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Cloncurry IOCG Workshop 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 Pty Ltd

chinova resources

Deep Mining Queensland 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)
Adrian Pratt (Mining Engineer)

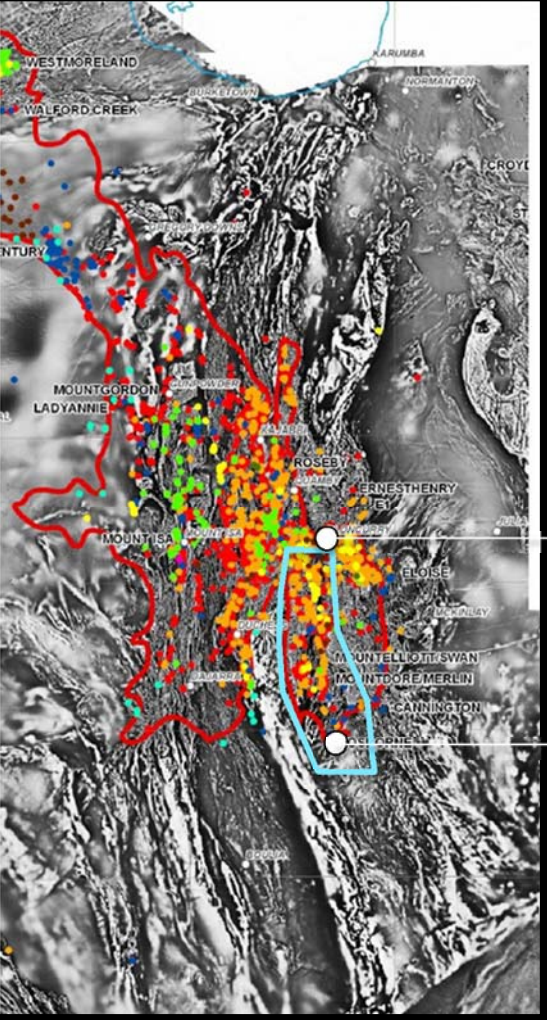
Acknowledgements

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

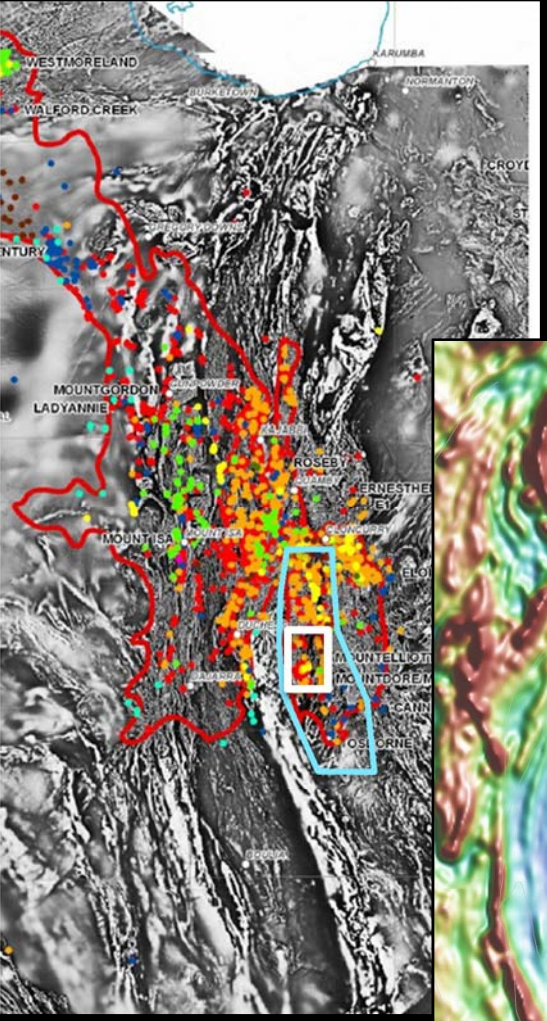
Deep Mining Queensland Project Location

