Exploring Outside the Box 2016

'New insights into the Architectural Development of the southern Cloncurry IOCG Terrain - Controls and Timing of Mineralization'

Mark Hinman

Queensland Government
Department of Natural Resources and Mines
Geological Survey of Queensland

Fullagar Geophysics

chinova resources

DMQ Project - southern Cloncurry Belt

'Prospectivity - Mineability - Viability'

Overall aims to reduce risk of exploring for large, mass-mineable deposits at depth in the southern Cloncurry Belt.

Reported here:

(1) Updated solid geology, structural, & tectono-stratigraphic interpretation which builds on the published GSQ 100K solid geology, utilizing the smaller scale prospect geology & detailed geophysics made available by Chinova

(2) Some resource-scale examples of timing and controls on IOCG-style mineralisation

DMQ Project Team

Dr Travis Murphy (Exploration & Mine Geology)
Dr Mark Hinman (Exploration & Mine Geology)
Dr Mark Pirlo (Exploration Geochemistry)
John Donohue (Exploration Geophysics)
Mark Jones (Software Engineering & Database Support)

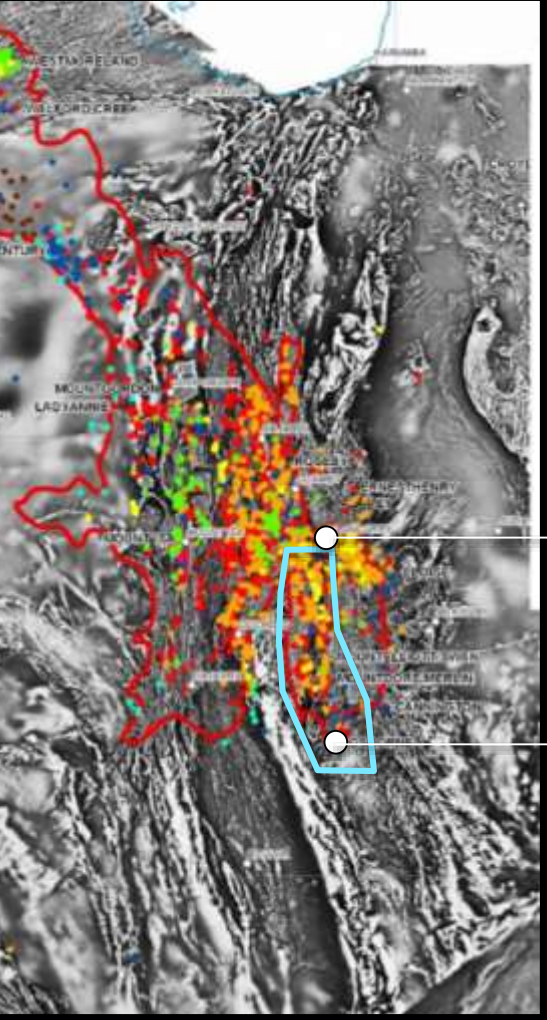
Acknowledgements

Chinova … data including detailed geophysics, detailed prospect mapping & project ddh databases
GSQ … pre-release 100K mapping (Selwyn, Mount Angelay), geochron database
Historic Mapping … Leishman, 1970s-80s; Searl, 1952; … *& others*
Personal … understanding gained during contract work for Ivanhoe, Inova & Chinova, 2011-2015

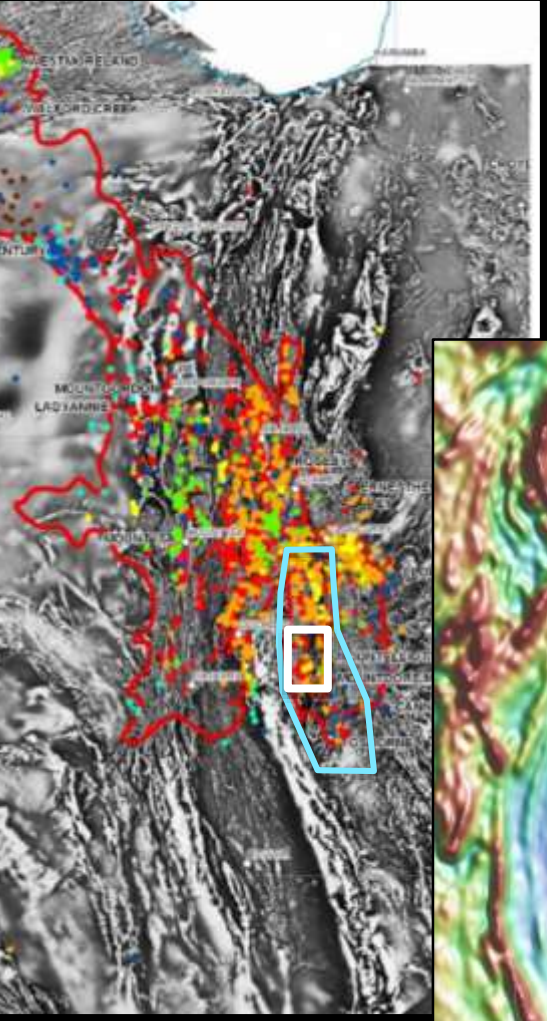
Deep Mining Queensland Project Location

Eastern Fold Belt between Cloncurry & Osborne

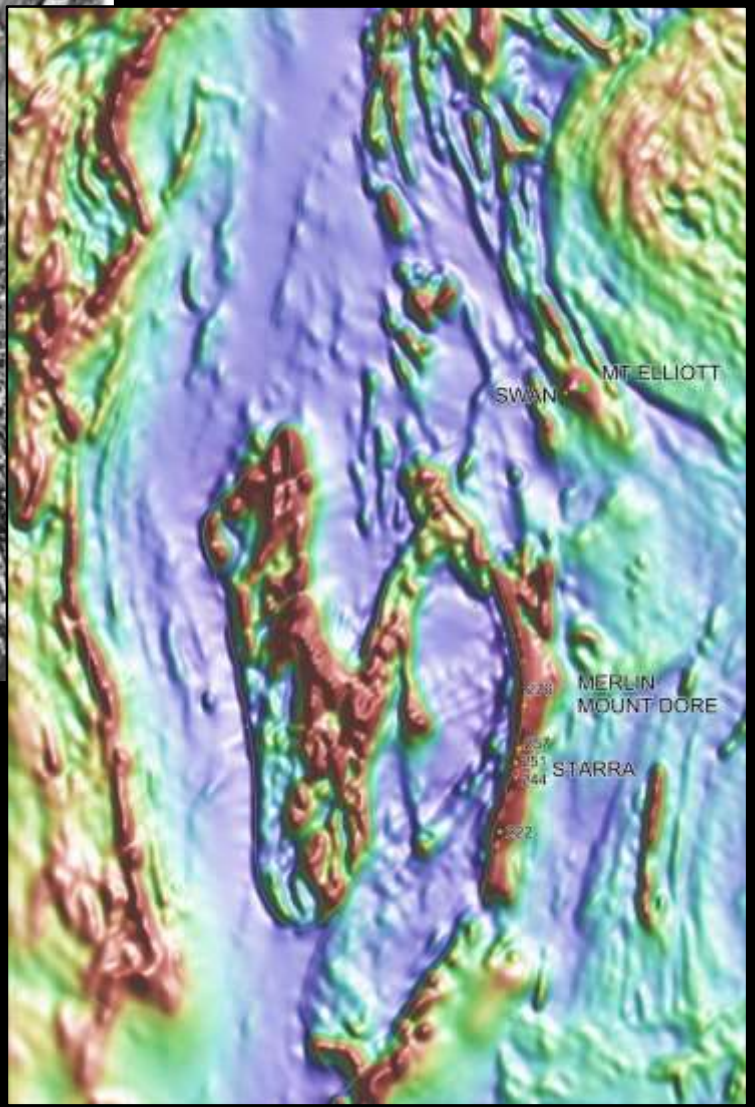
***approx* 180x50km**



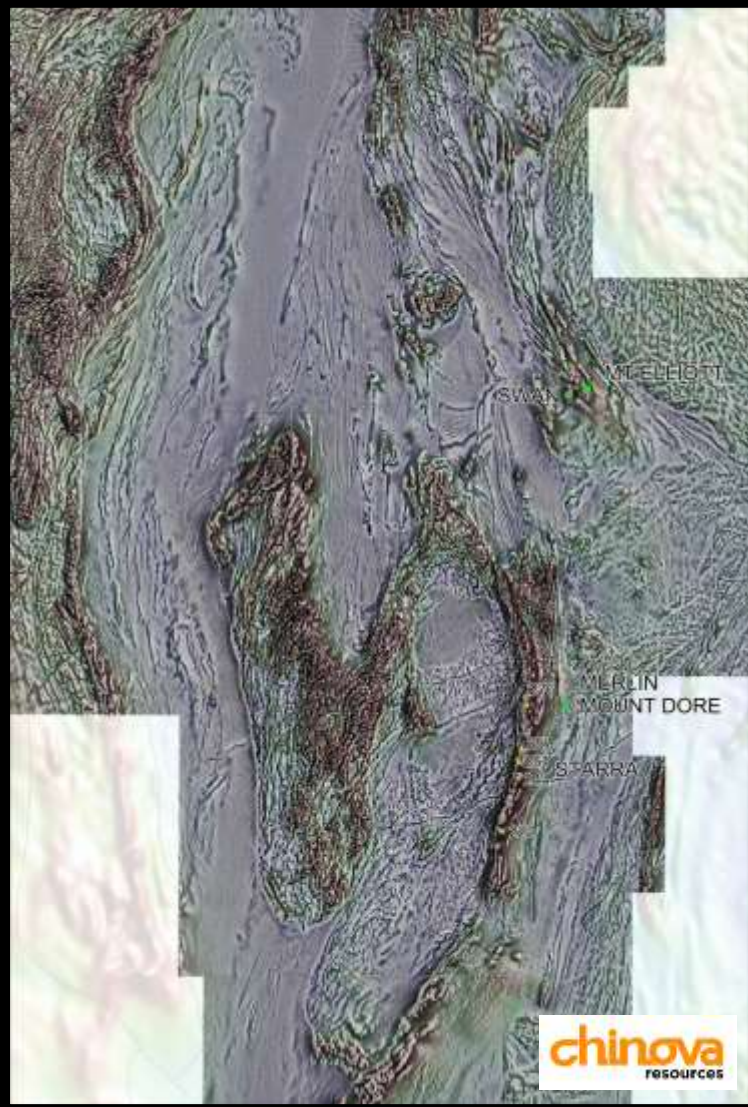
Regional *vs* Detailed Magnetics



GA Mag tmi-rtp v6 (**2015**) 80m grid



Chinova detailed Mag merge vrmi-2vd (**201x**) 10m grid



Very significant difference in resolution

… has allowed a high fidelity interpretation

> package continuity
> package architecture
> faulting and fine structure

KEY POINTS

DMQ southern Cloncurry IOCG Belt

- **IOCG-style mineralisation focuses within late Isan** (D3-4), **brittle, fracture-breccia networks that are controlled by local competency contrast & strain partitioning.**

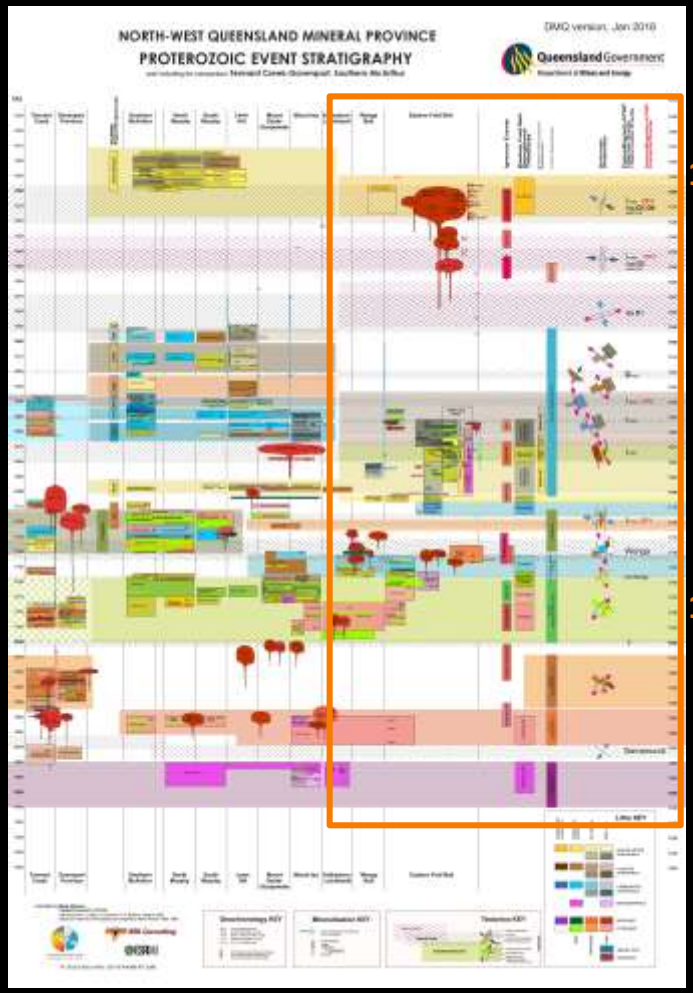
- **D3-4 structuring comprises short-strike / small-displacement faults, and localised reactivation of older structures** …. in contrast with, **D2 faults which are regional in strike & commonly juxtapose packages of contrasting lithology & age.**

(Dichotomy: D2 structure well imaged (mapping, seismic, geophysics ..) cf. D3-4 structures, likely highly seismic, but generally not well imaged!)

- **In D3-4 time, crystallising granites** (that drive the high temp, IOCG fluid systems) **themselves locally play roles in strain partitioning which drives the brittle failure focusing IOCG mineralisation.**

- **Pre-orogenic architectures likely play critical roles in the geometries of intrusion, brittle deformation, IOCG fluid circulation, & the localisation of ore formation.**

Tectono-Stratigraphic Development of Eastern Fold Belt

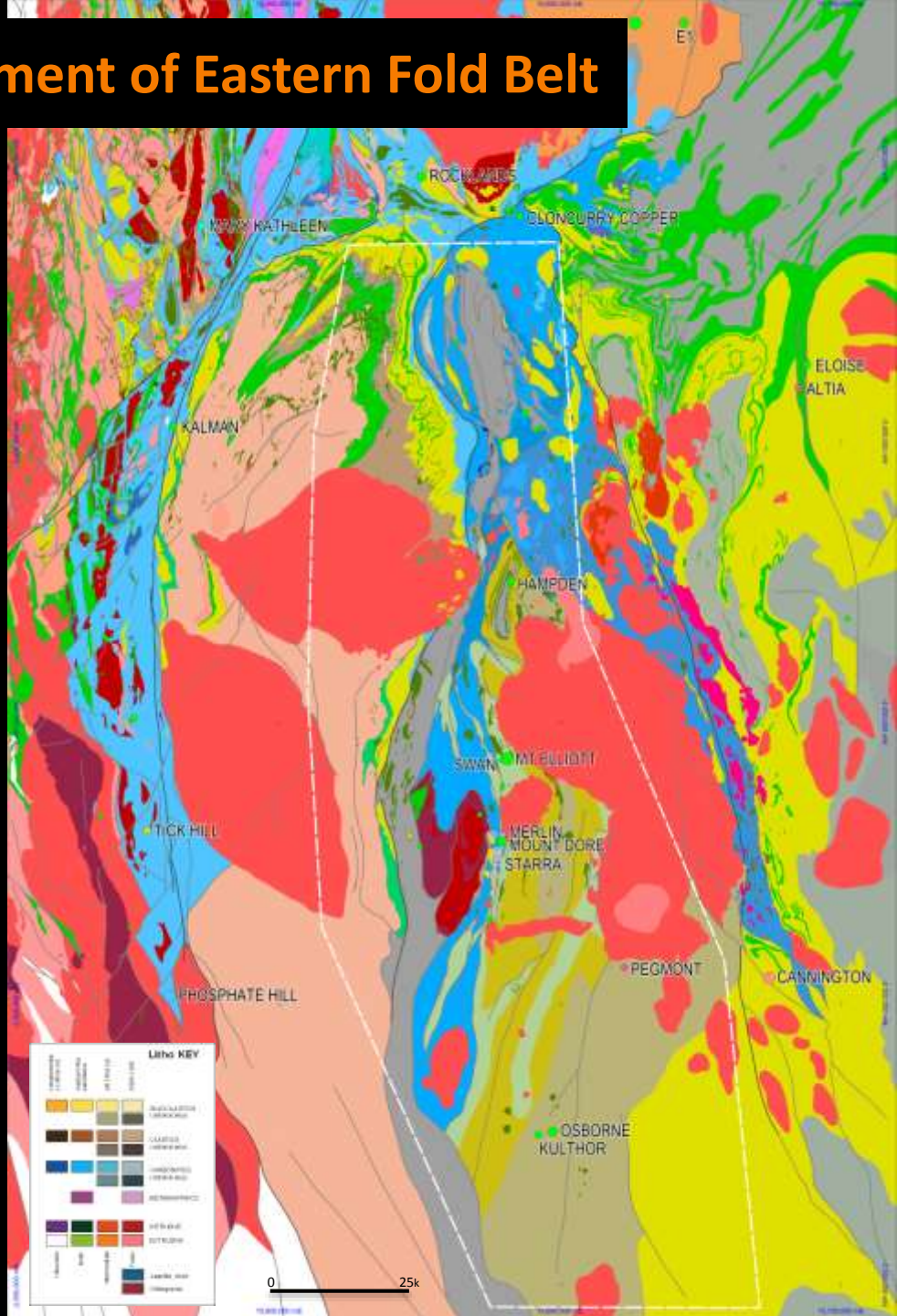


1400Ma

1770Ma

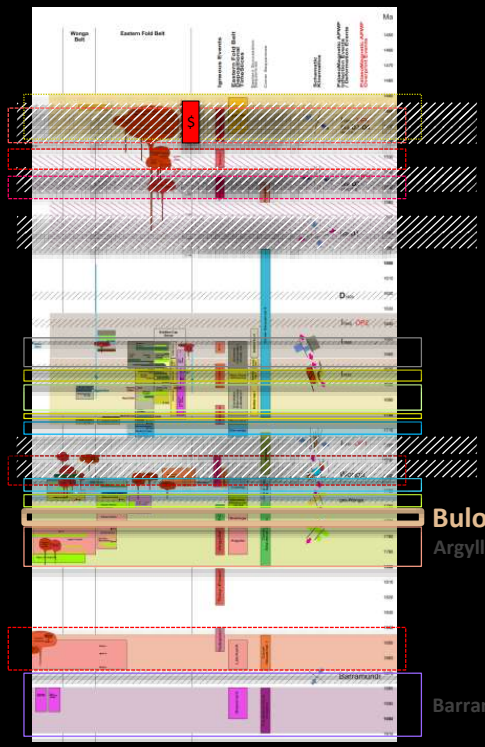
Updated 2000 NWQMP Tx Chart
to reflect current understanding of EFB package relationships &latest geochronology (Withnall-Parsons, 2007-2009; NWQMEP, 2011)

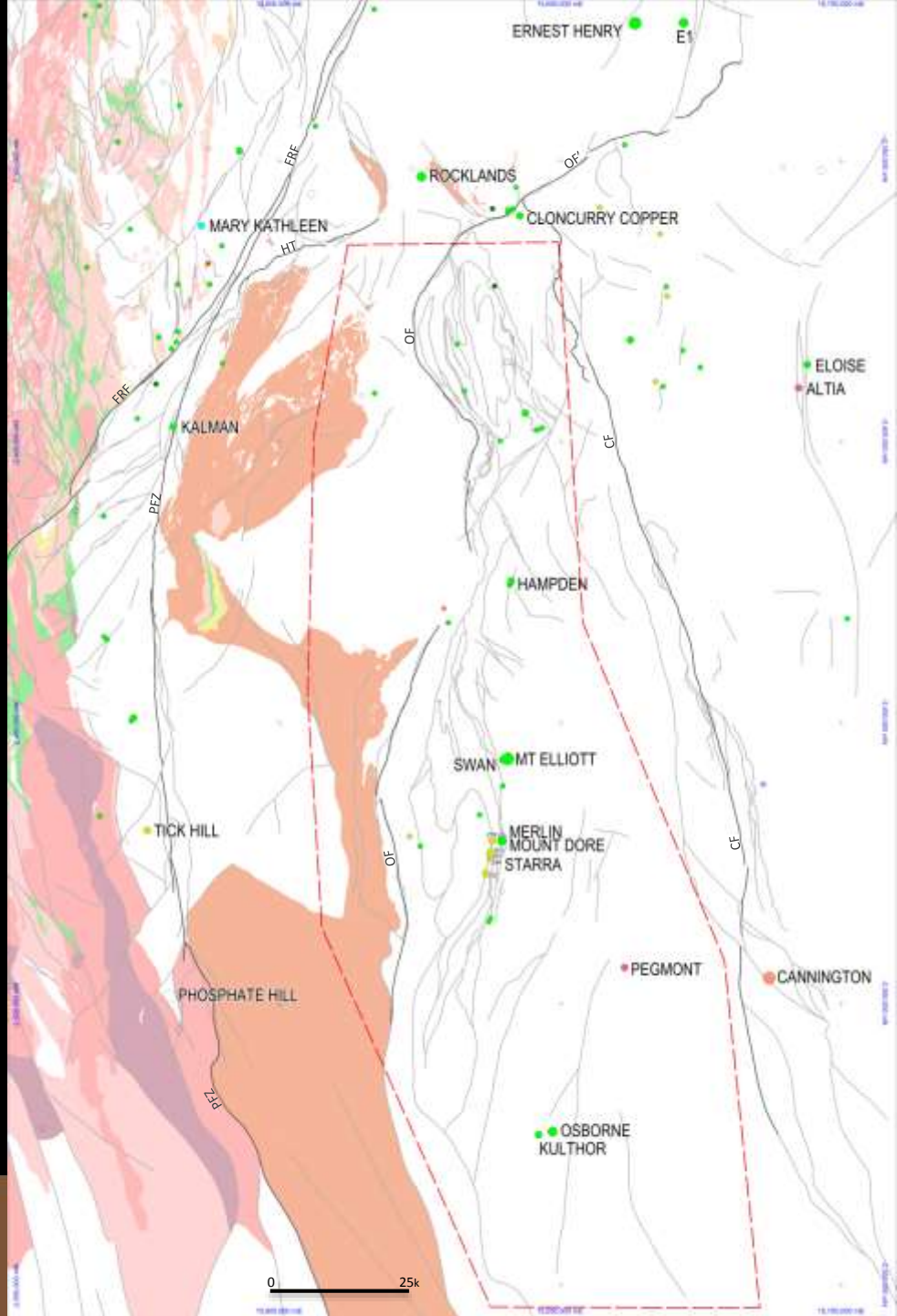
Re-built EFB Solid Geology
highlighting packages & deformation events that impact their geometry



~1775-1765Ma

Bulonga





FRF = Fountain Range Fault
PFZ = Pilgrim Fault Zone
HT = Highway Thrust
OF = Overhang Fault
CF = Cloncurry Fault

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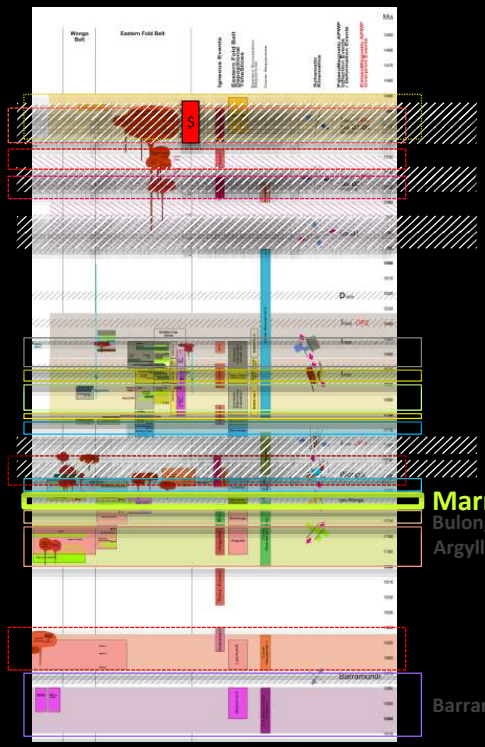
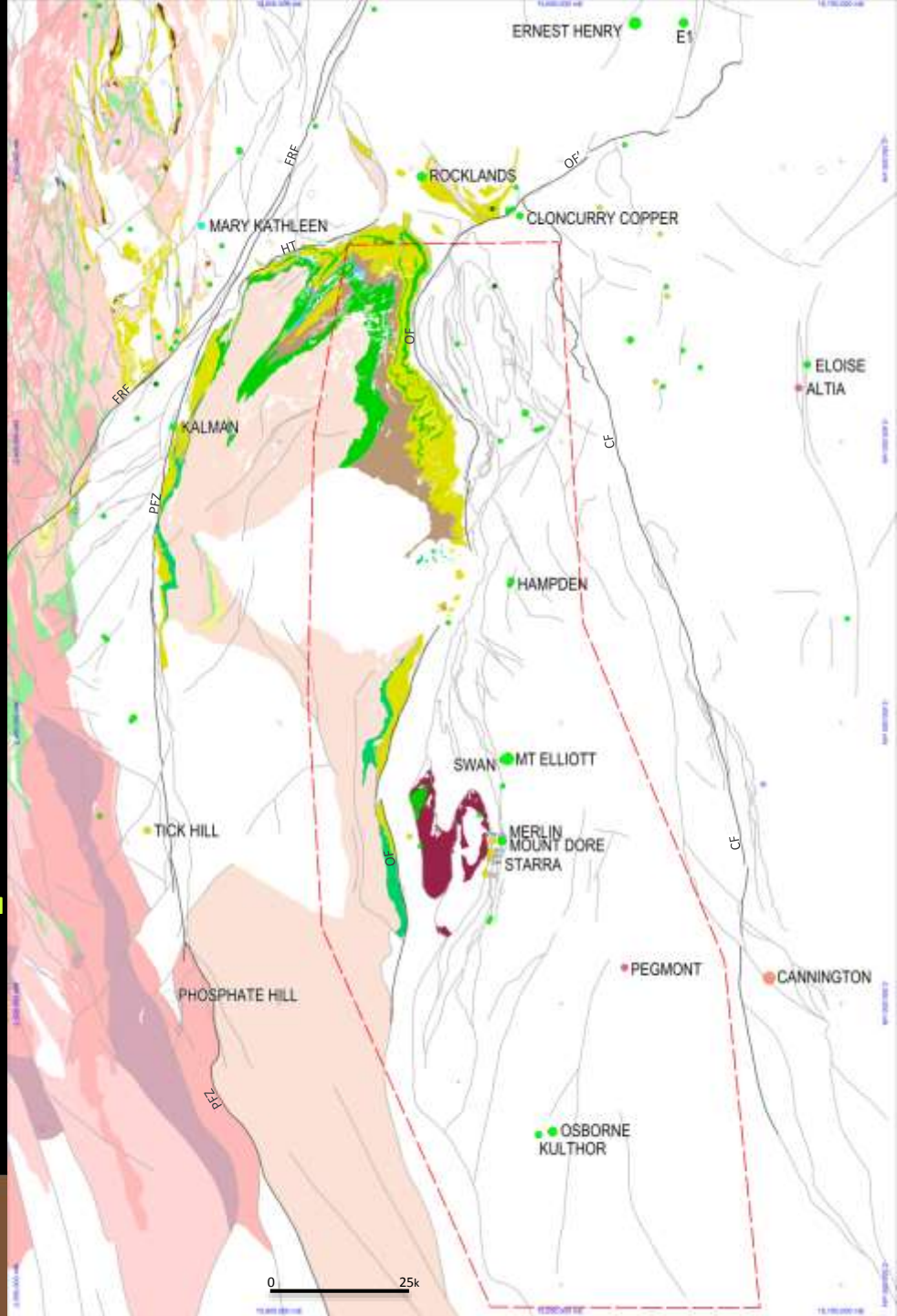
~1765-1755Ma

Marraba-Mitakoodi-Double Crossing Meta





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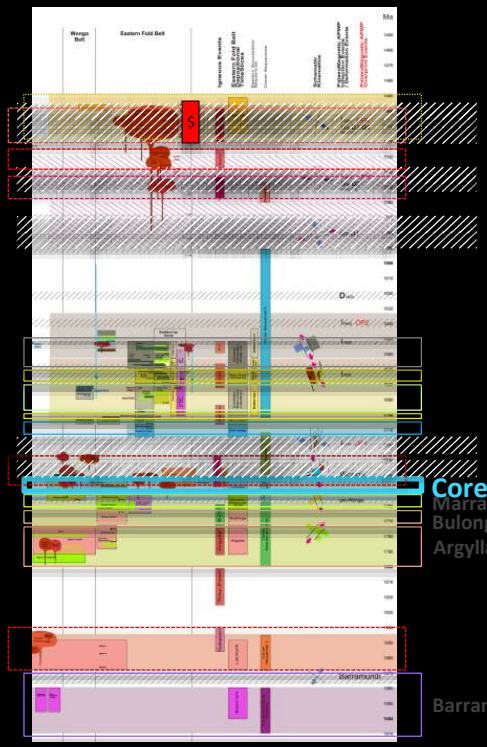
~1755-1740Ma

Corella



Corella

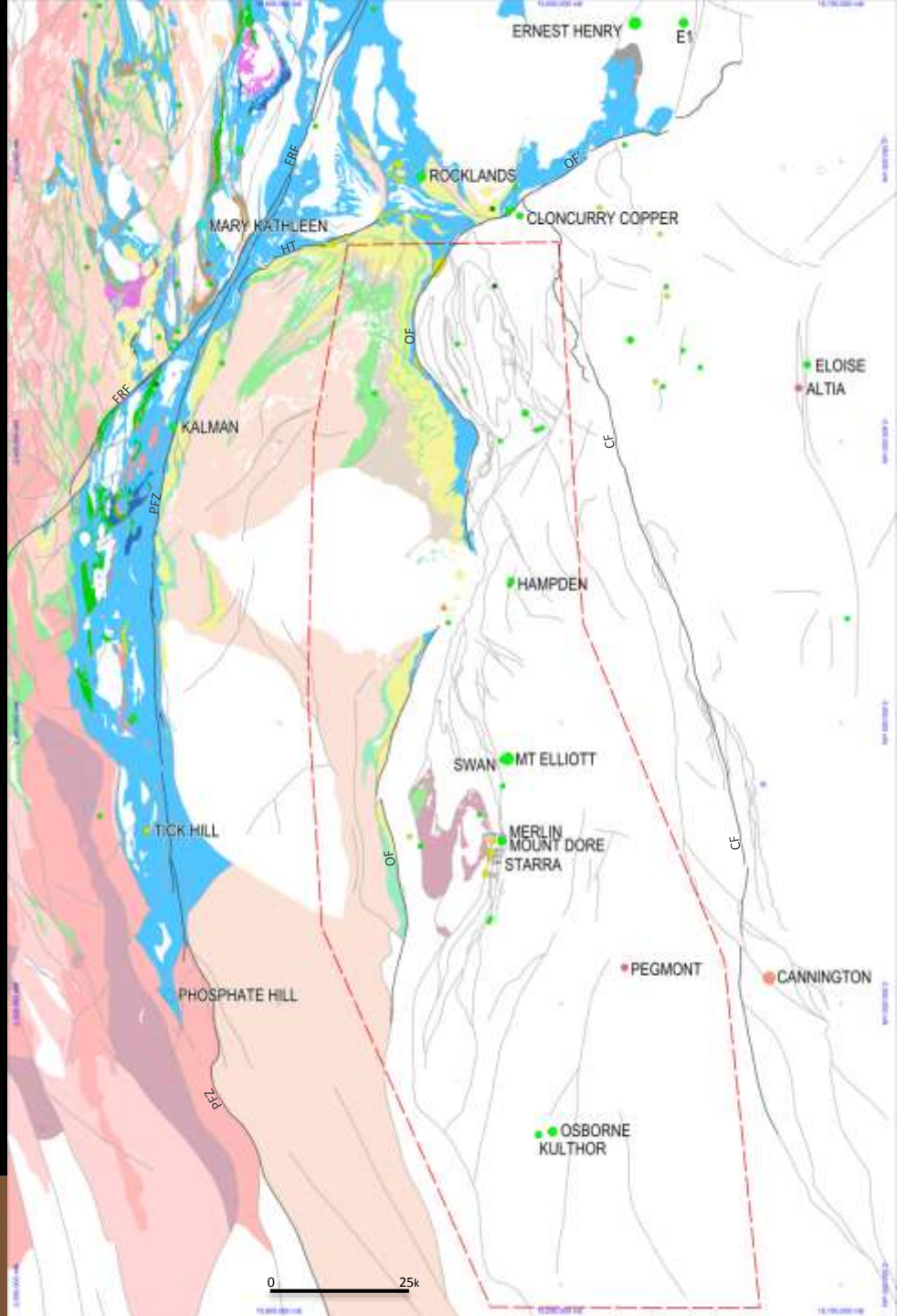
Marraba-Mitakoodi-DCM

Bulonga

Argylla

Kalkadoon
Leichardt Volcs

Barramundi



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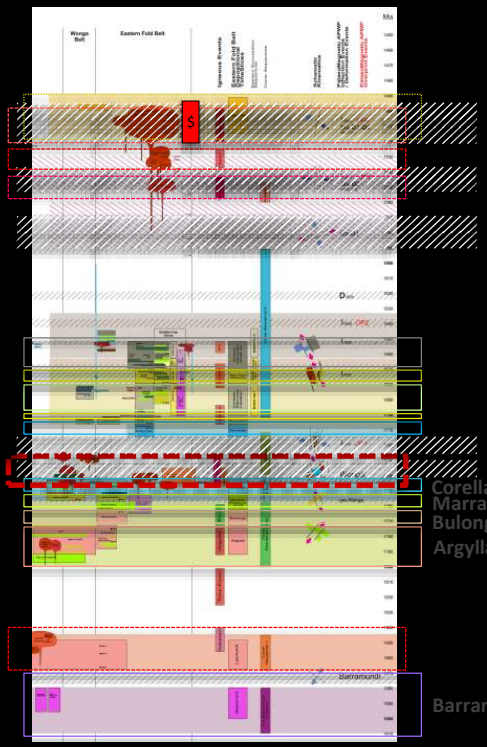
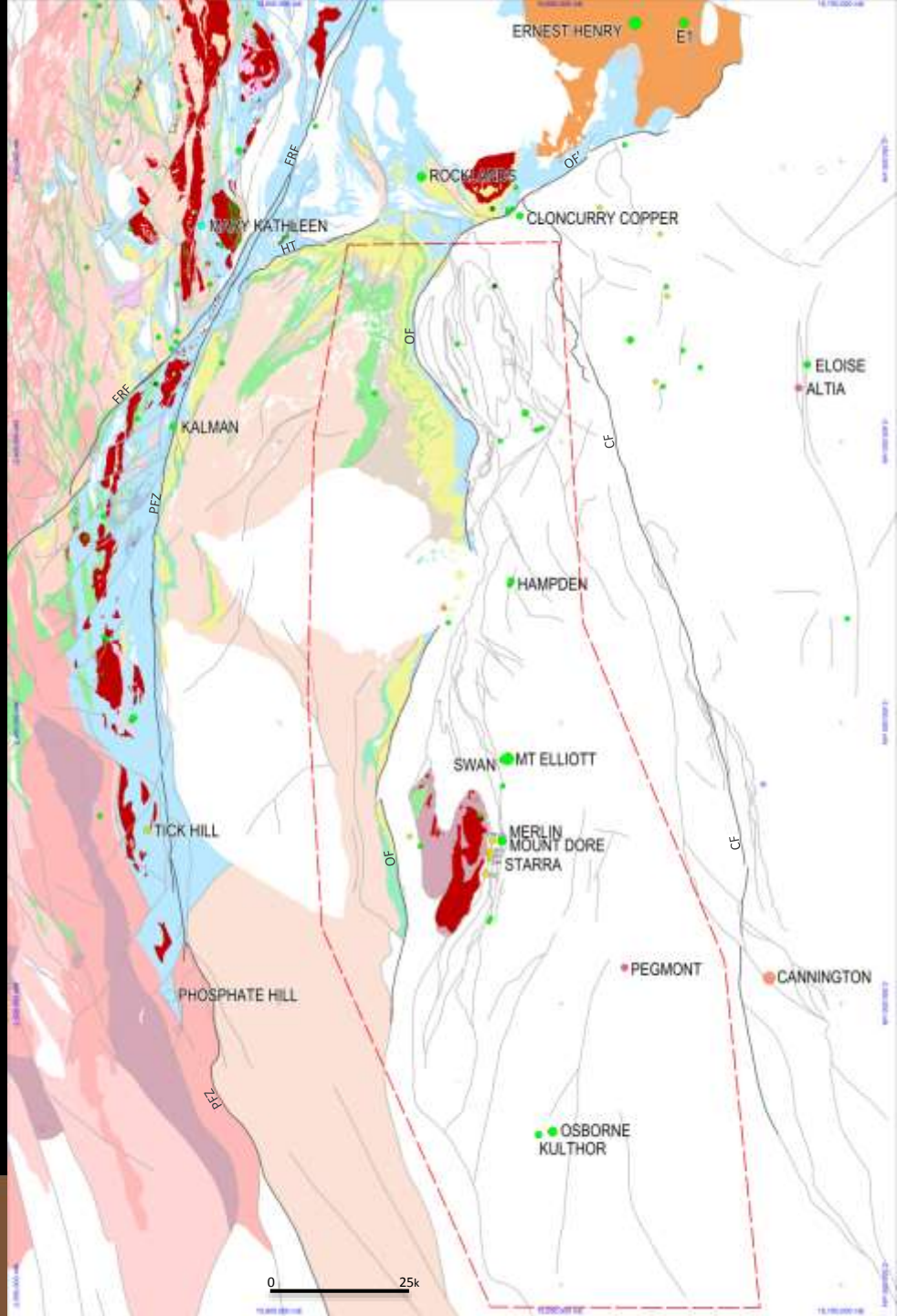
~1740Ma

WONGA Extension

~1740-1745Ma

Mount Fort Constantine Volcanics





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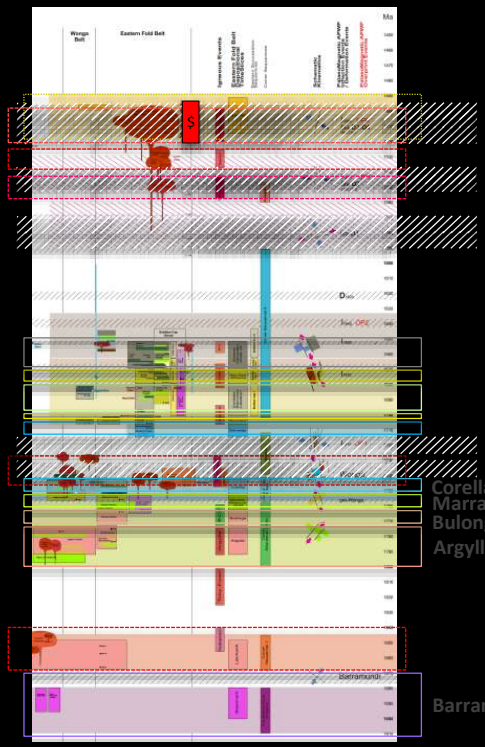
~1710Ma