Eastern Fold Belt between Cloncurry & Osborne

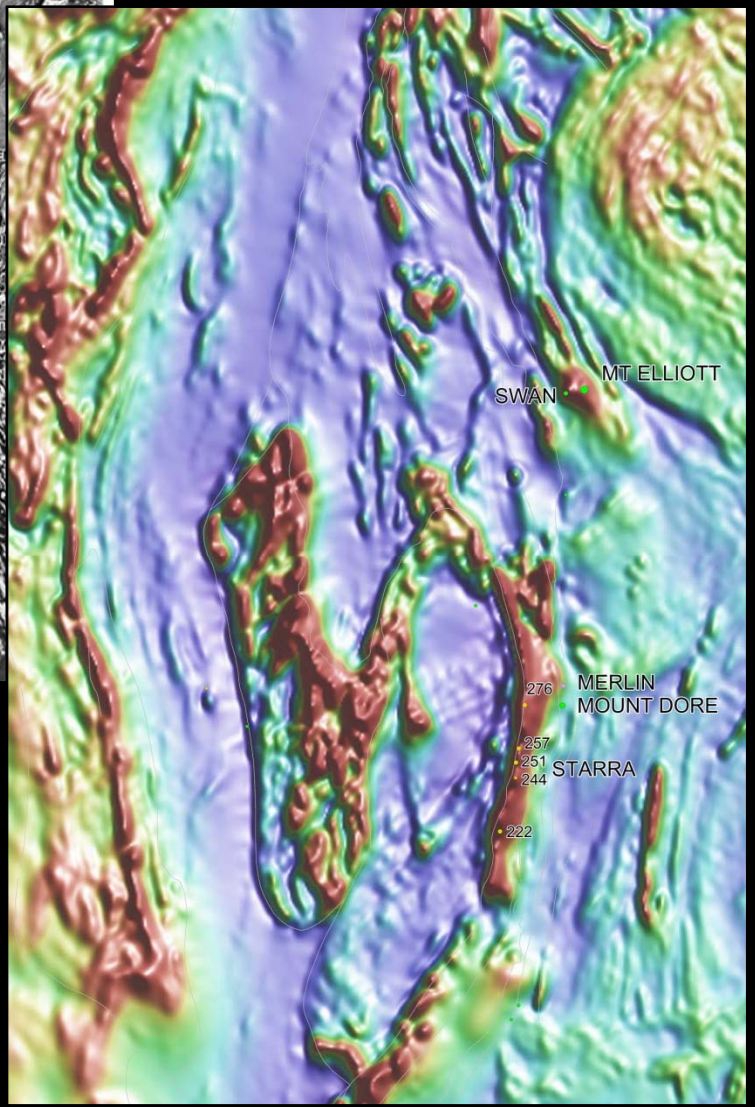
***approx* 180x50km**



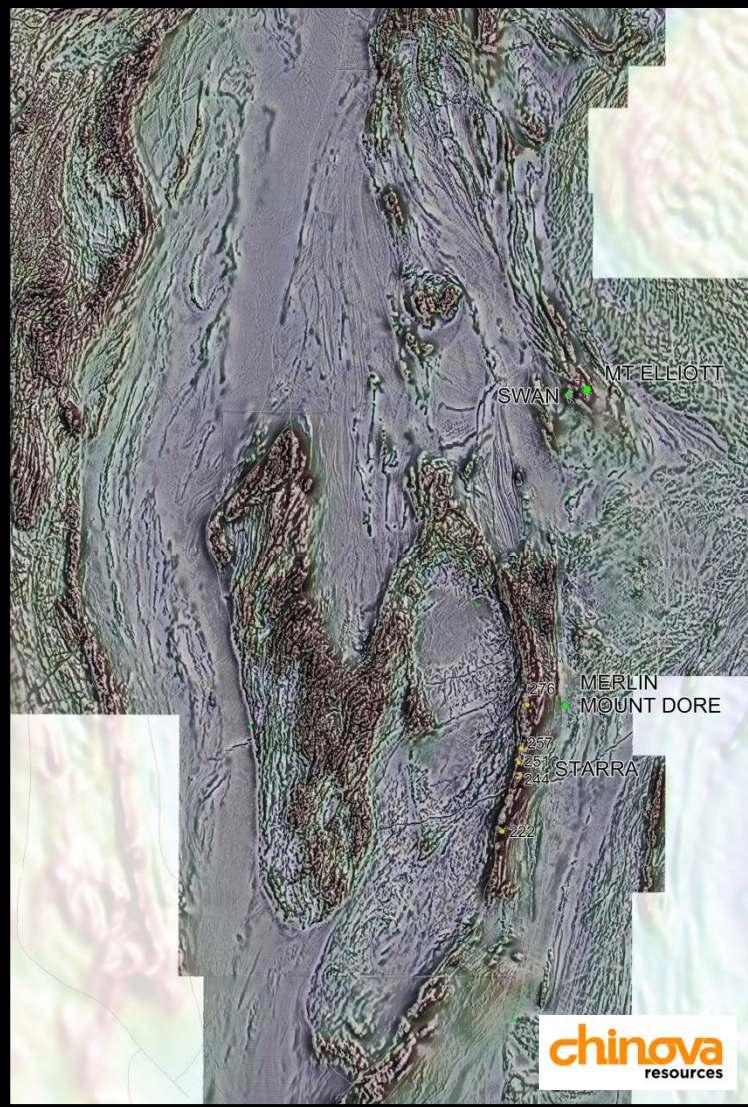
Regional *vs* Detailed Magnetics



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



Chinova detailed Mag merge vrmi-2vd (**2010**) 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), **brittle, fracture-breccia networks that are controlled by local competency contrast & strain partitioning.**