⇨⇦ OP1 Deformation

APWP for the Palaeo-MesoProterozoic of Northern Australia **(Idnurm, 2000)**



Wonga MFCV

Kalkadoon Leichardt Volcs

OP1 ⇨⇦

WONGA

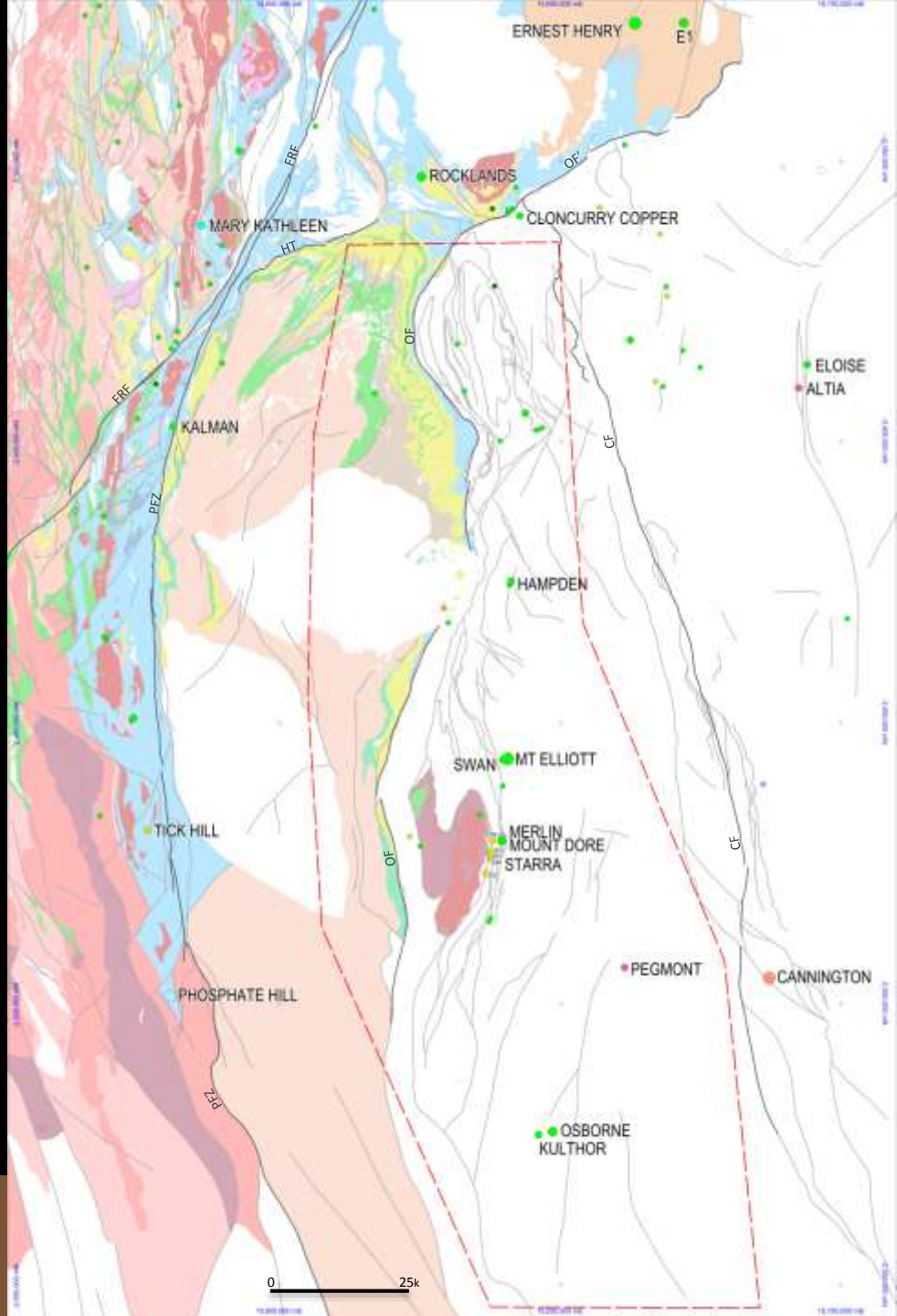
Corella

Marraba-Mitakoodi-DCM

Bulonga

Argylla

Barramundi



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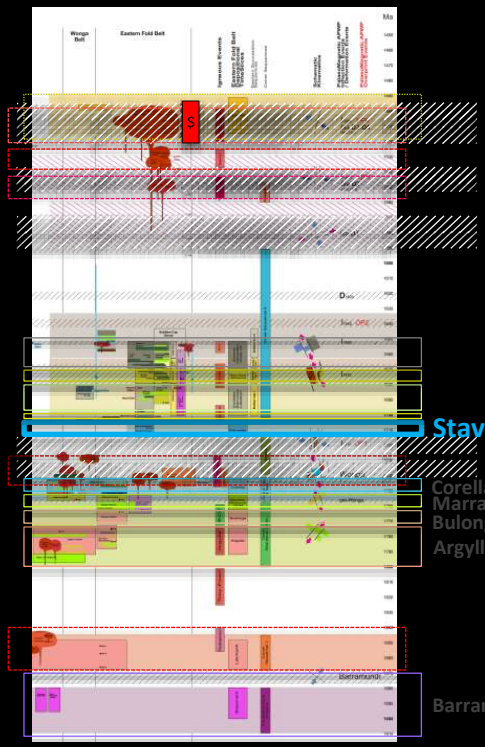
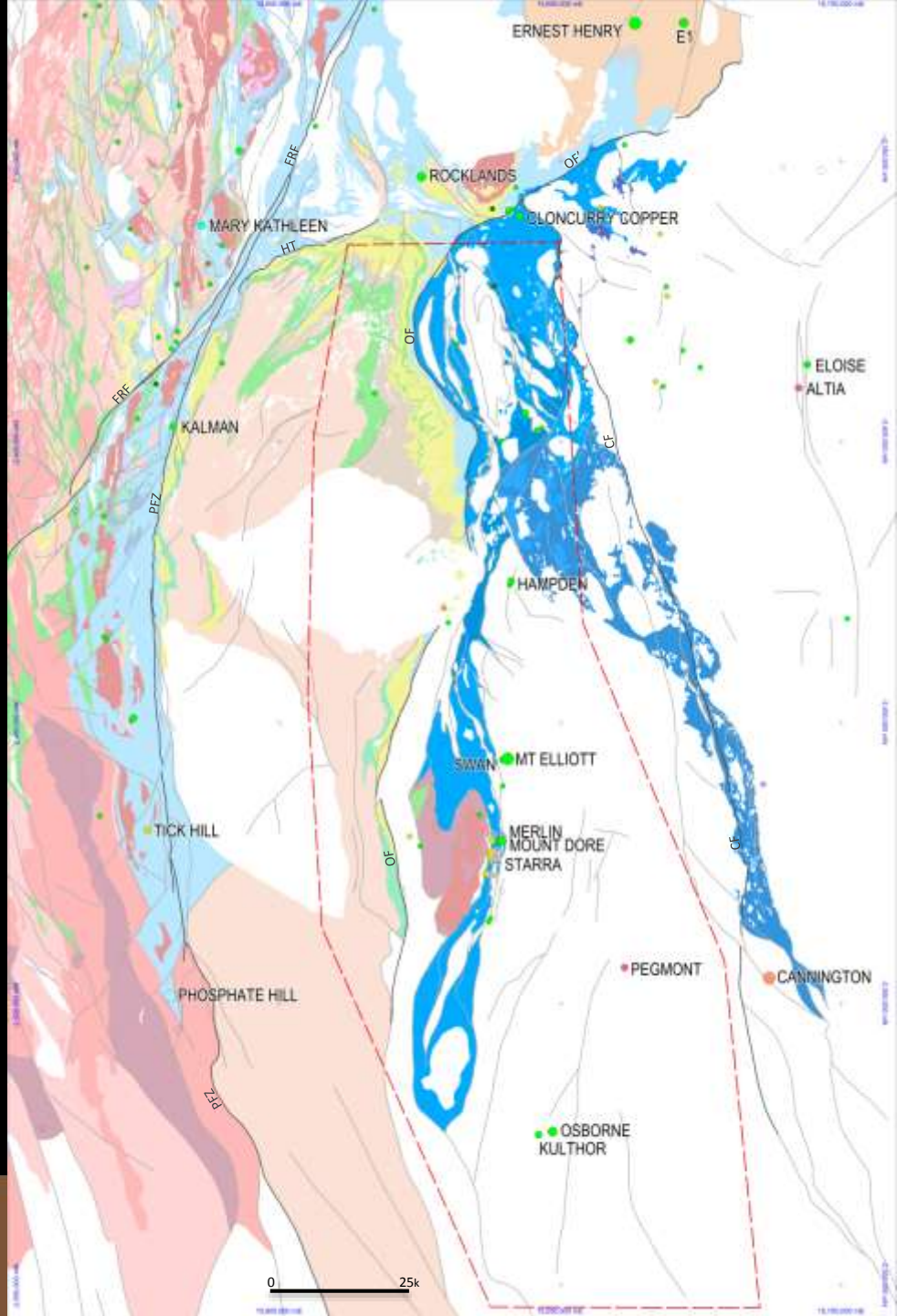
~1715-1710Ma

Staveley





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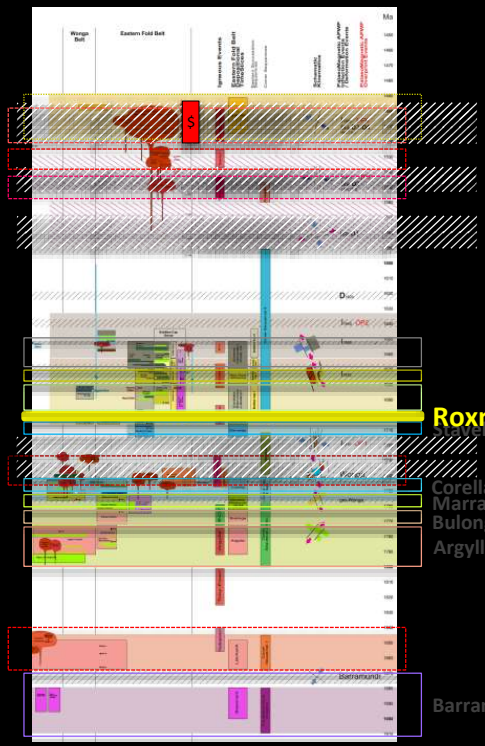
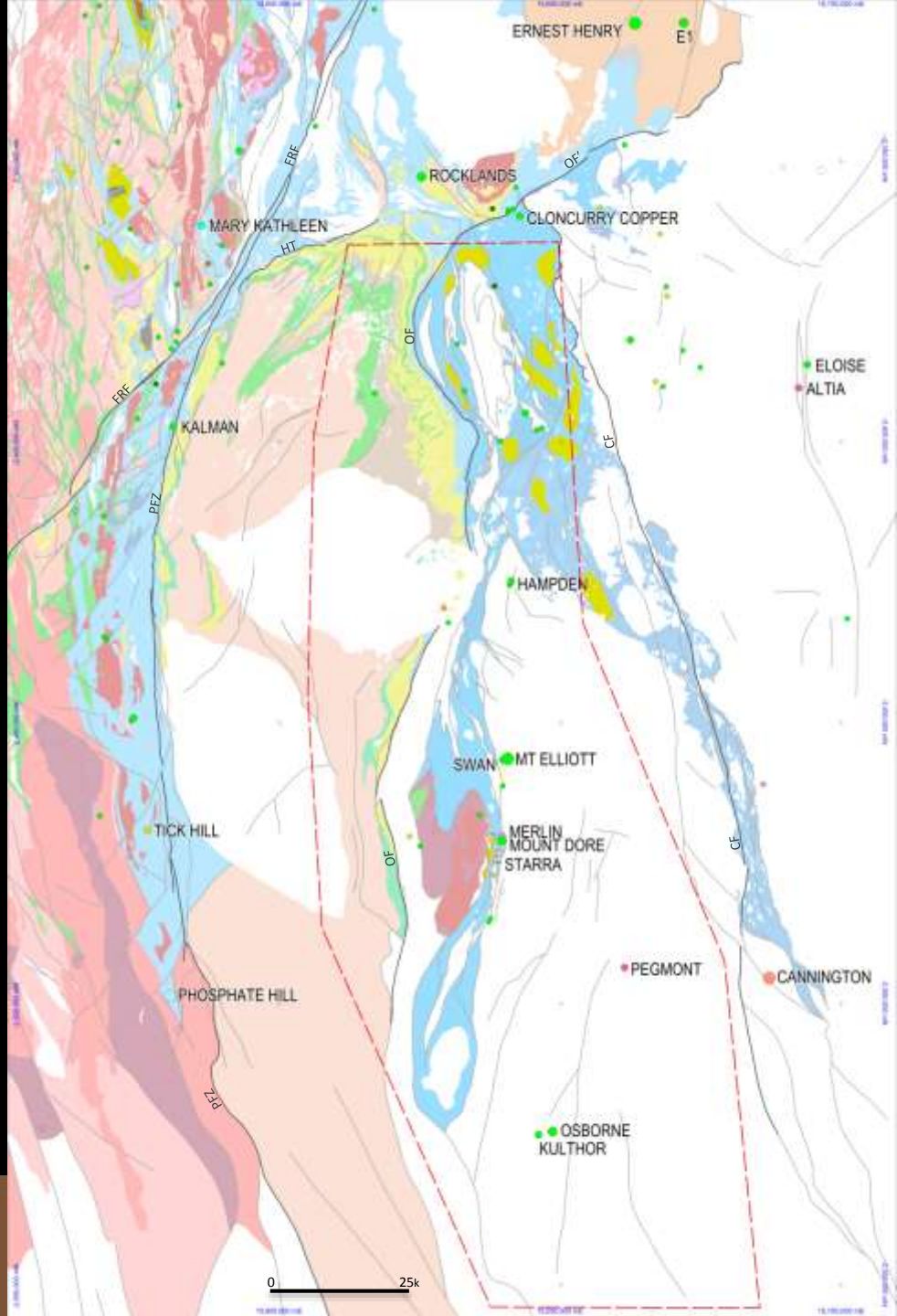
~1710Ma

Roxmere





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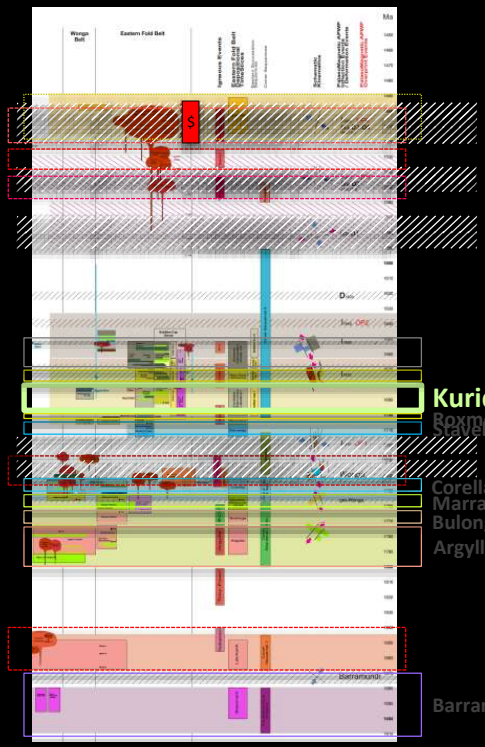
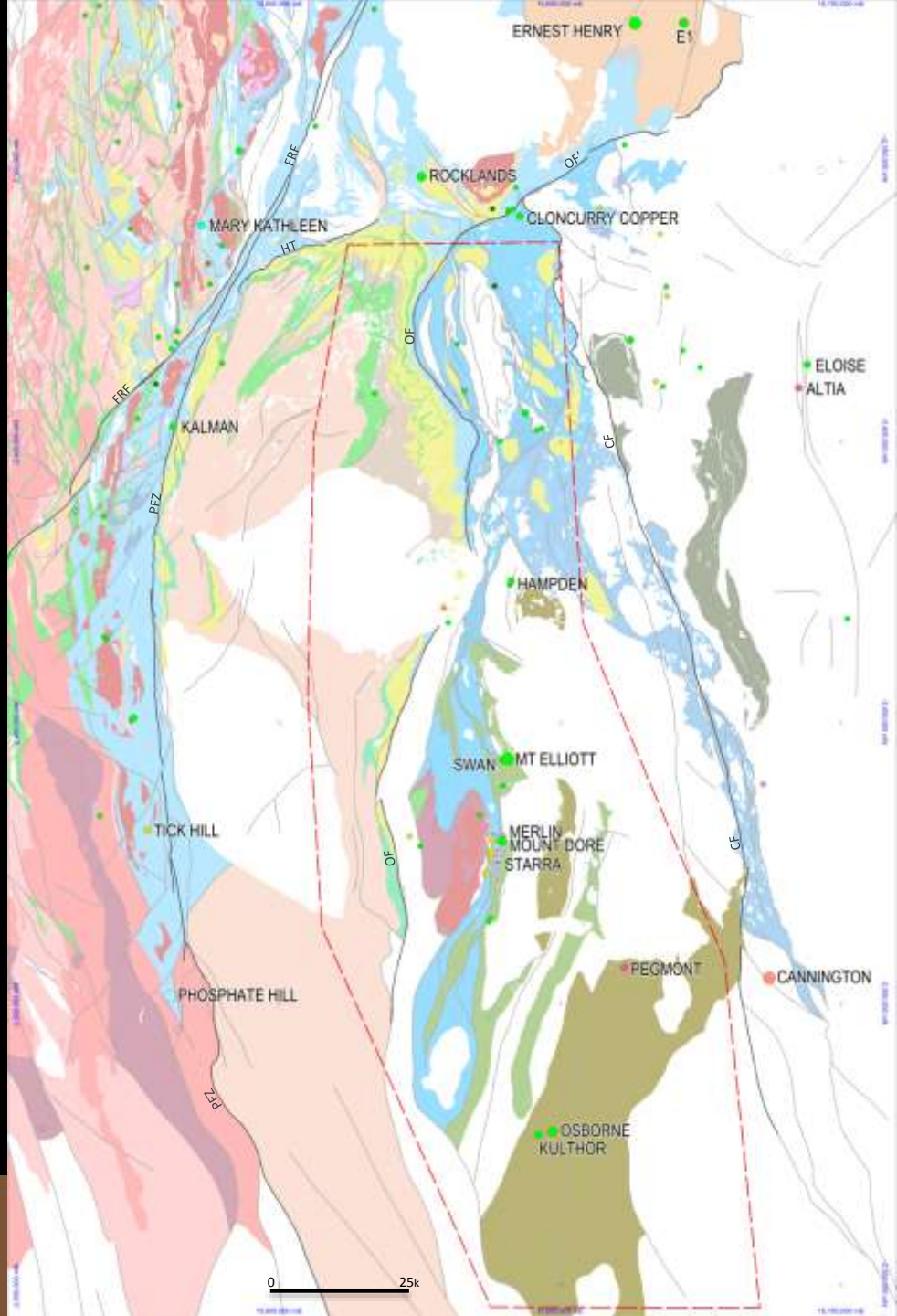
~1710-1680Ma

Kuridala-Starcross-Llewelyn





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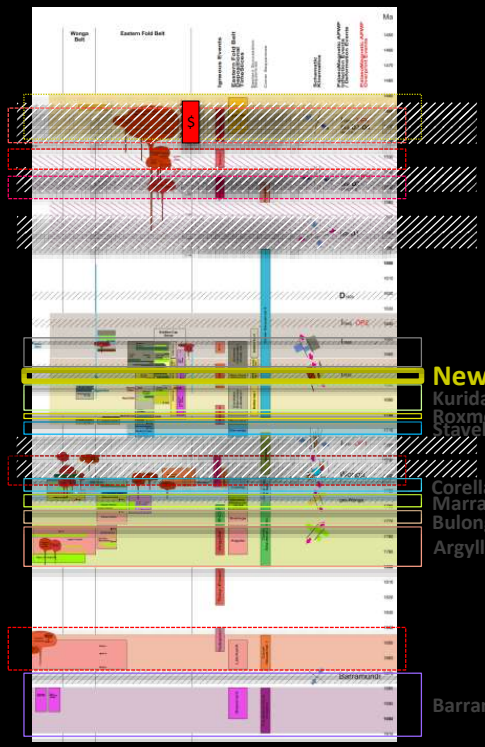
~1680-1690Ma

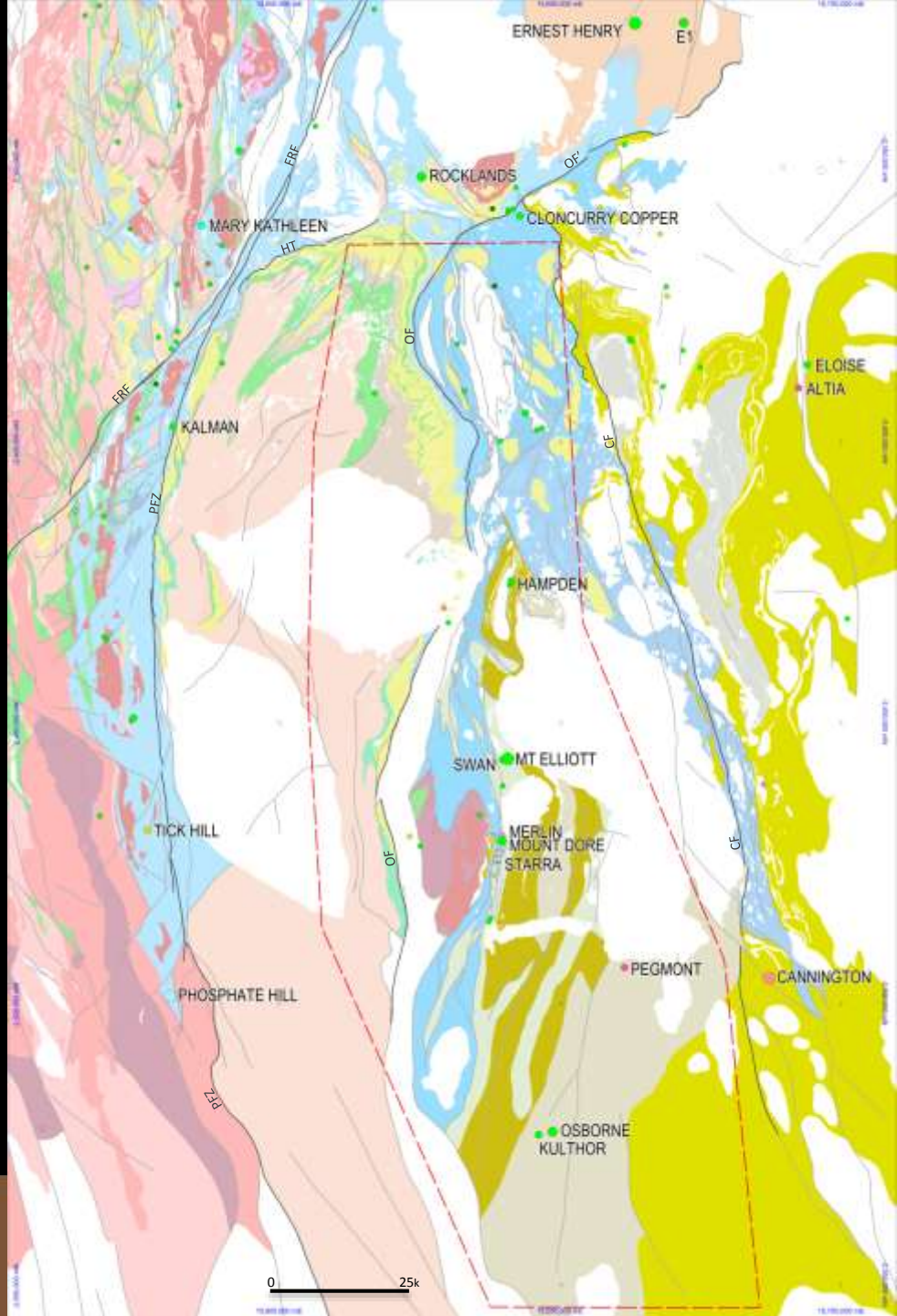
New Hope-Mt Norna



New Hope-Mt Norna
Kuridala-Starcross-Llewelyn
Roxmere
Staveley
OP1
WONGA
Corella
Marraba-Mitakoodi-DCM
Bulonga
Argylla
Barramundi

Wonga MFCV

Kalkadoon Leichardt Volcs



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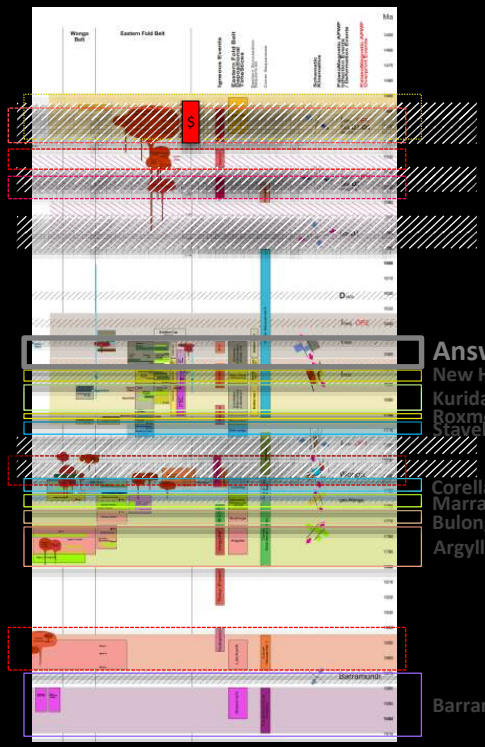
~1690-1650Ma