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

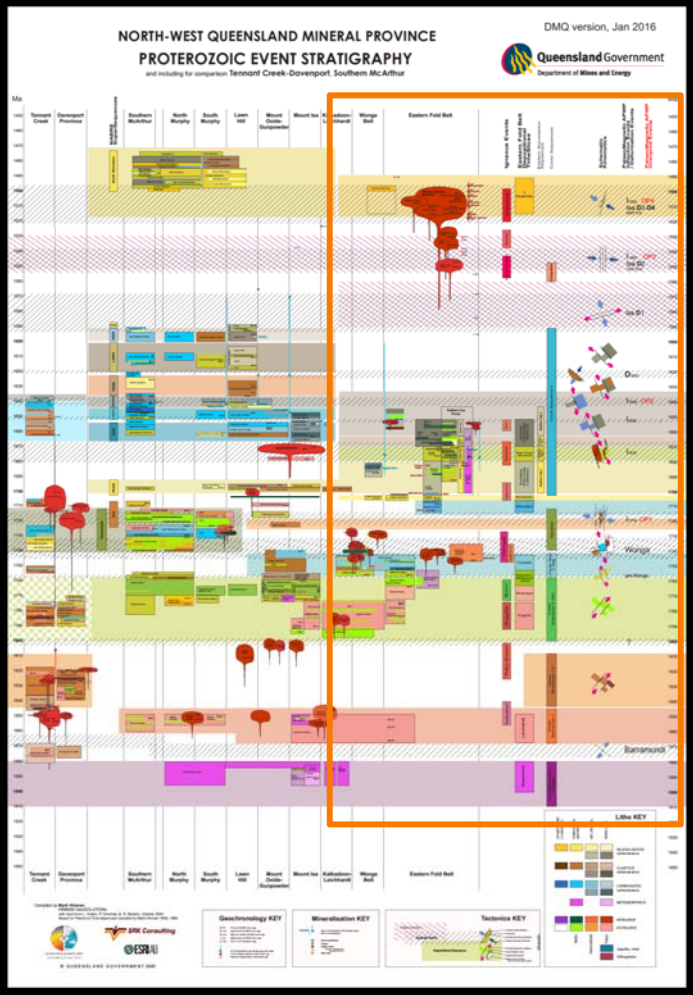
- **D3 structuring comprises short-strike / small-displacement faults, and localised reactivation of older structures** …. in contrast with**, D2 faults which are regional in strike & commonly juxtapose packages of contrasting lithology & age.**

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

- **In D3 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.**

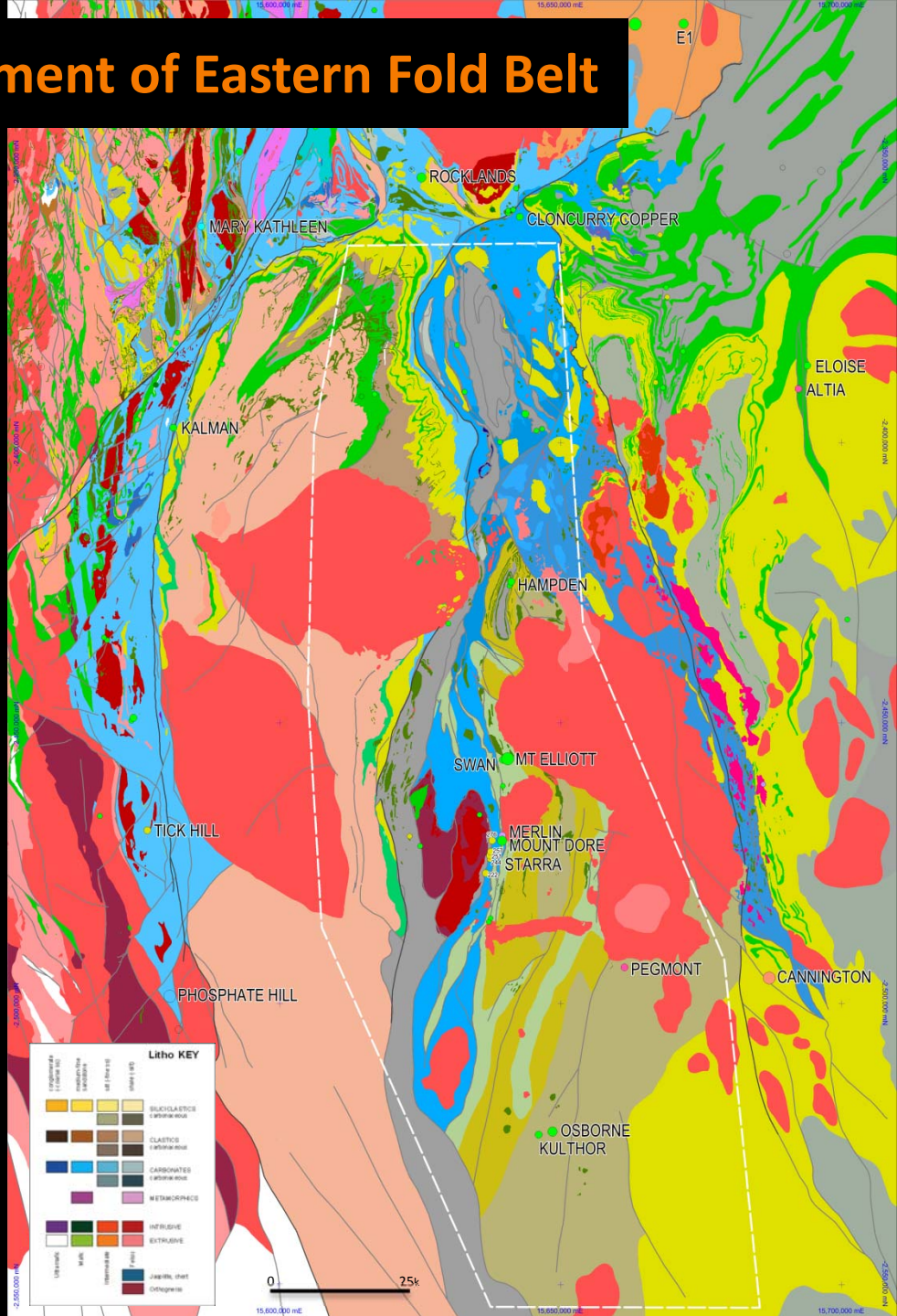
- **Pre-orogenic architectures likely play critical roles in the geometries of intrusion, brittle deformation, IOCG fluid circulation, & the localisation of ore formation.**