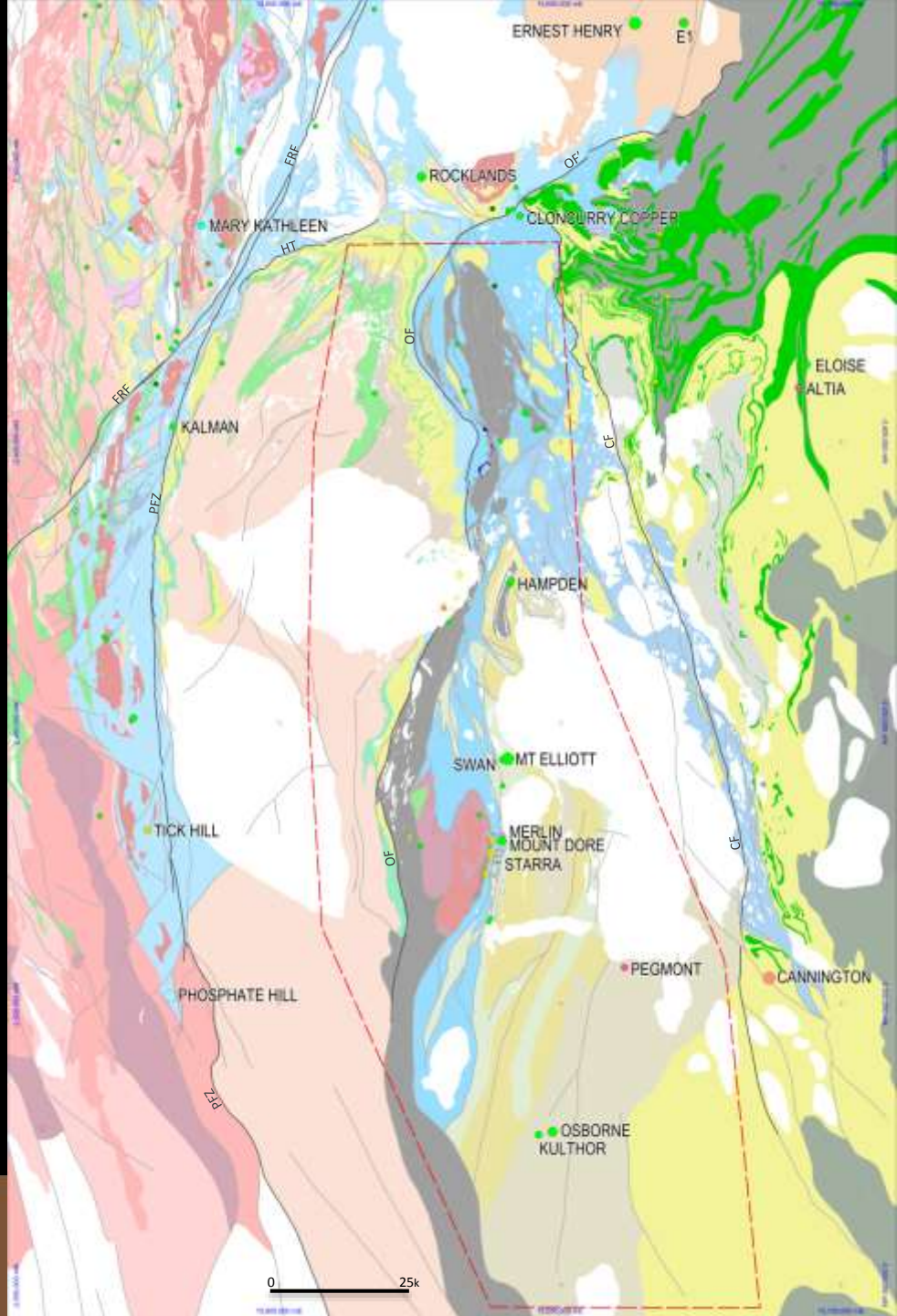
Answer-Toole Creek



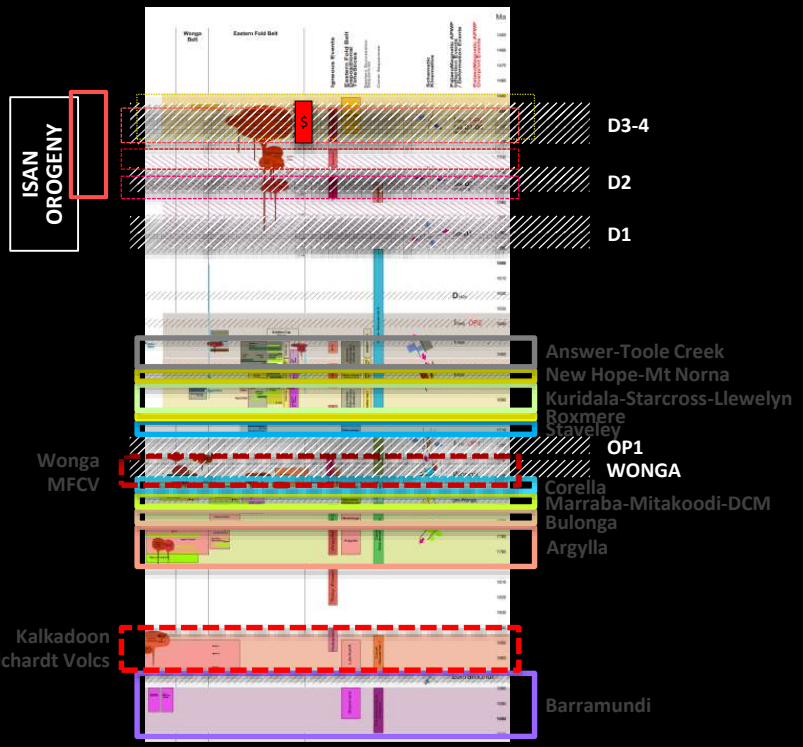
Answer-Toole Creek
New Hope-Mt Norna
Kuridala-Starcross-Llewelyn
Roxmere
Staveley
OP1
WONGA
Corella
Marraba-Mitakoodi-DCM
Bulonga
Argylla
Barramundi

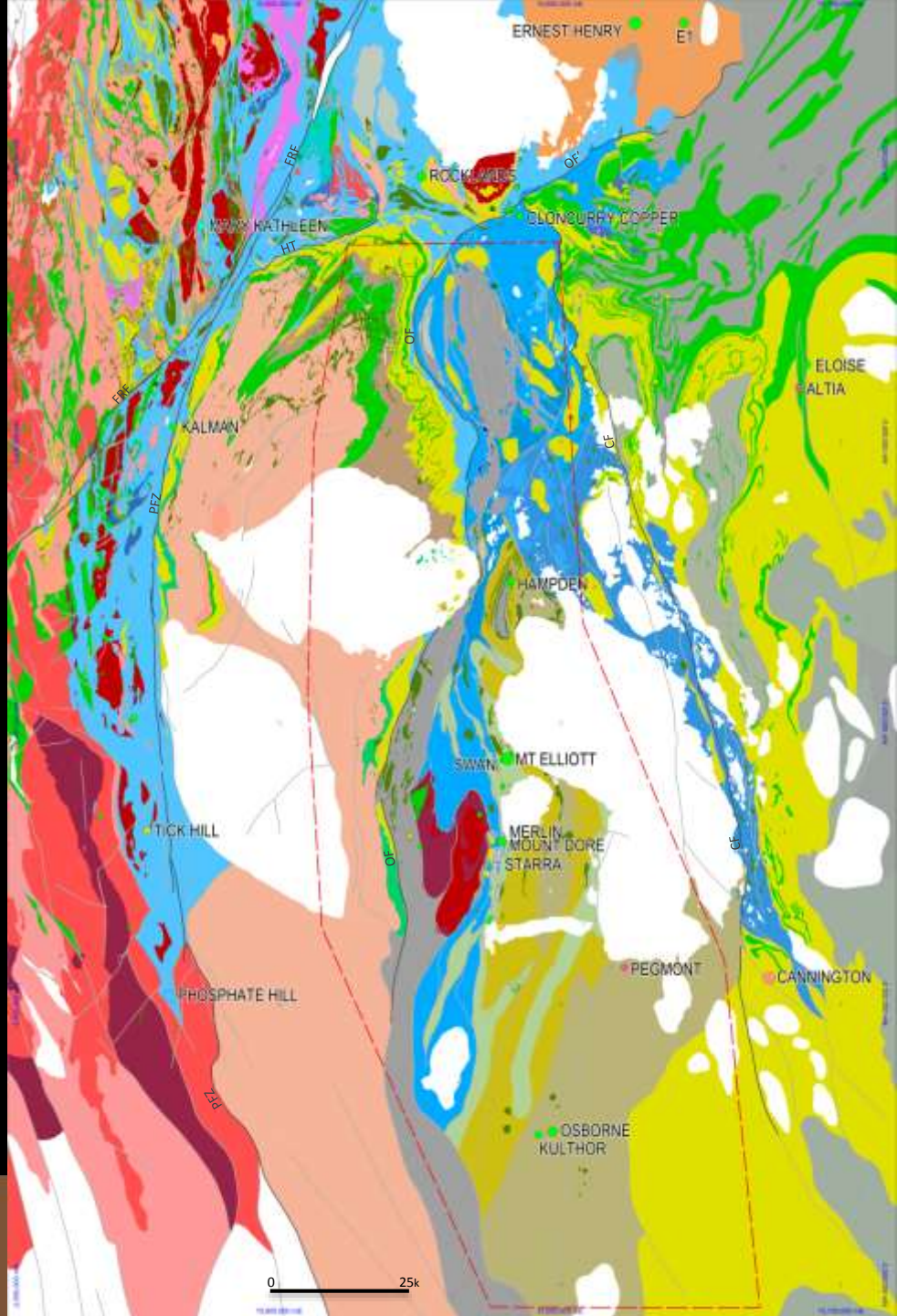
Wonga MFCV

Kalkadoon Leichardt Volcs



~1650Ma





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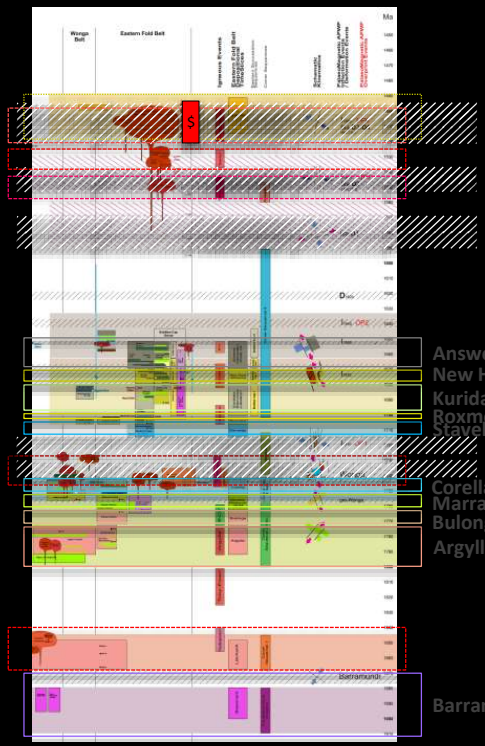
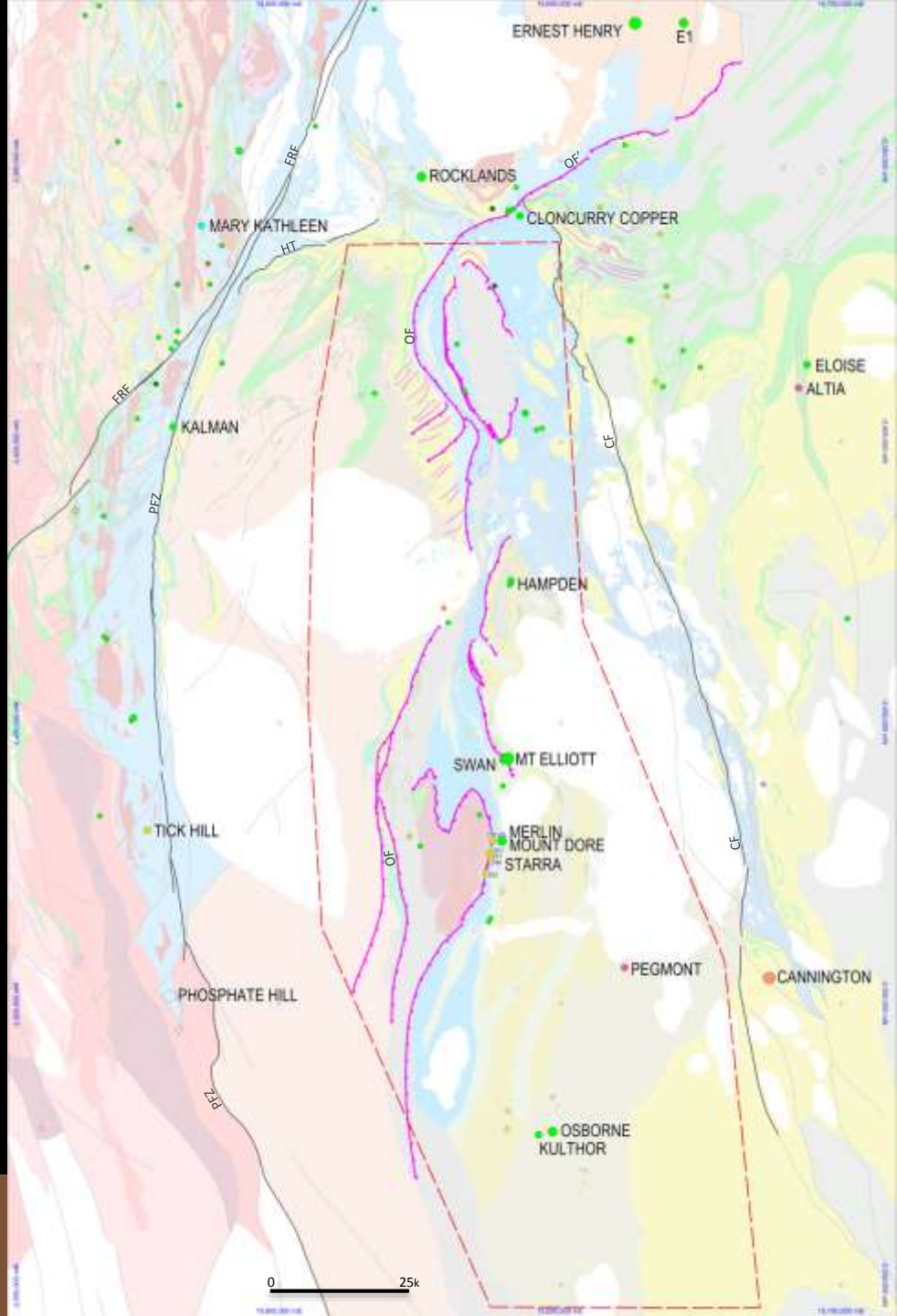
~1590-1575Ma

Isan D1 Folding & Thrusting

THIN-SKINNED





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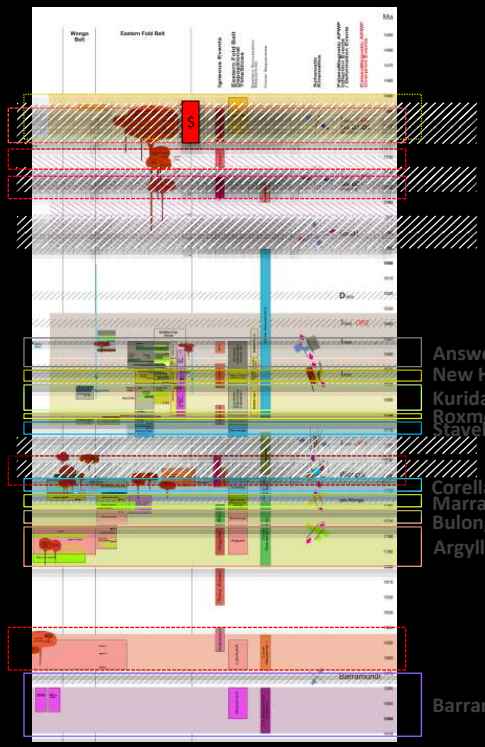
~1555-1535Ma

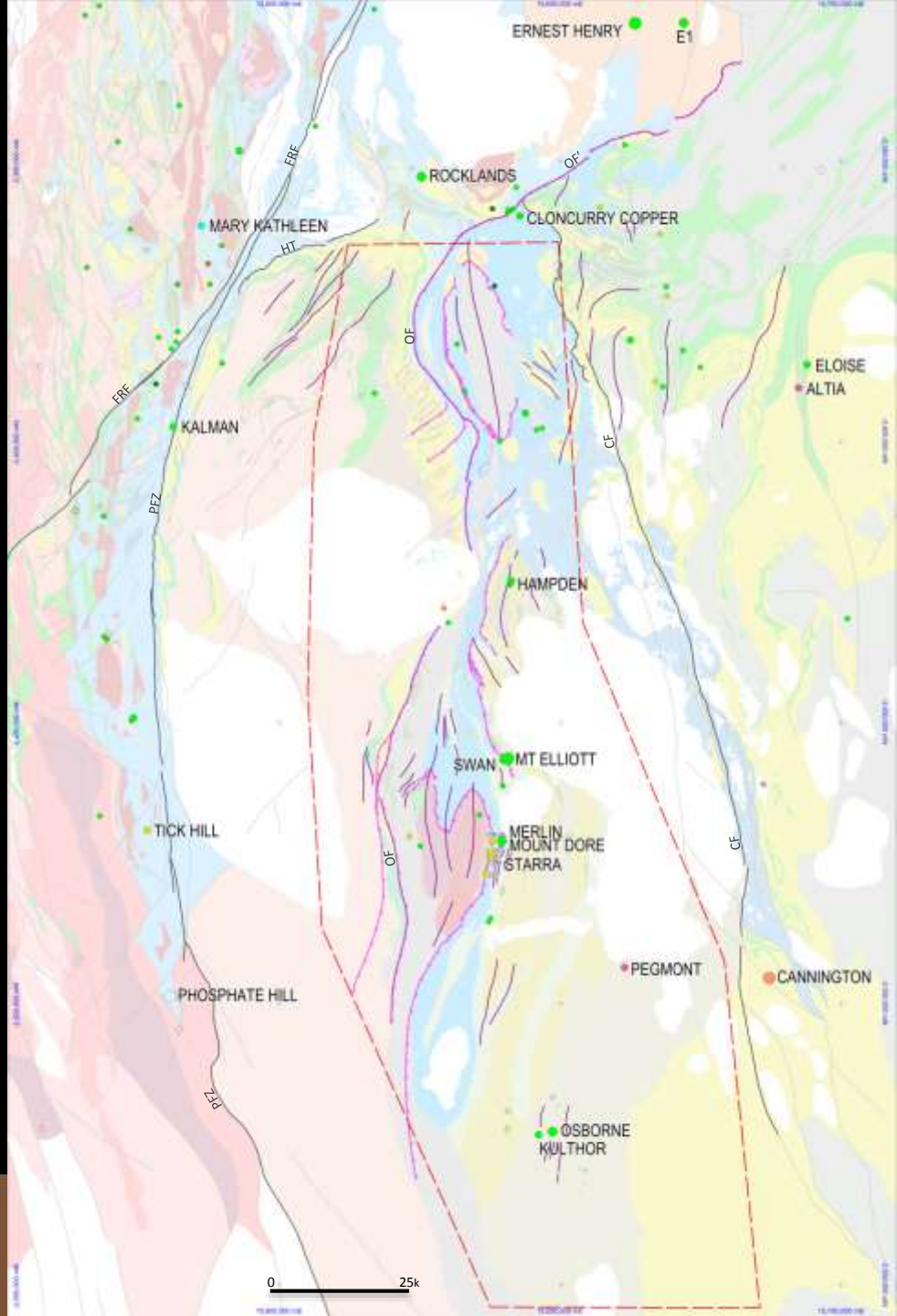
Isan D2 Folding

THICK-SKINNED



Wonga MFCV

Kalkadoon Leichardt Volcs



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CF = Cloncurry Fault

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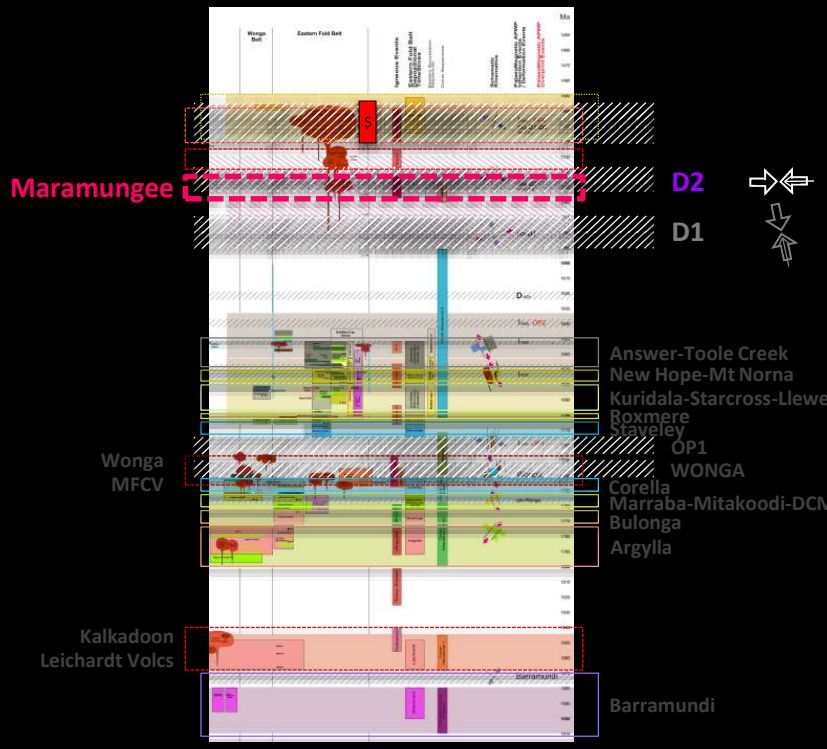
~1555-1535Ma