Tectono-Stratigraphic Development of Eastern Fold Belt



Updated 2000 NWQMP Tx Chart

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



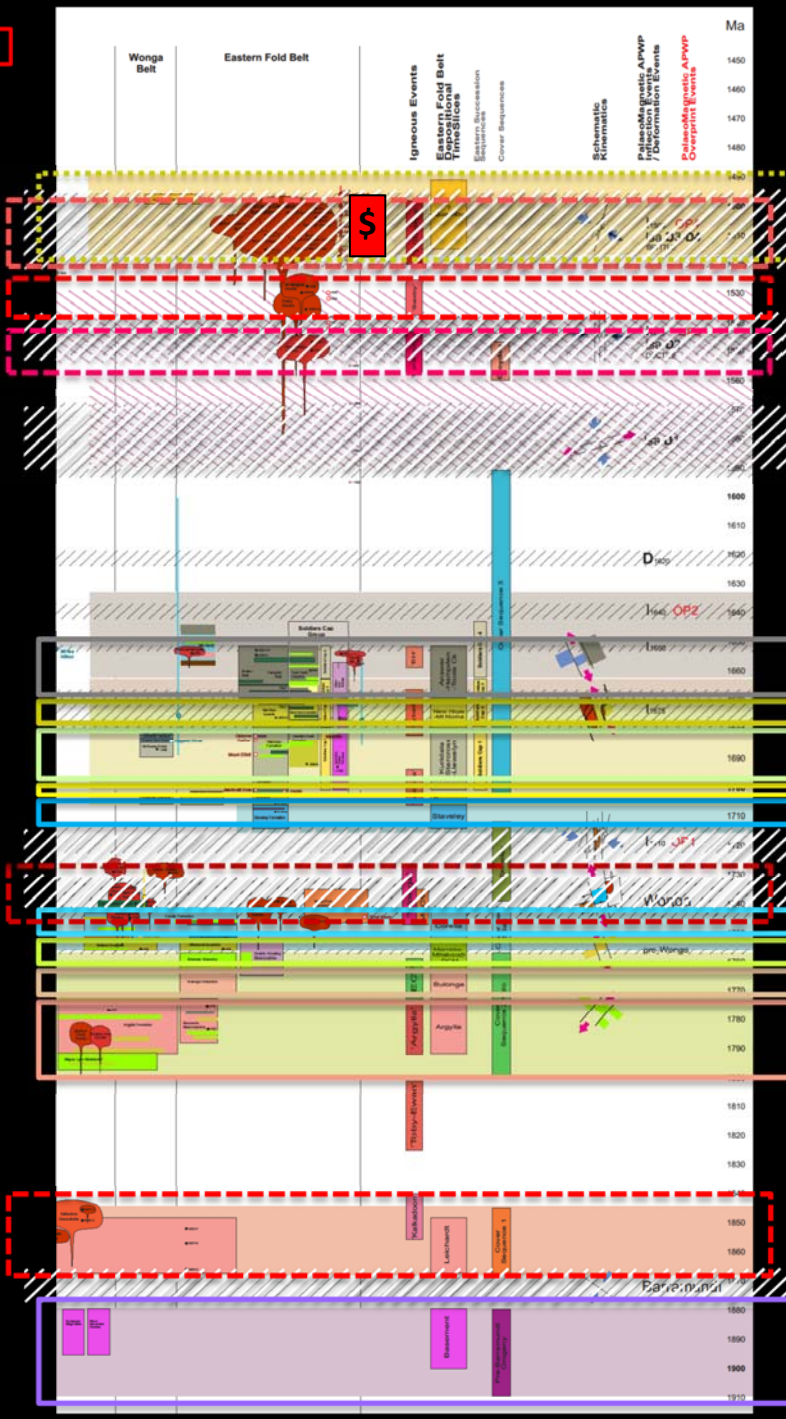
Re-built EFB Solid Geology

highlighting packages & deformation events that impact their geometry

Magmatism

Depositional Timeslices

Deformation



~1515-1500Ma **Williams**

~1530Ma **Saxby**

~1545Ma **Maramungee**

~1745-1730Ma **Wonga**
Mt Fort Constantine Volcs

~1865-1845Ma **Kalkadoon**
Leichardt Volcs

?? Ma **Quamby**

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

~1555-1535Ma **Isan D2**
DUCTILE thick-skinned

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

1400Ma

~1690-1650Ma **Answer-Toole Creek**

~1680-1690Ma **New Hope-Mt Norna**

~1710-1680Ma **Kuridala-Starcross-Llewelyn**

~1710Ma **Roxmere**

~1715-1710Ma **Staveley**

~1710Ma **OP1 Deformation**

~1740Ma **WONGA Extension**

~1755-1740Ma **Corella**

~1765-1755Ma **Marraba-Mitakoodi-Double Crossing**

~1775-1765Ma **Bulonga**

1770Ma

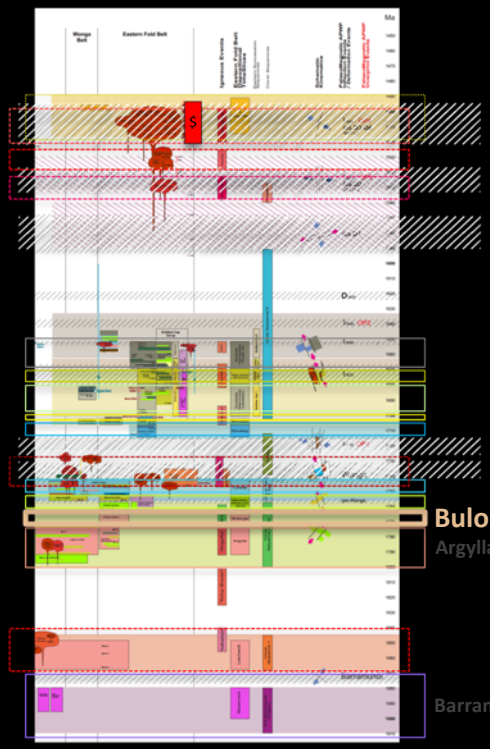
~1800-1775Ma **Argylla**

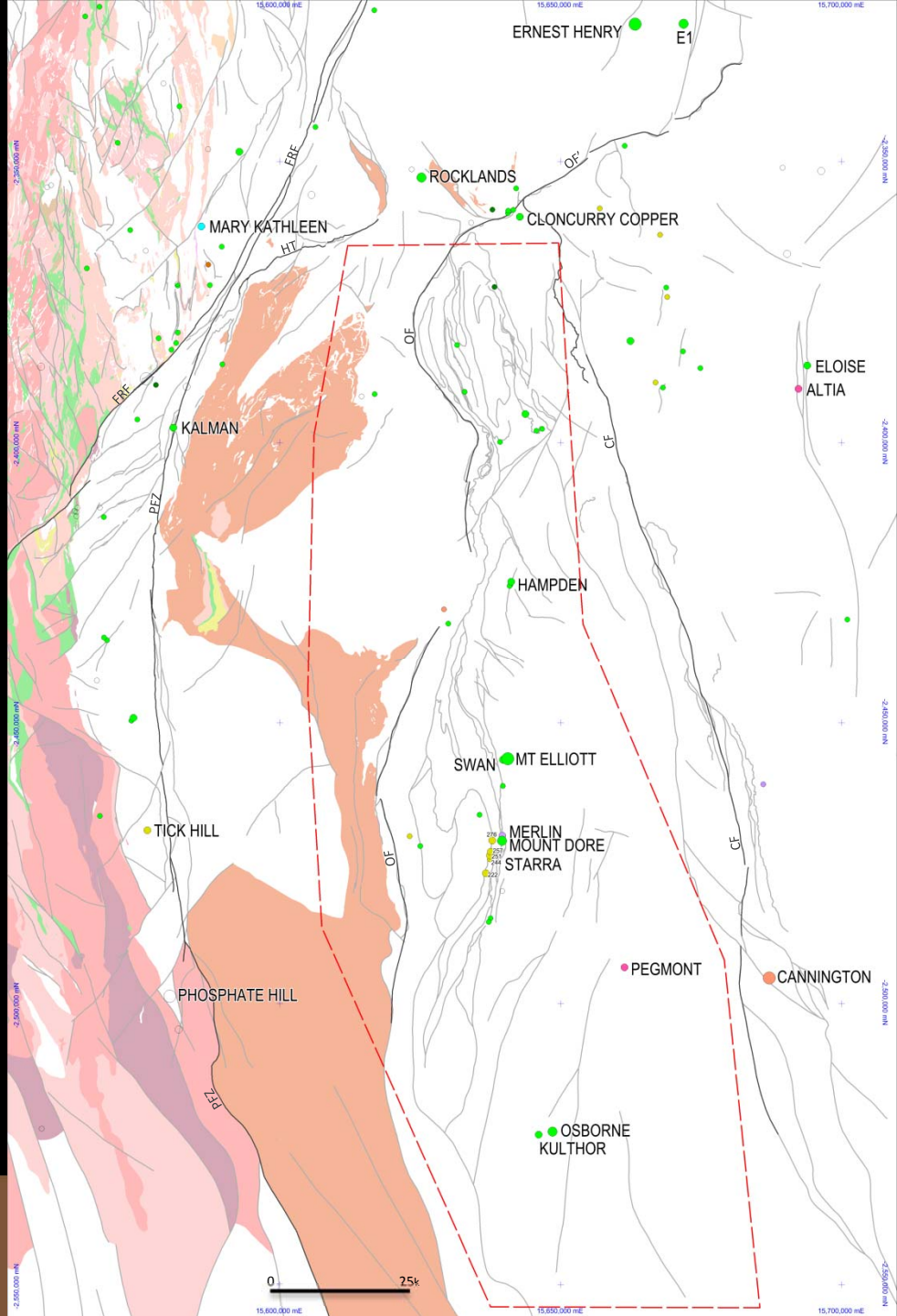