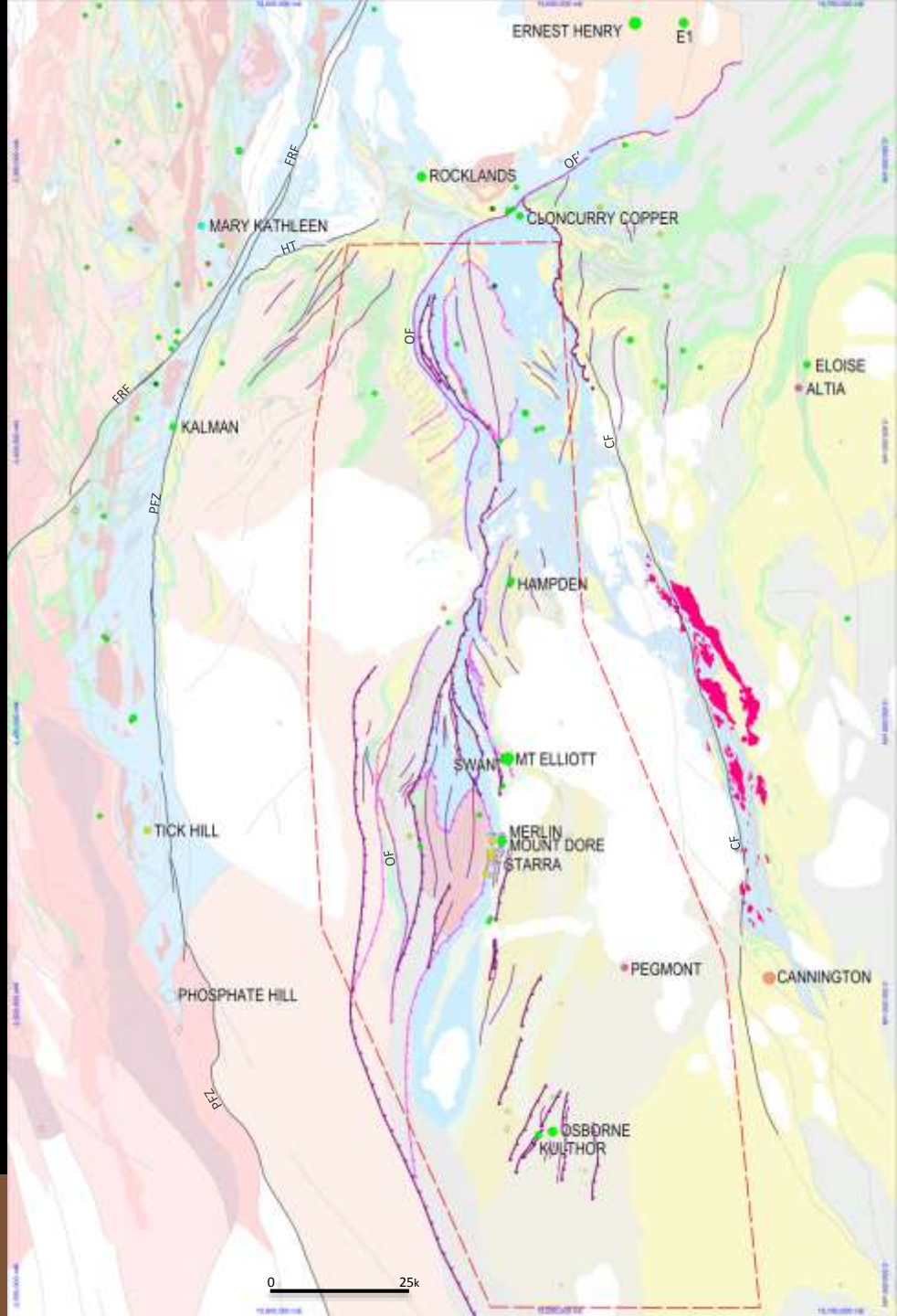
Isan D2 Faulting

THICK-SKINNED

~1545Ma

Maramungee





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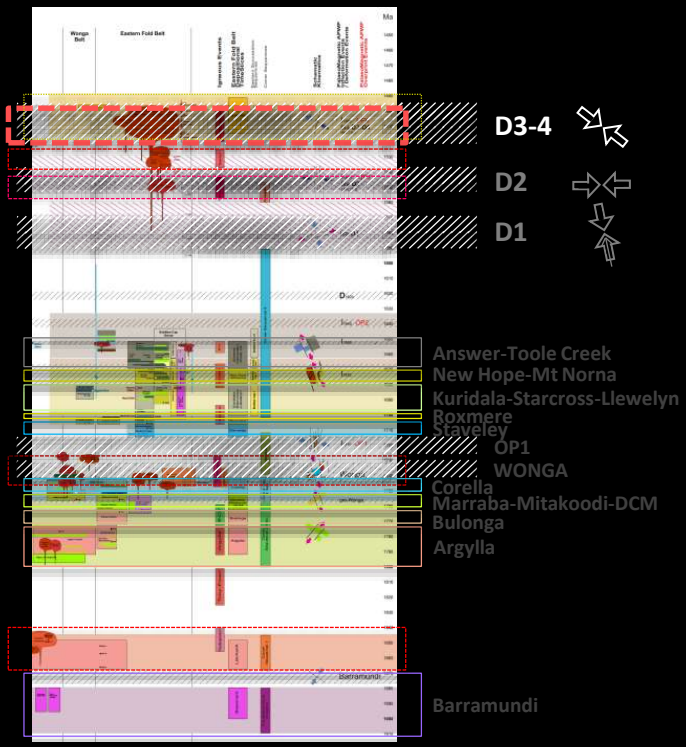
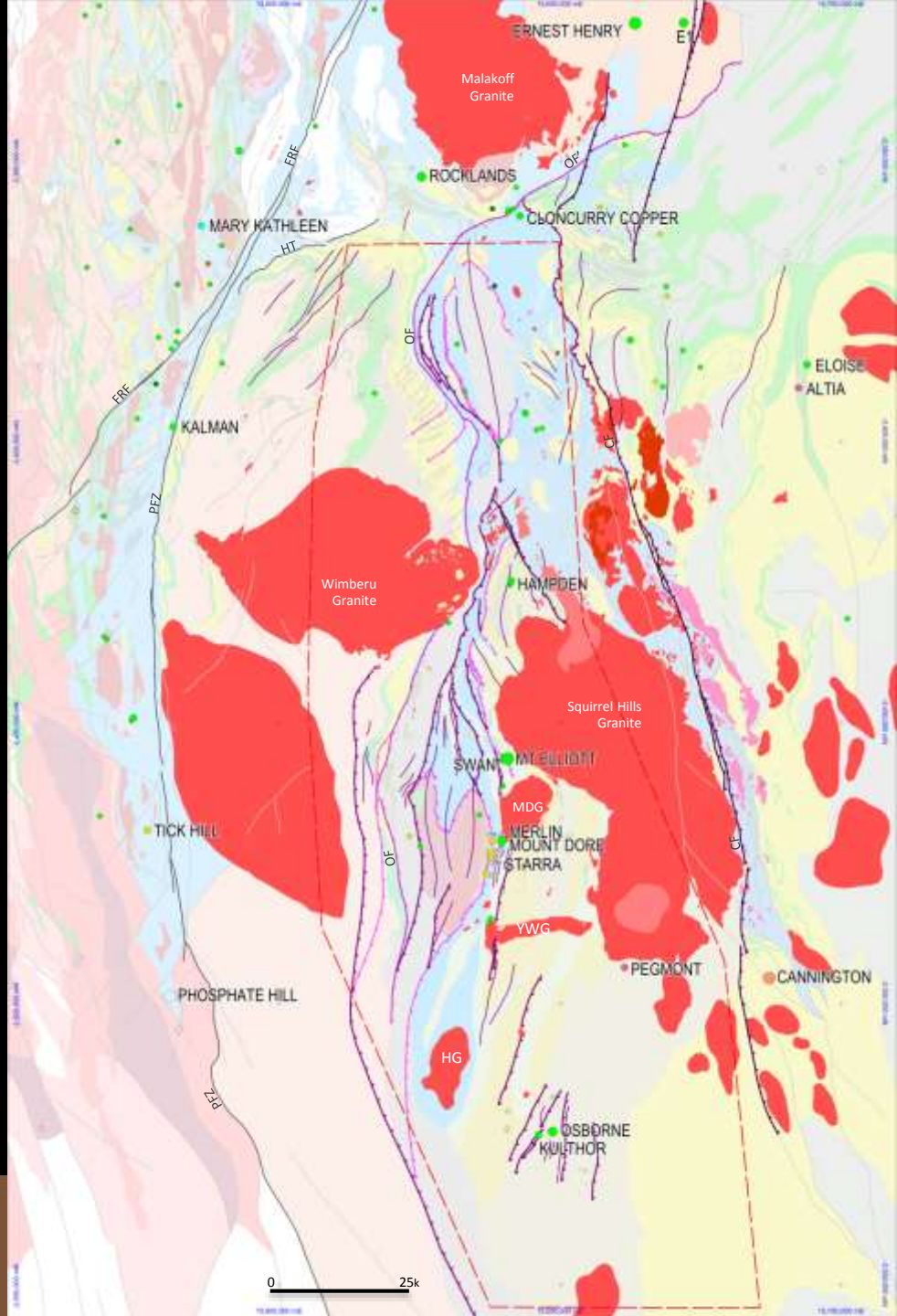
~1515-1500Ma

Williams Suite

~1515-1500Ma

D3-4 shortening





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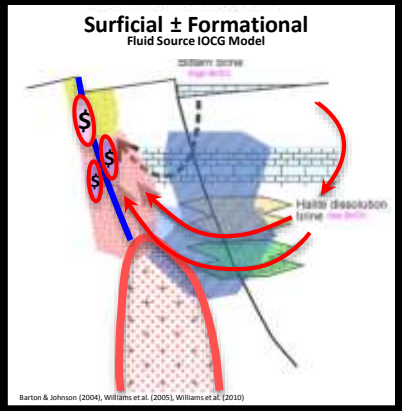
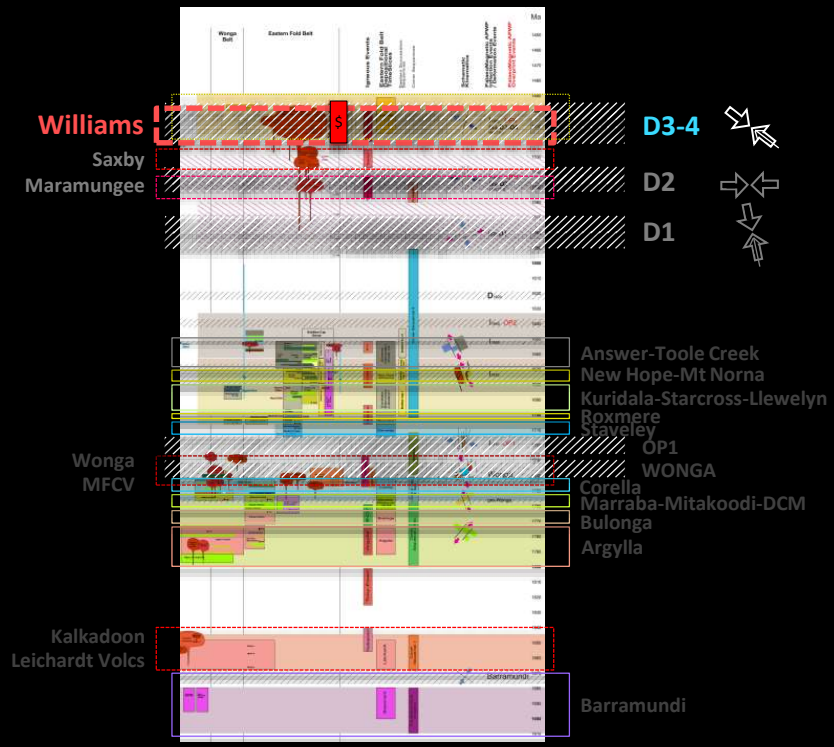
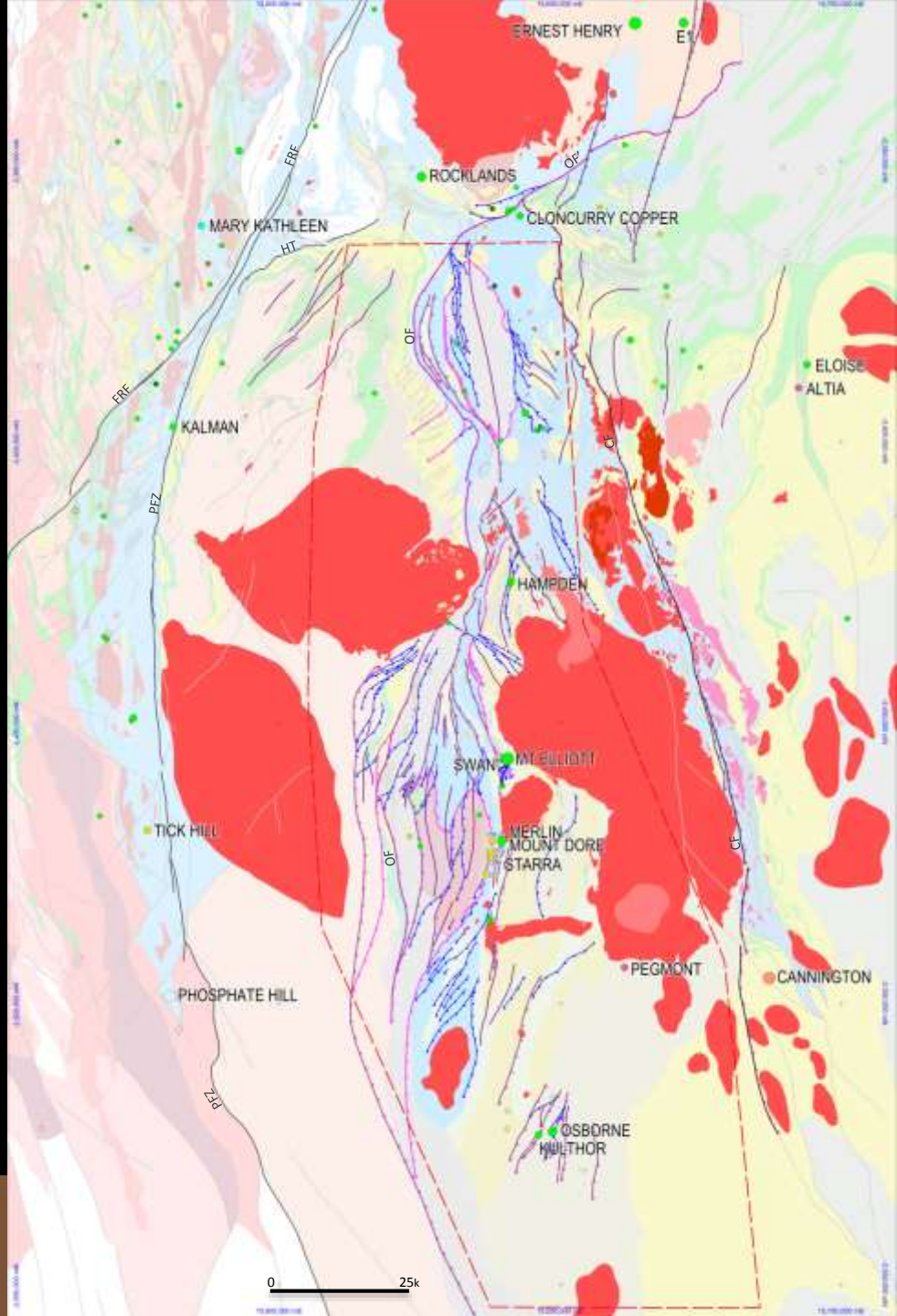
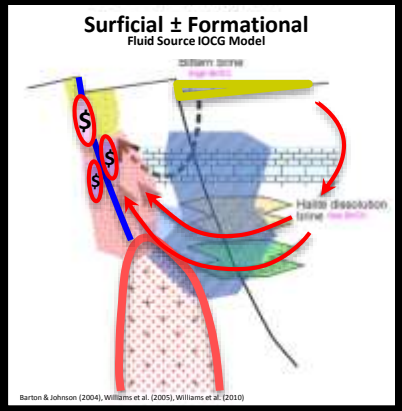


~1515-1500Ma
Williams Suite
~1515-1500Ma
early D3-4 Faulting

Cu-Au, Au-Cu, Mo-Cu







~1515-1500Ma

Williams Suite

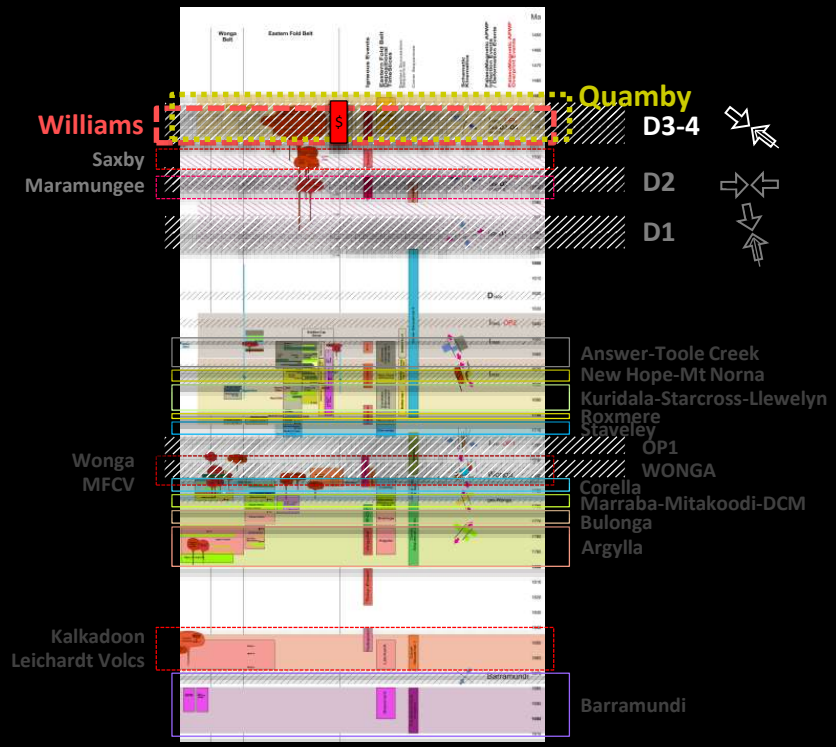
~1515-1500Ma

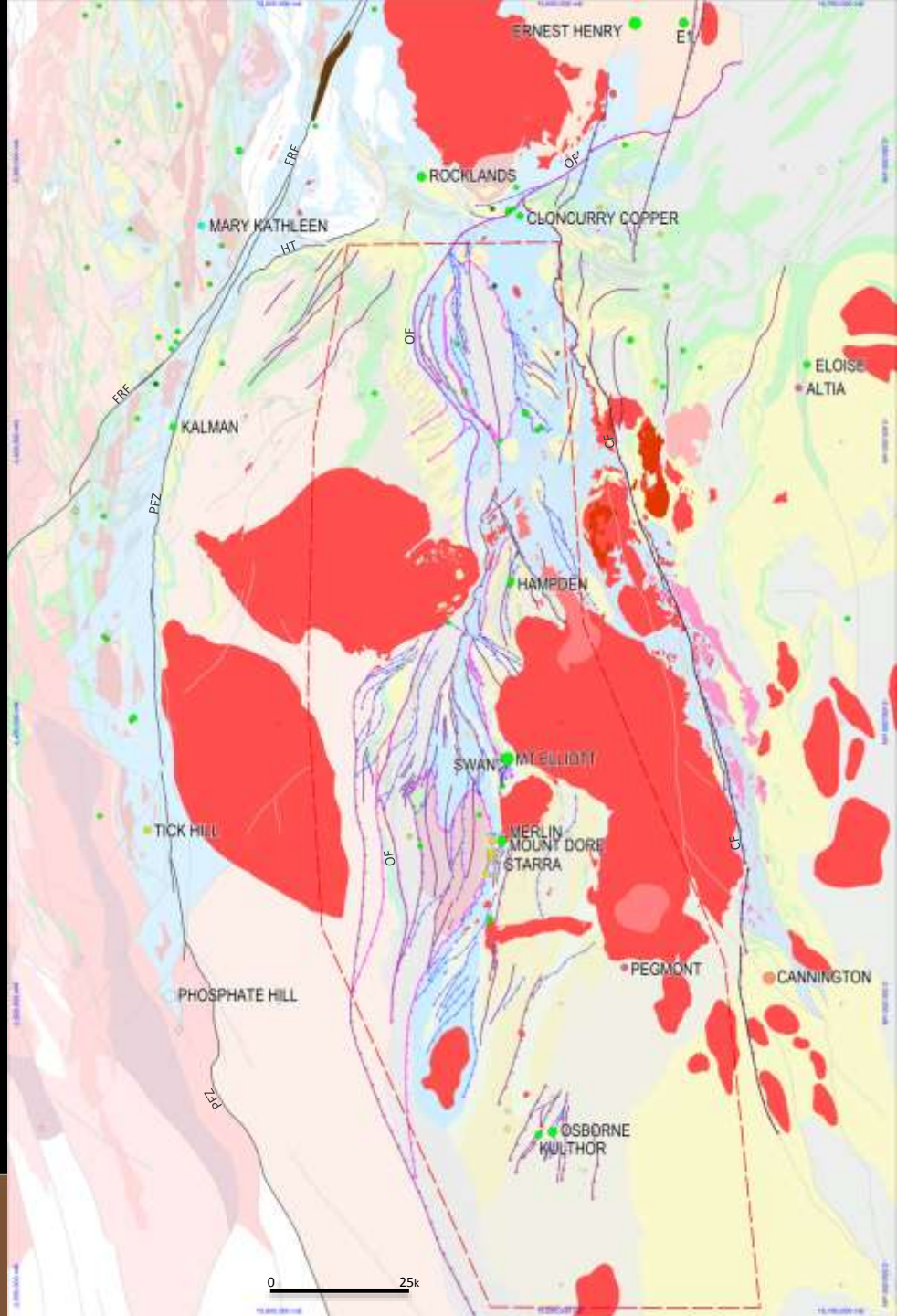
early D3-4 Faulting

???? Ma

Quamby

Cu-Au, Au-Cu, Mo-Cu





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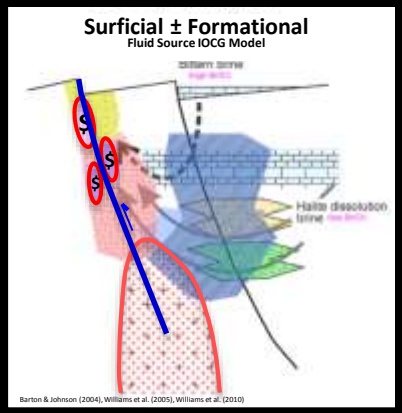