~1870Ma **Barramundi Orogeny**

>1900-1880Ma pre-**Barramundi**

~1775-1765Ma

Bulonga





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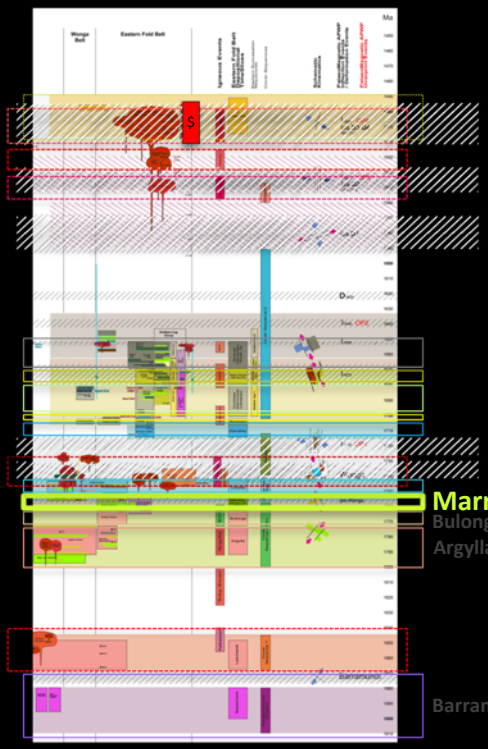
FRF = Fountain Range Fault
PFZ = Pilgrim Fault Zone
HT = Highway Thrust
OF = Overhang Fault
CF = Cloncurry Fault

~1765-1755Ma

Marraba-Mitakoodi-Double Crossing Meta



ERNEST HENRY
E1
ROCKLANDS
CLONCURRY COPPER
MARY KATHLEEN
HT
FRF
OF
CF
PFZ
KALMAN
ELOISE
ALTIA
HAMPDEN
SWAN
MT ELLIOTT
TICK HILL
MERLIN
MOUNT DORE
STARRA
PEGMONT
CANNINGTON
PHOSPHATE HILL
OSBORNE
KULTHOR
0
25k

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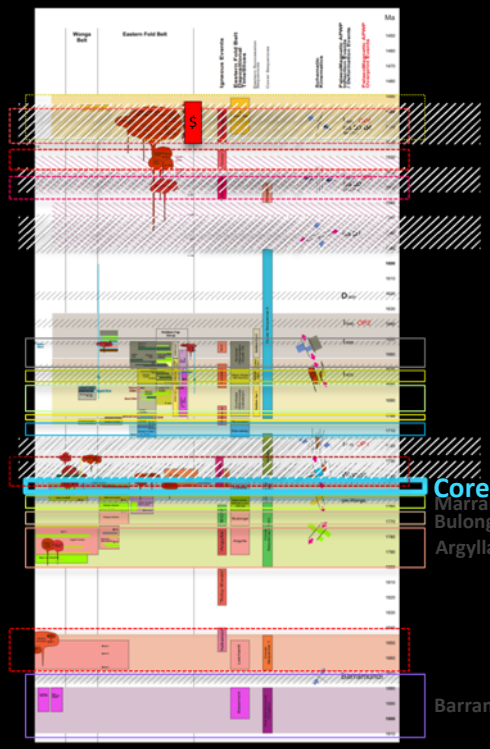
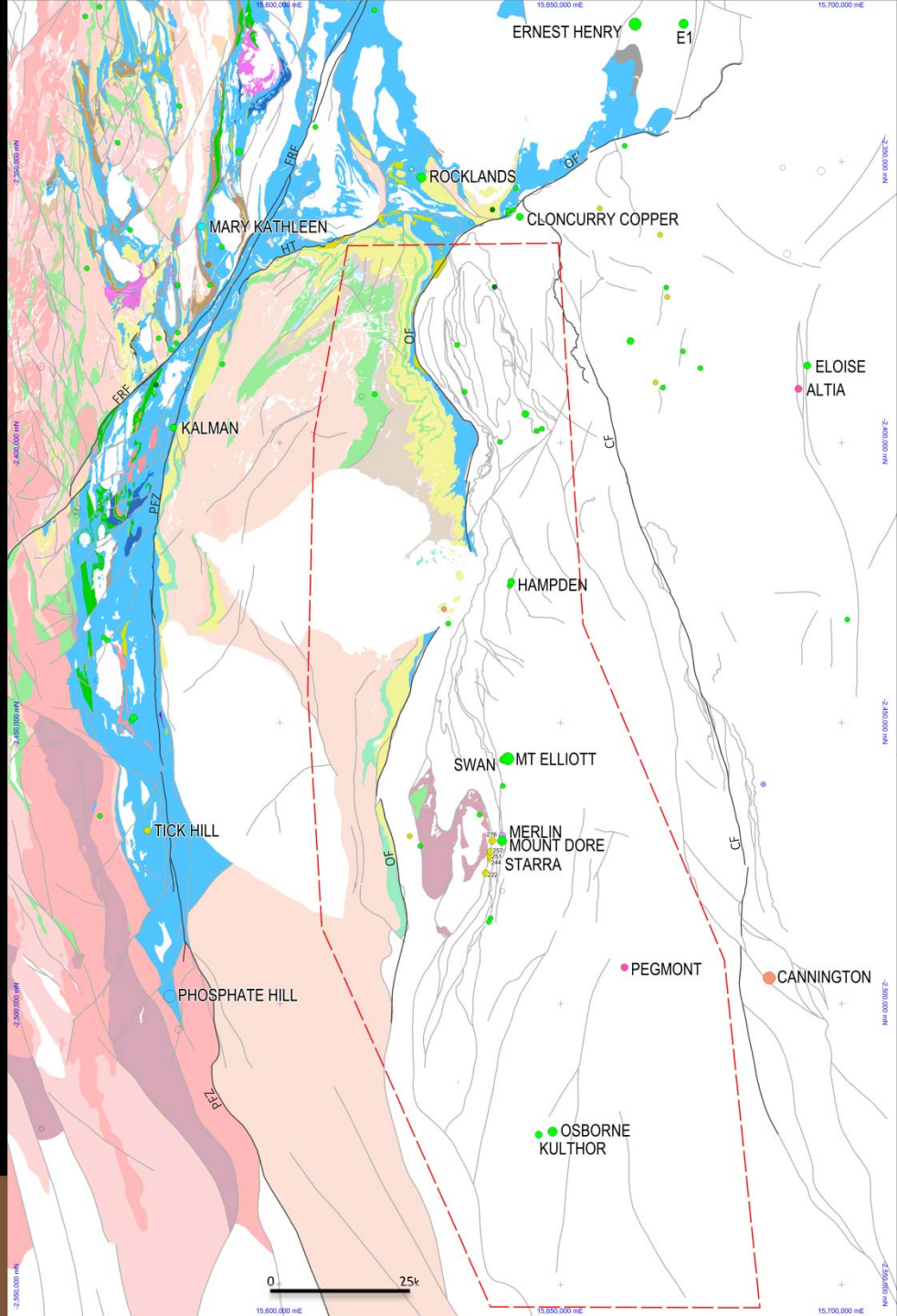
~1755-1740Ma