~1545Ma

Williams Suite

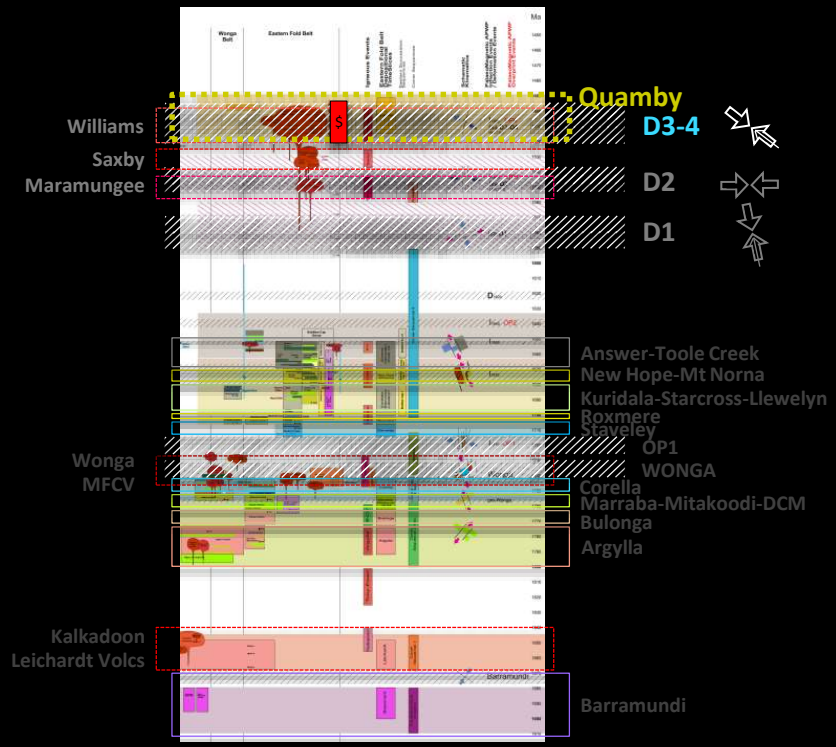
~1555-1535Ma

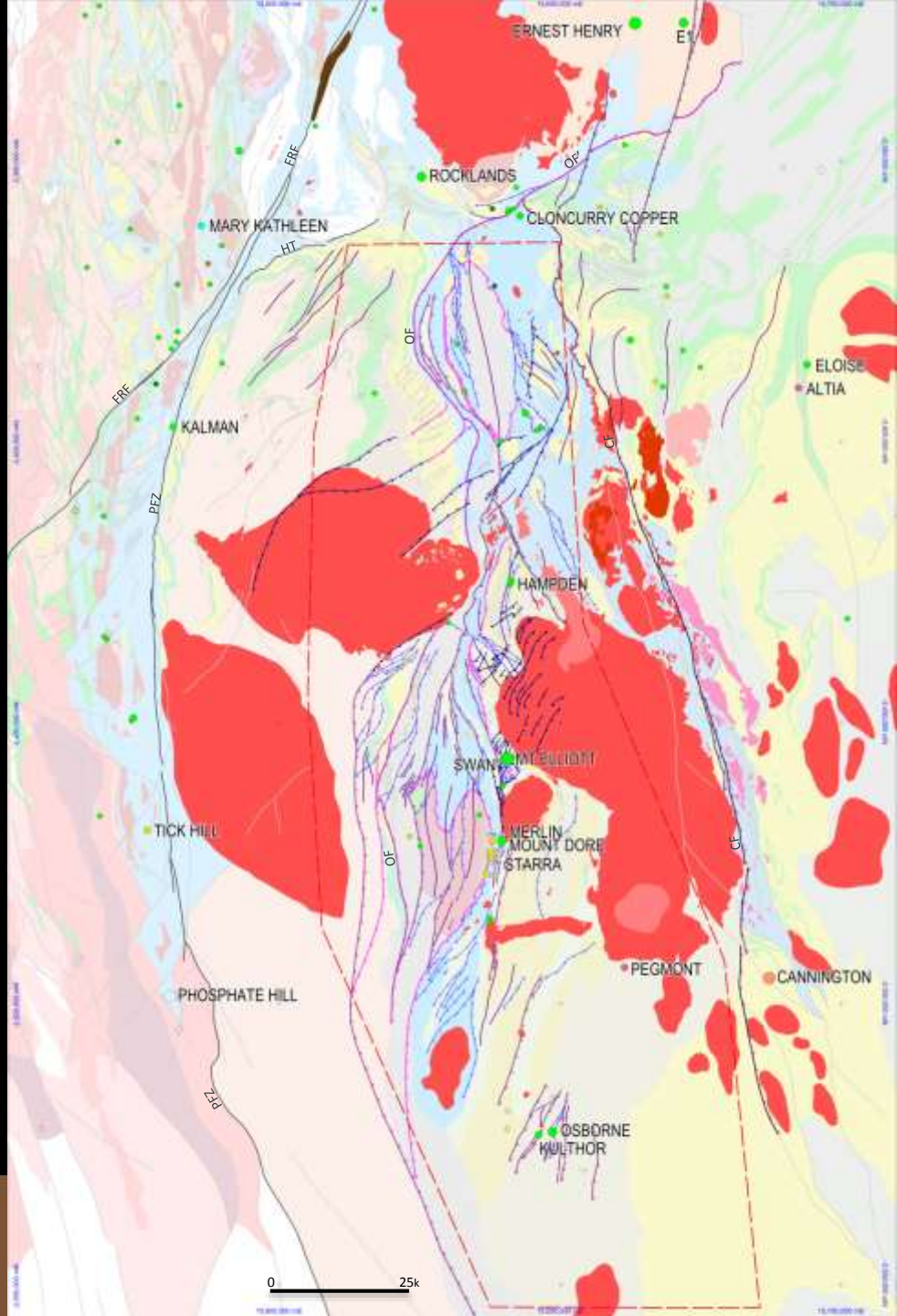
late D3-4 Faulting

???? Ma

Quamby

Cu-Au, Au-Cu, Mo-Cu





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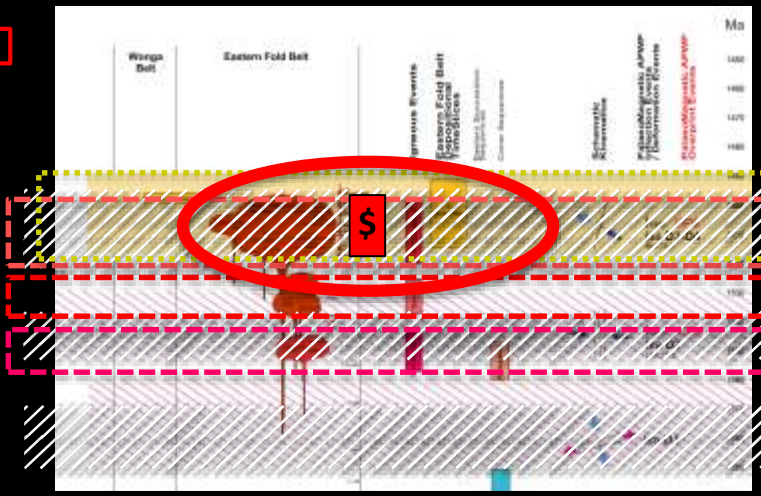
WH Bryan Mining & Geology Research Centre

FRF = Fountain Range Fault
PFZ = Pilgrim Fault Zone
HT = Highway Thrust
OF = Overhang Fault
CF = Cloncurry Fault

Magmatism

Depositional Timeslices

Deformation



~1515-1500Ma **Williams**

~1530Ma **Saxby**

~1545Ma **Maramungee**

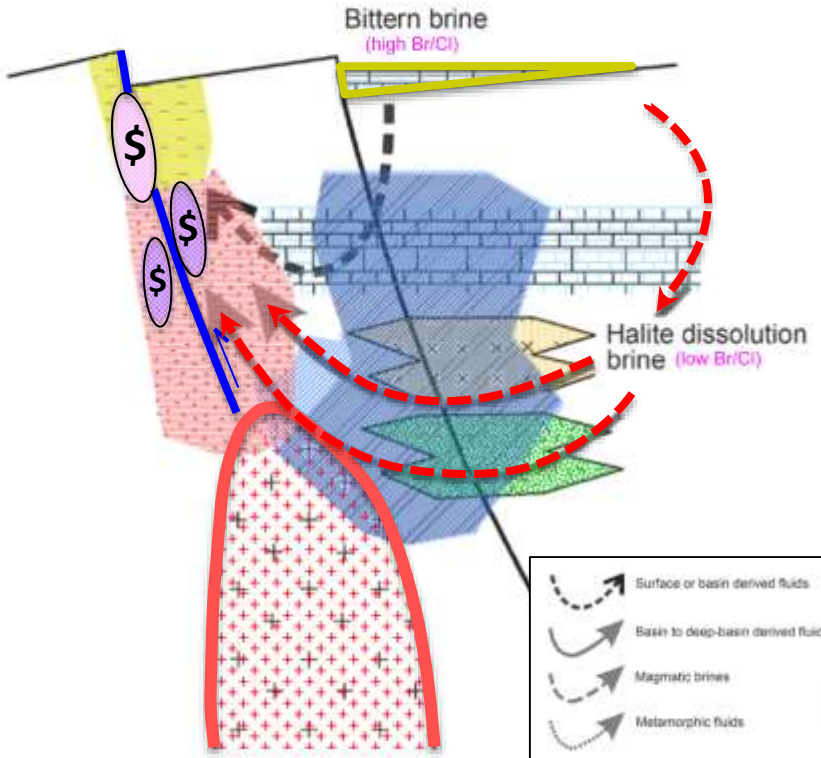
?? Ma **Quamby**

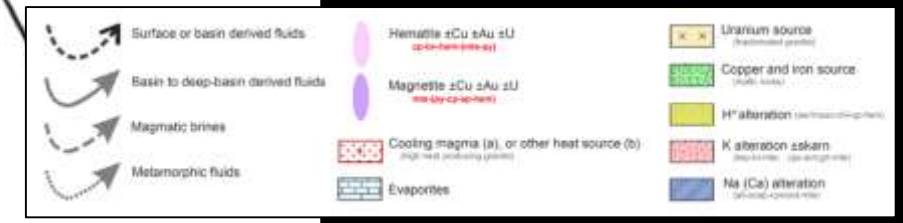
~1520-1490Ma **Isan D3-D4**
BRITTLE shallow crustal

~1590-1570Ma **Isan D2**
DUCTILE thick-skinned

~1590-1570Ma **Isan D1**
DUCTILE thin-skinned

Surficial ± Formational
Fluid Source IOCG Model





Barton & Johnson (2004), Williams et al. (2005), Williams et al. (2010)

Williams Suite - HEAT source - circulation driver

Isan D3-D4 - BRITTLE, shallow crustal deformation

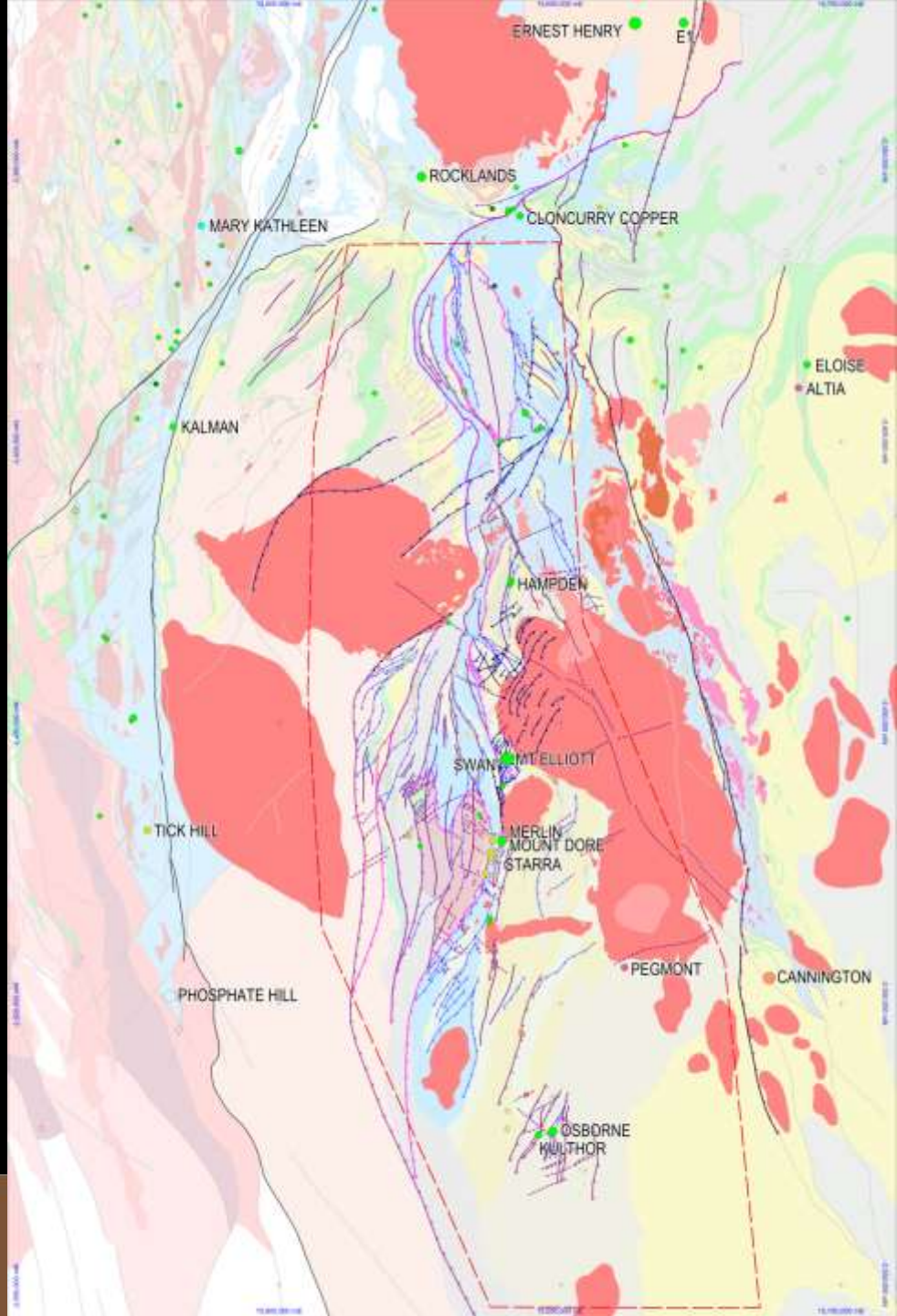
Quamby Basin - continental, oxidised, evaporitic?

>> IOCG Mineralisation

<1500Ma

post Isan Faulting

widespread



FRF = Fountain Range Fault
PFZ = Pilgrim Fault Zone
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<1500Ma
post Isan Faulting
widespread & appears to reflect ….

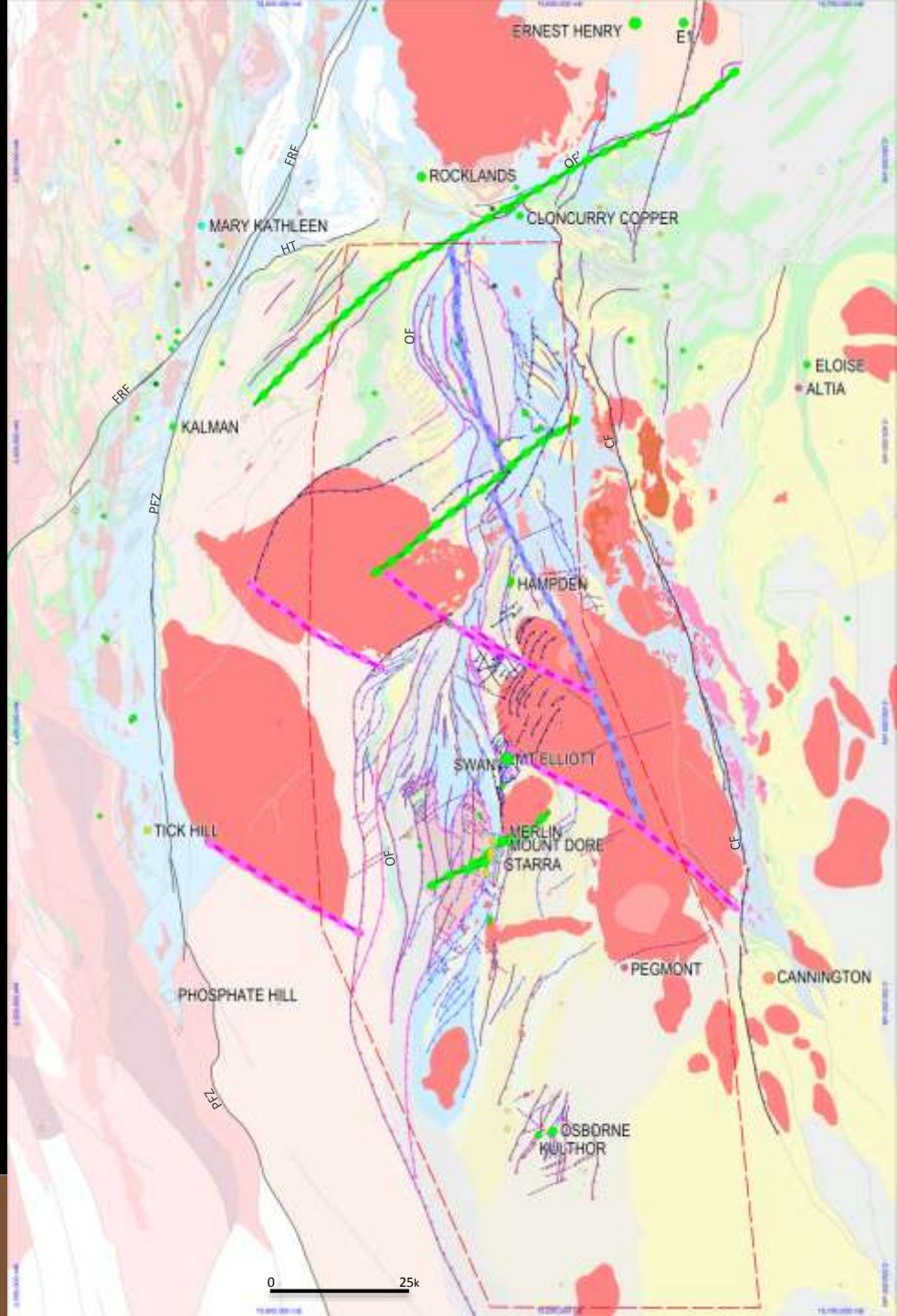
…. older, pre-orogenic architectures
‘significant crustal penetration & persistance’

NE architecture
Wonga-reactn>MFCV margin
Mitakoodi culmination D2 folding
D1 & D2 deformation partitioning
post-Williams reactn

NW architecture
Williams margins
D2 deformation partitioning
post-Williams reactn

older NNW architecture
post-Williams reactn

>>> significant influence on IOCG mineral system geometry and ultimate sites of metal accumulation



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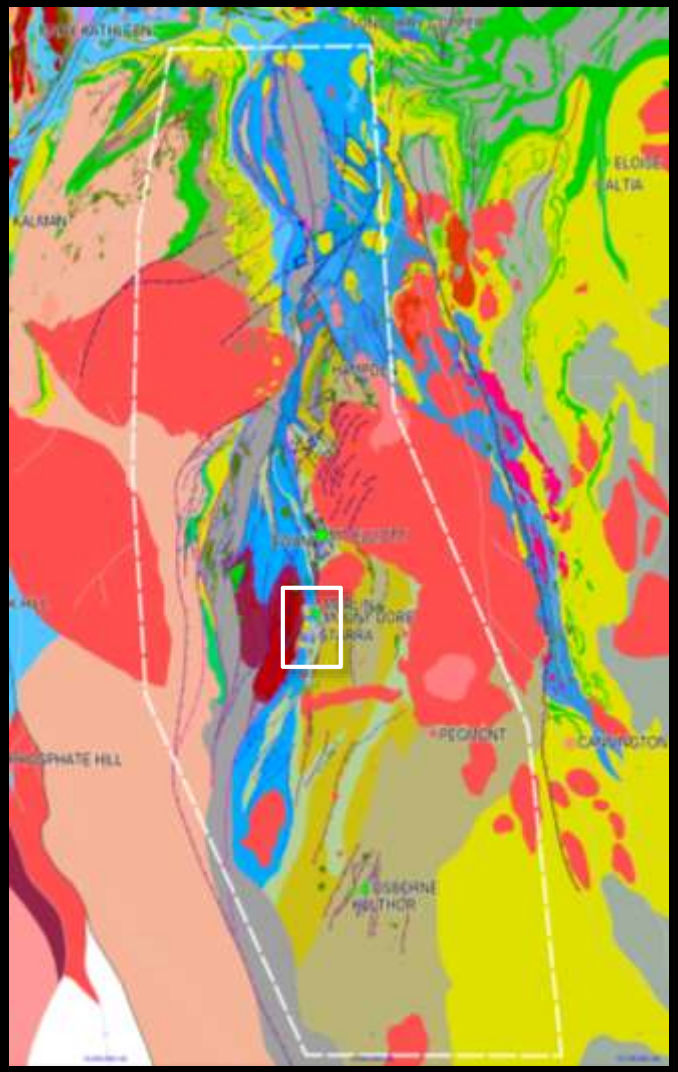
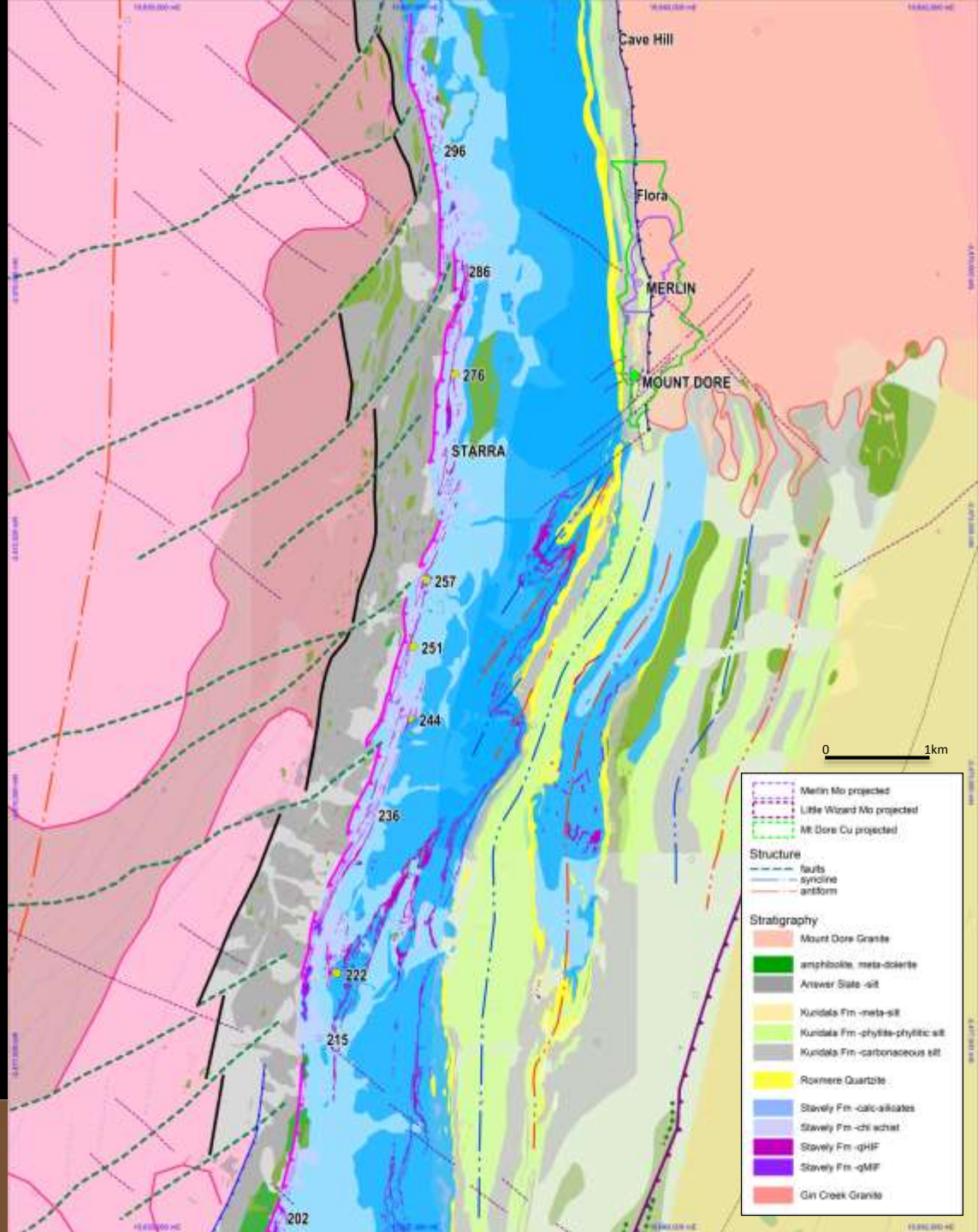
Starra-Merlin-Mount Dore

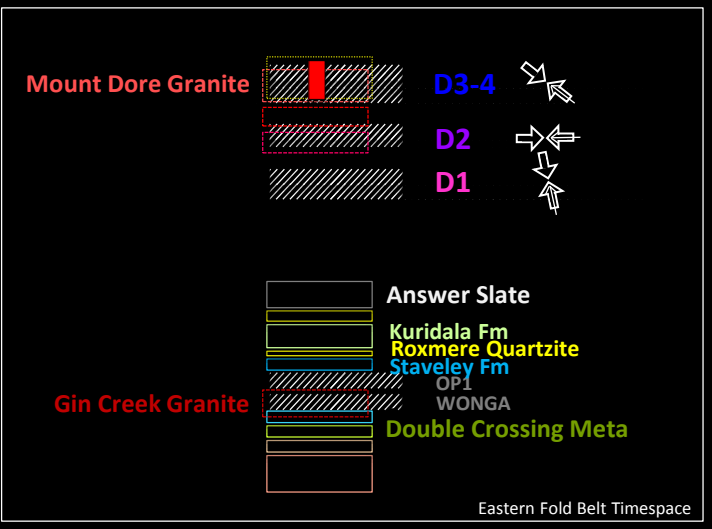


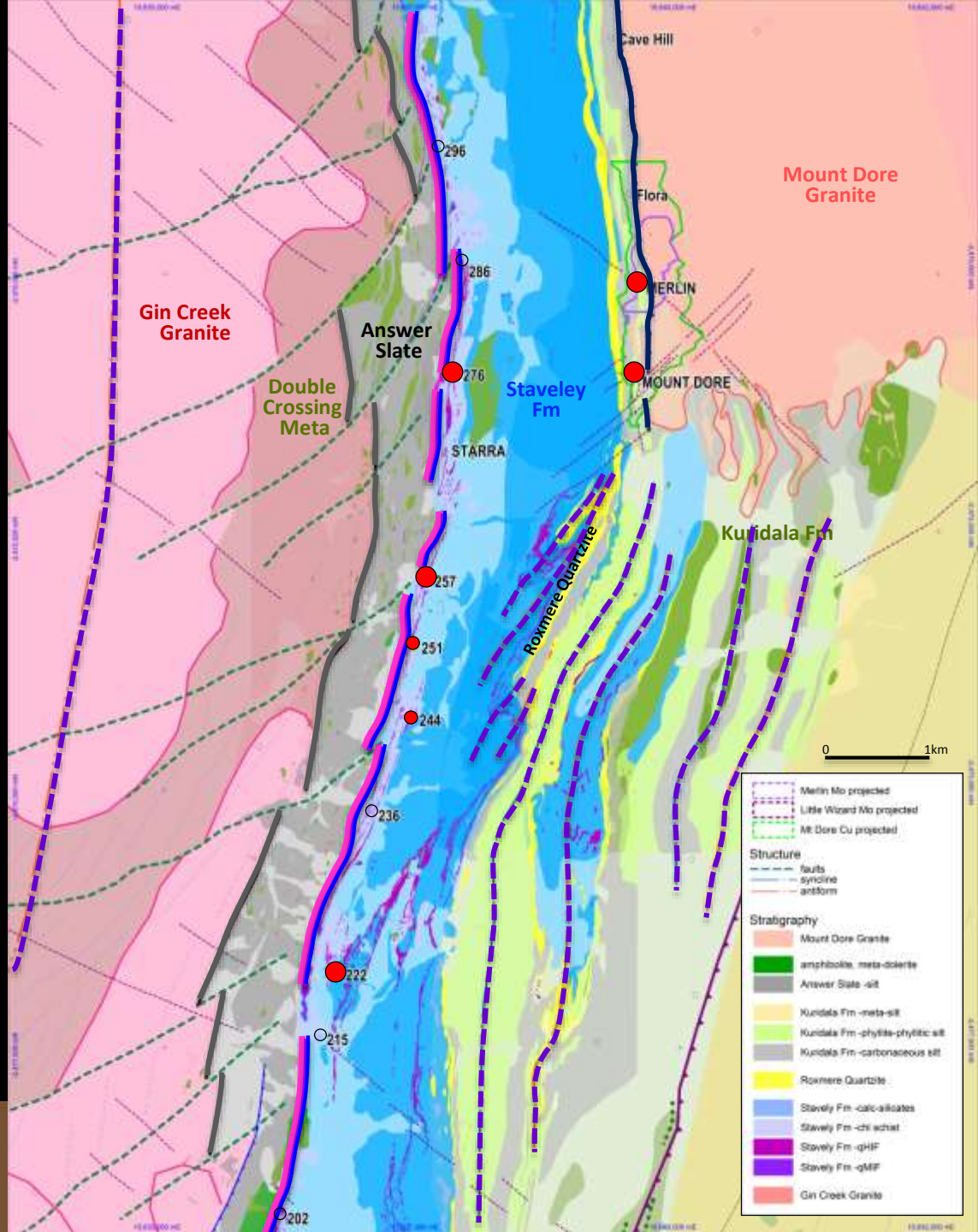


Starra-Merlin-Mount Dore

5K-10K Leishman Geology (1970s-1980)
DMQ Interpretation (2016)

- **unconformable onlap of Answer Slate**
- **D1 N'ward overthrust of Staveley over Answer**
  > EW F1 folds; highly attenuated/folded MIF-HIF
  > preserves FW block architecture
- **D2 folding of D1 overthrust into vertical**
  > F1 fold sub-vertical *vs* sub-horiz F2 folds
- **D3-4 shortening: transpressive BRITTLE reactivation**
  > at Starra, footwall architecture contribution to fract-bx
  > at Merlin-Mt Dore, strain intensification
- **post-mineral reverse faulting of MDG over M-MD**





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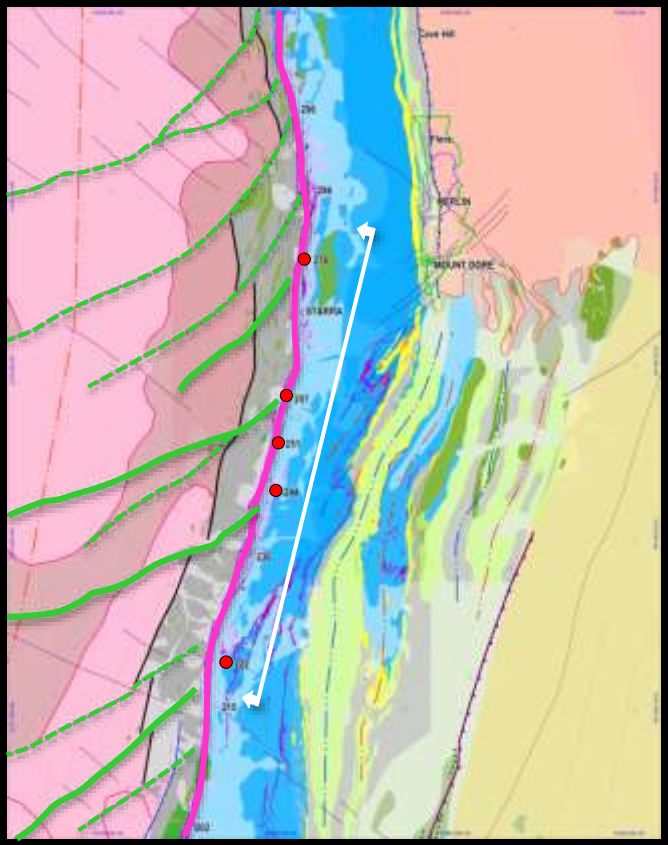
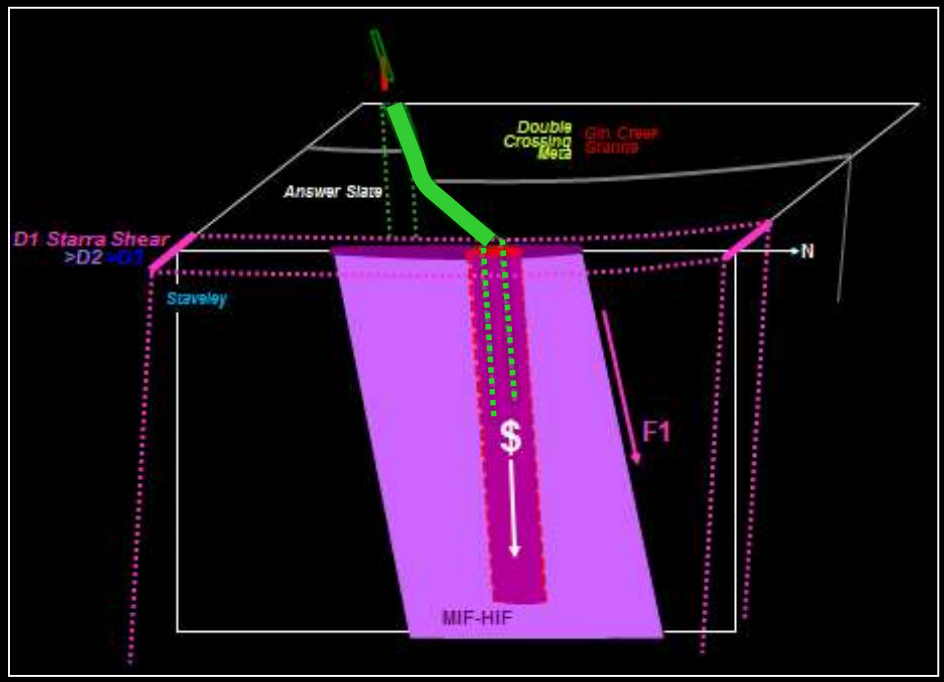
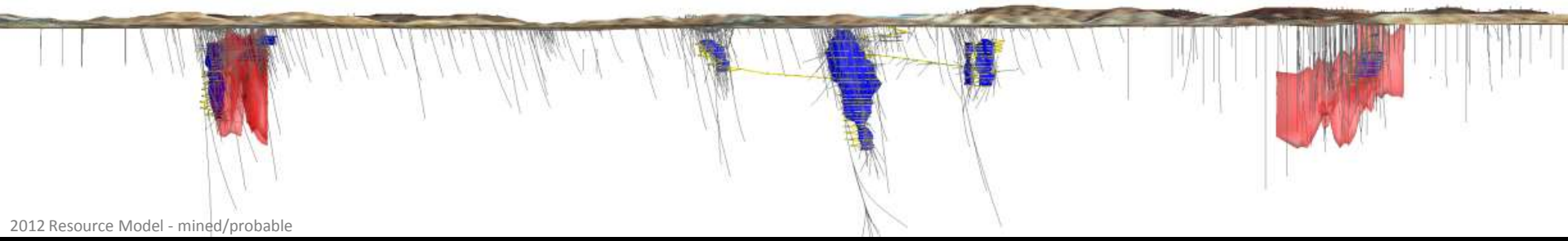
Starra Line - Long Section



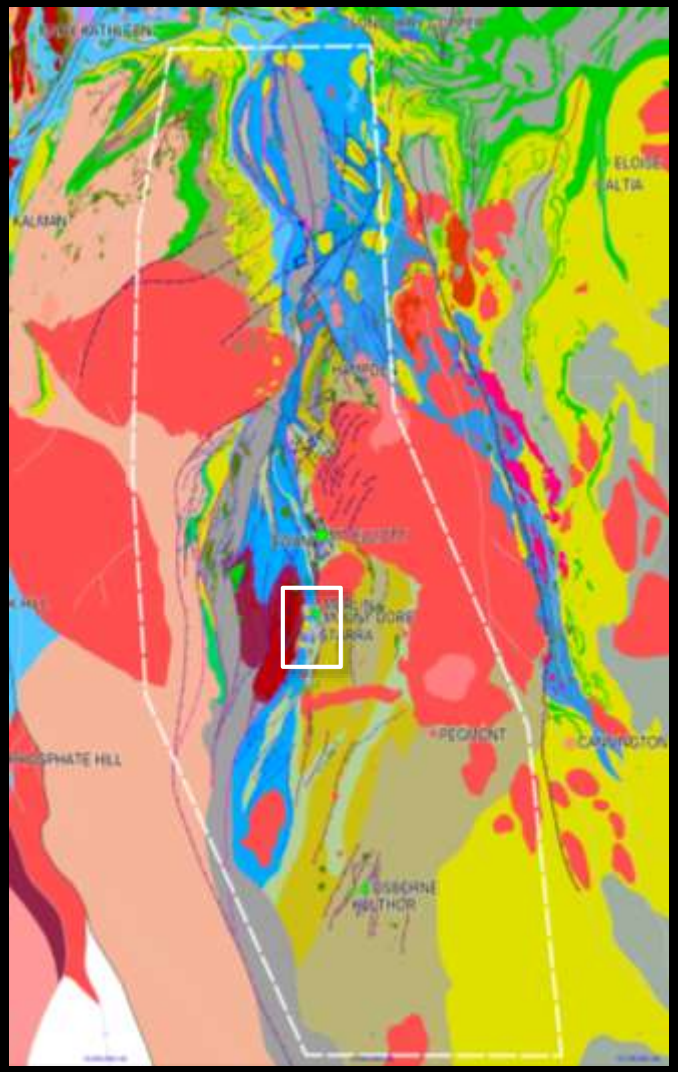


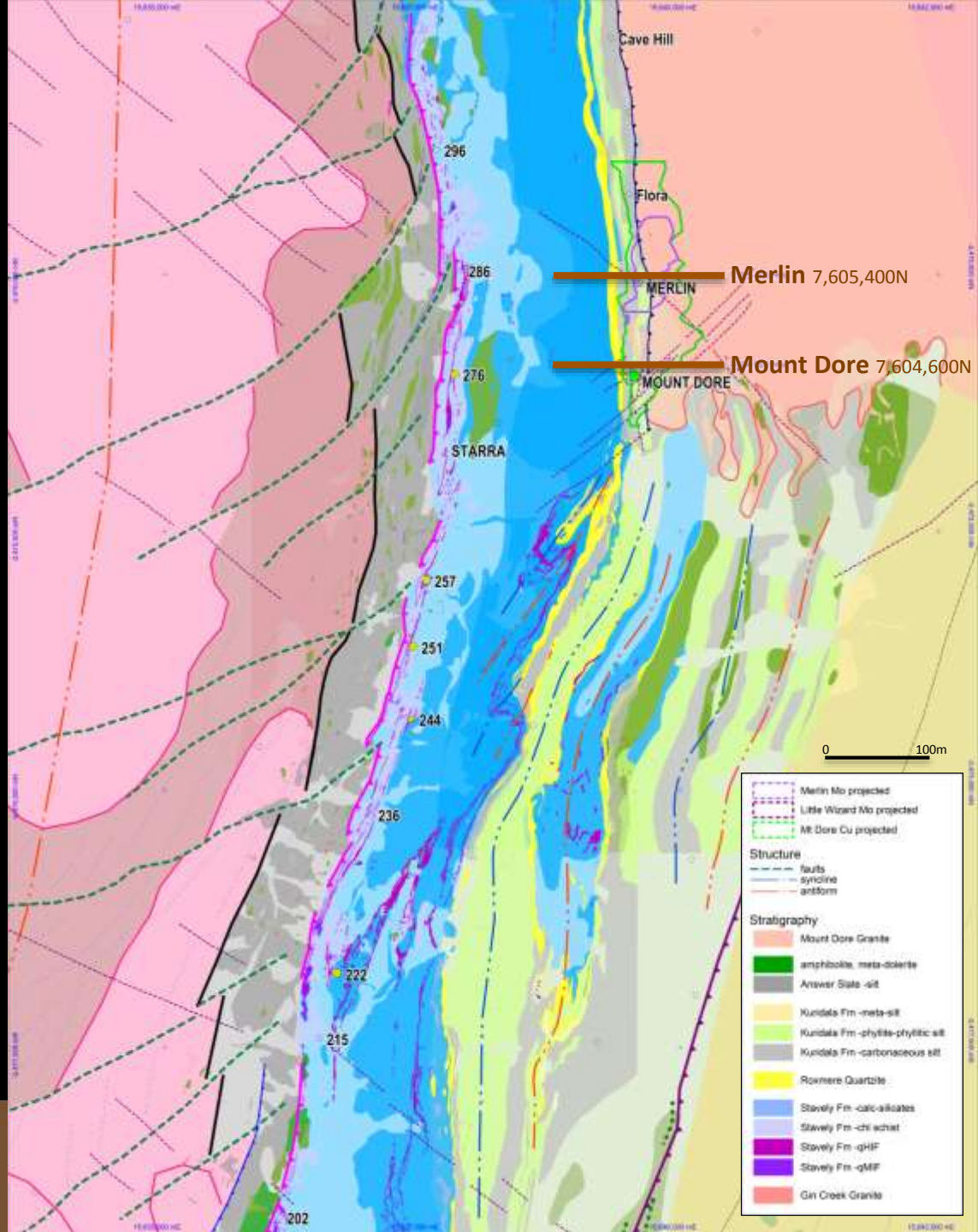
S 222 236 244 251 257 276 N



2012 Resource Model - mined/probable

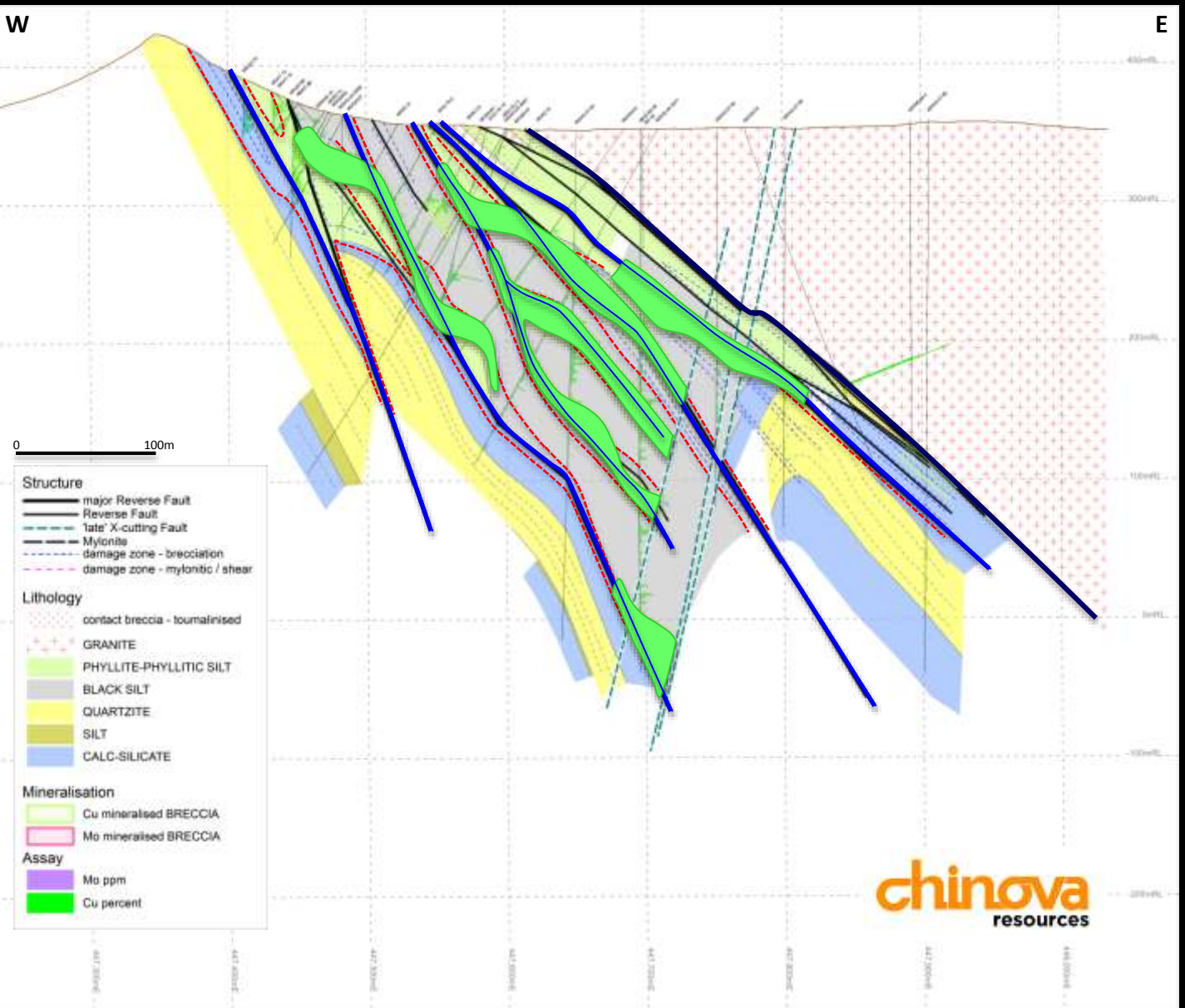
Mount Dore-Merlin





Mt Dore - Cross Section

7,604,600N



Gradational stratigraphy:
Staveley-Roxmere-(SF)-Kuridala
Kuridala: carb silt dominant

D3 Faulting:
complex, curvilinear, anastomosing

Brittle, fracture & breccia Damage Zones …
… in carbonaceous silts
& along reactivated contacts
.. host Cu mineralisation

D3 Faults … small throws! NOT Regional Structures

Granite Reverse Fault
highly planar, post-mineral, significant throw

Merlin - Cross Section

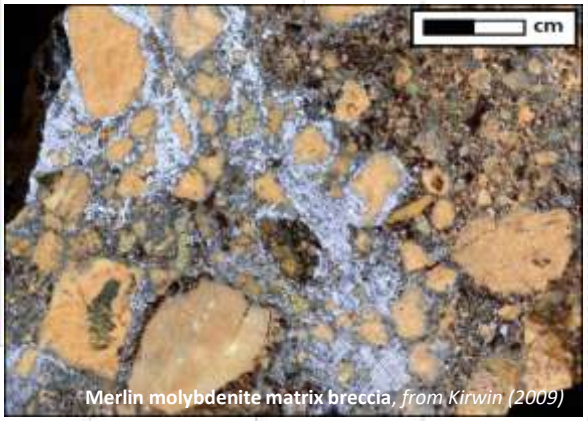
7,605,400N

W

E

0 100m

Structure
- major Reverse Fault
- Reverse Fault
- late' X-cutting Fault
- Mylonite
- damage zone - brecciation
- damage zone - mylonitic / shear



Merlin molybdenite matrix breccia, *from Kirwin (2009)*

chinova resources

Gradational stratigraphy:
Staveley-Roxmere-(SF)-Kuridala
Kuridala: phyllite dominant

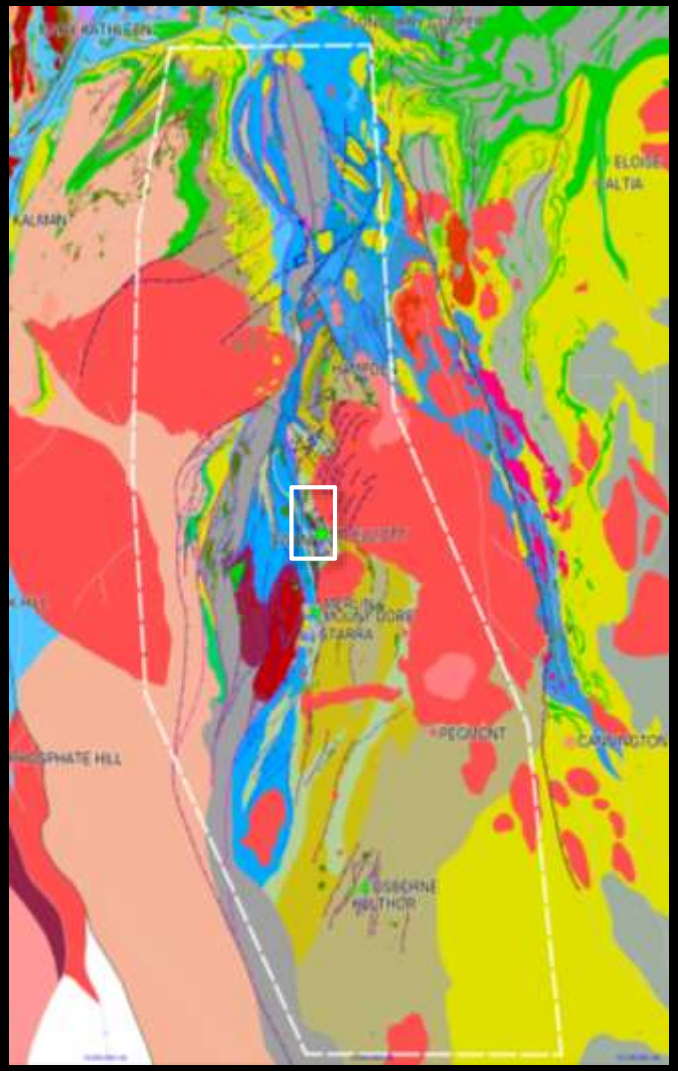
D3 Faulting: complex, curvilinear, anastomosing brittle in calc-silicate, carb silt ductile (*mylonitic*) in phyllite

Brittle, fracture & breccia zones host Mo minz …
.. along reverse fault where calc-silicate & carbonaceous silt are brecciated, and
.. where normal calc-silicate /carb silt contact is brecciated in FW & HW of reverse fault

D3 Faults … small throws! NOT Regional Structures

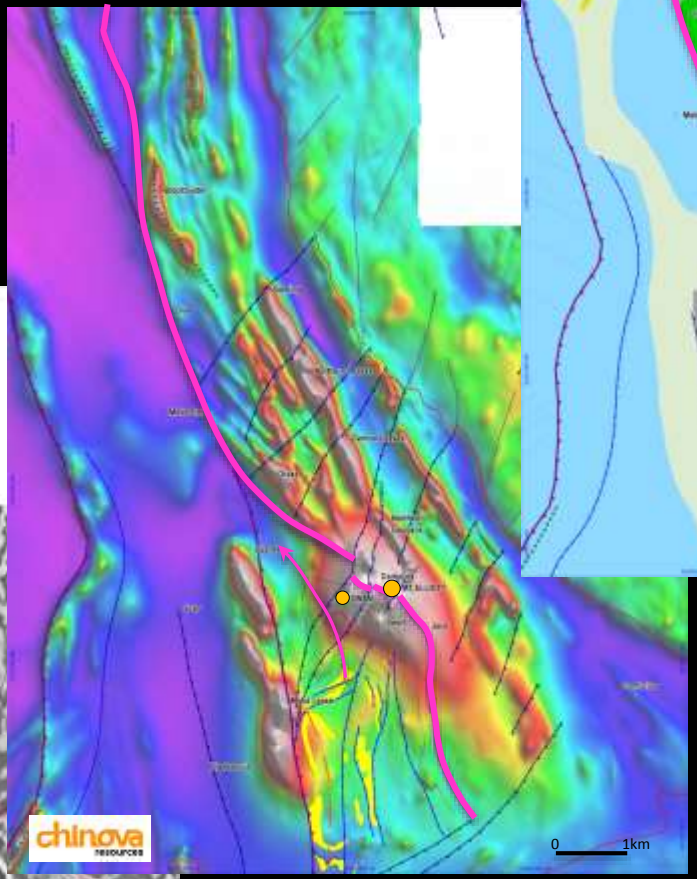
Granite Reverse Fault
highly planar, significant throw, post-mineral > reactivation > Mo-matrix breccias …

Mount Elliott - SWAN

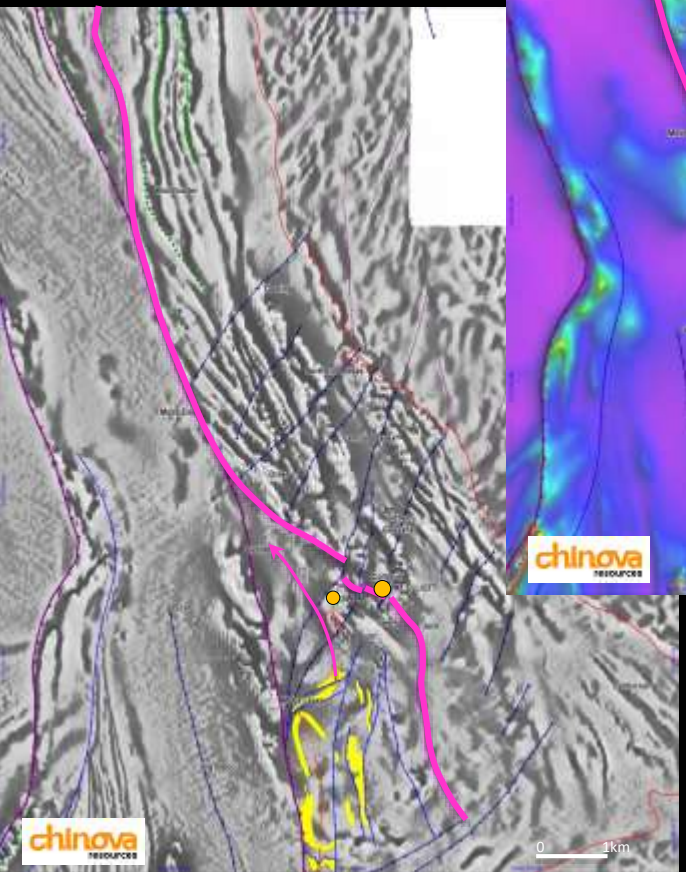


Mount Elliott - SWAN

detmag tmi-rtp

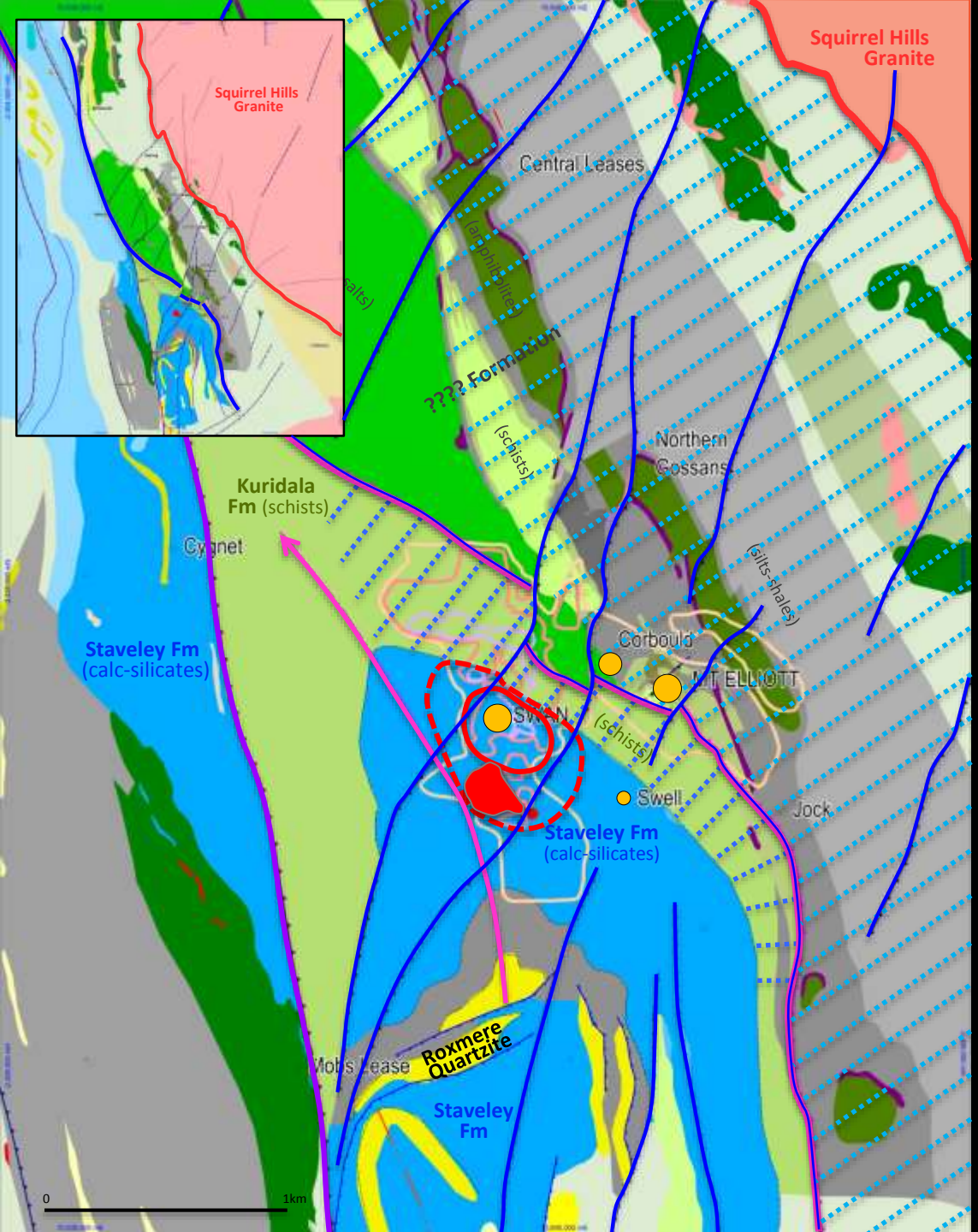


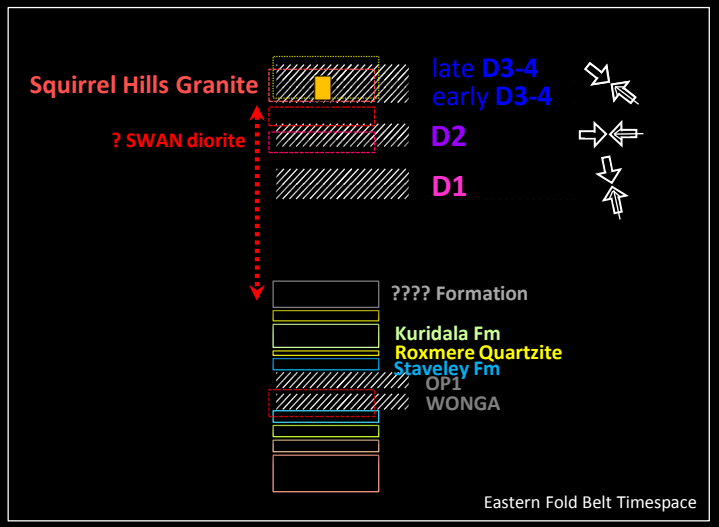
detmag vrmi-2vd



Close proximity to ?D1 structure

… juxtaposes, with significant HW truncations, strong mag-character package against benign Staveley-Kuridala packages

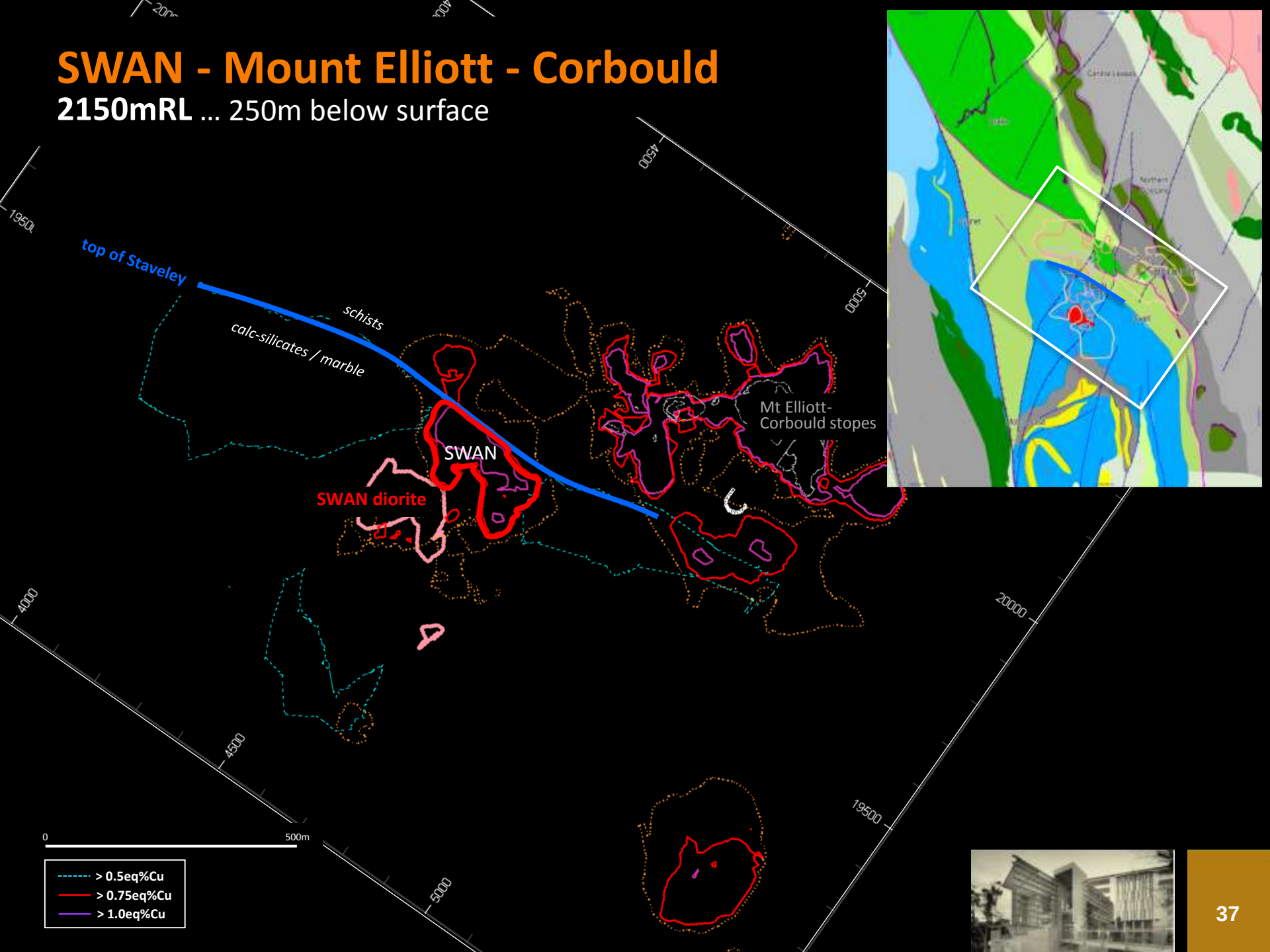




> 0.25eq%Cu
> 1.0eq%Cu
> 2.0eq%Cu

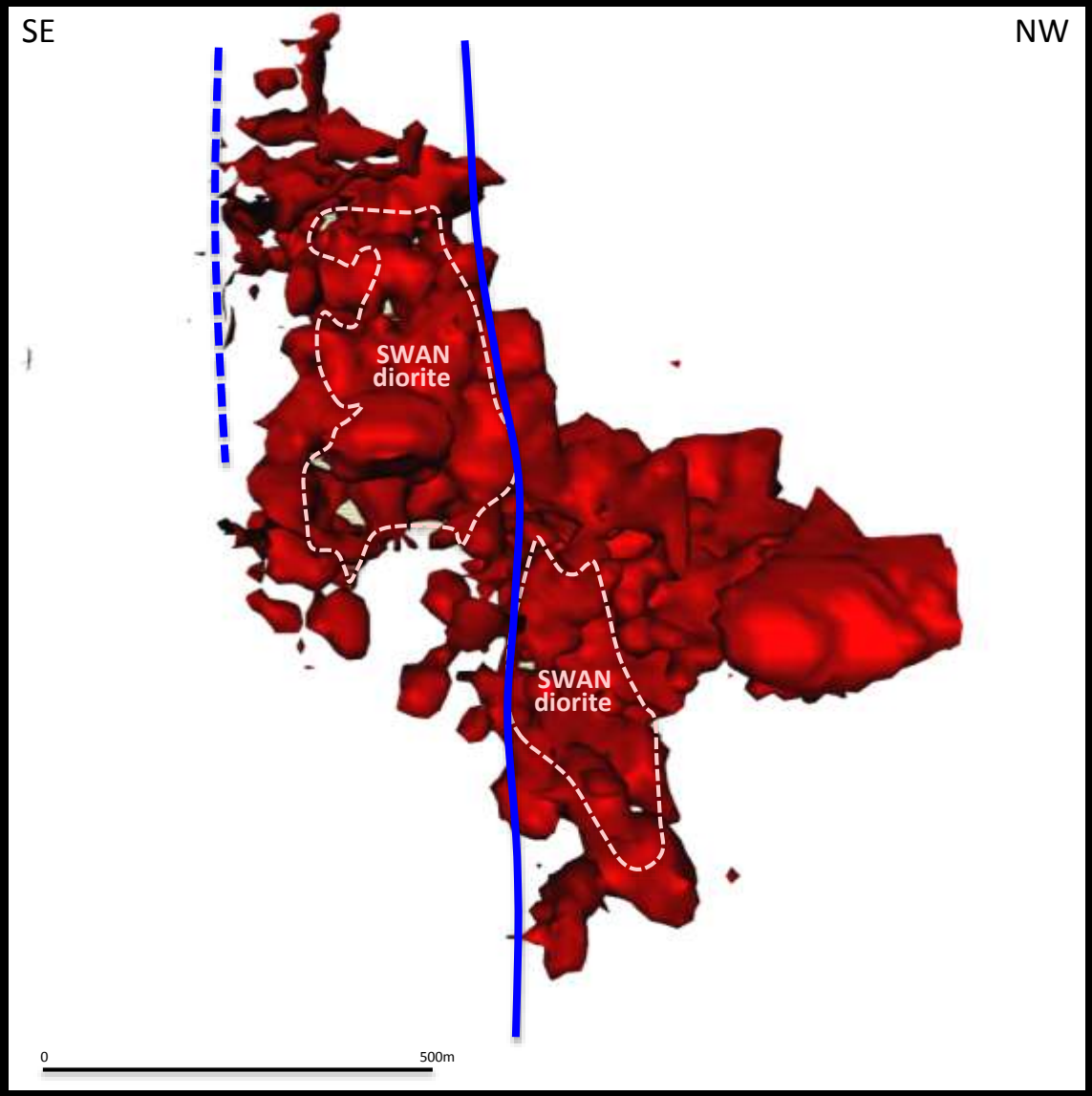
SWAN - Mount Elliott - Corbould

2150mRL … 250m below surface



SWAN 0.75eq%Cu

Long Section … looking SW **through** SWAN



- **post-mineral D3-4 Faults**
- **family cuts Squirrel Hills Granites**

CONCLUSIONS

DMQ southern Cloncurry IOCG Belt

- **Reliable geochronology suggests IOCG-style mineralisation forms during late orogenic, shallow-crustal, brittle, deformation** (Isan D3-4)

- **IOCG-style mineralisation forms via a complex interplay in the geometries of thermally-driven, circulation of** (?basinal) **brines, and the contemporaneous** Isan D3-4 **patterns of brittle, fracture-breccia deformation**

- **Ore deposition is focused within brittle, breccia/fracture networks that are ubiquitously post-peak metamorphic**

- **Local competency contrasts & strain partitioning play critical roles in the geometries of brittle failure & ore localisation**

- **D3-4 faulting comprises short-strike / small-displacement faults, and localised reactivation of older structures**
- Contrasts with **D2 faults which are regional in strike & commonly juxtapose packages of contrasting lithology & age**

(Dichotomy: D2 structure well imaged (mapping, seismic..) cf. D3-4 structures, likely highly seismic, but generally not well imaged!)

- In D3-4 time**, crystallising granites** (that drive the high temp IOCG fluid systems) **themselves locally play roles in strain partitioning which drives the brittle failure that focuses IOCG mineralisation**

- **Subtle pre-orogenic,** (potentially depositional), **architectures play critical roles in:** (1) (Isan) **deformation partitioning,** (2) **intrusion geometry, and** (3) **IOCG-forming, fluid circulation patterns … and therefore, strongly impact on localisation of IOCG ore formation**

DMQ Project going forward, aims to tease these controls & interplays into 3D!