Corella





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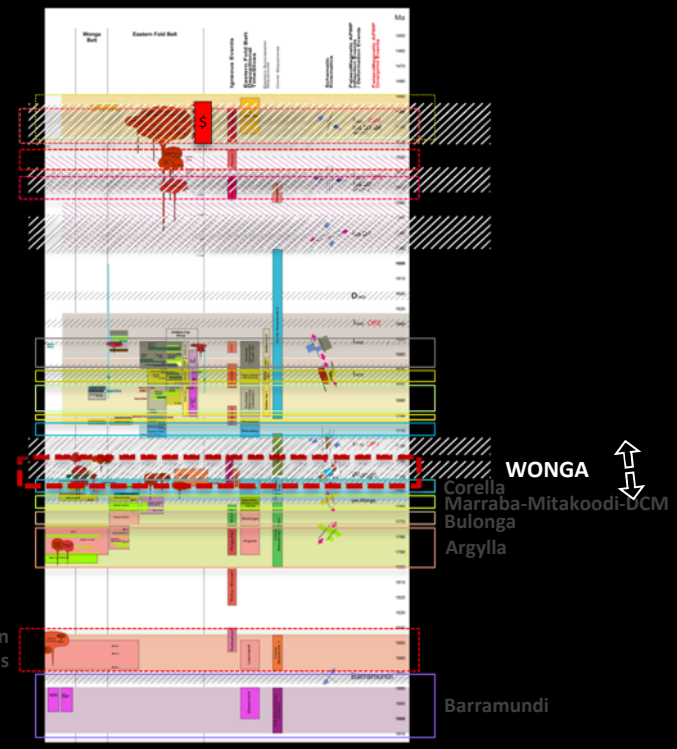
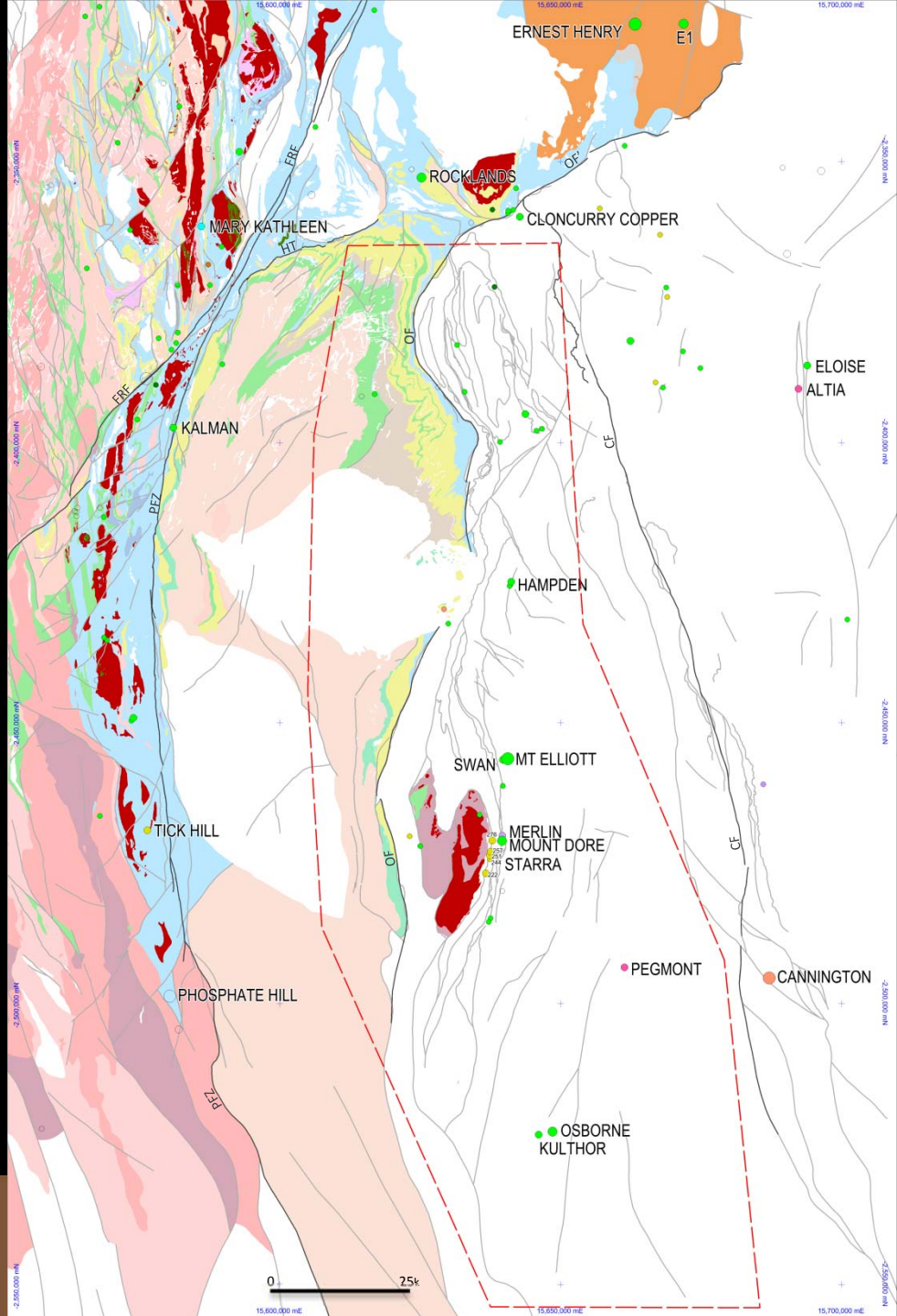
~1740Ma
WONGA Extension
~1740-1745Ma
Mount Fort Constantine Volcanics





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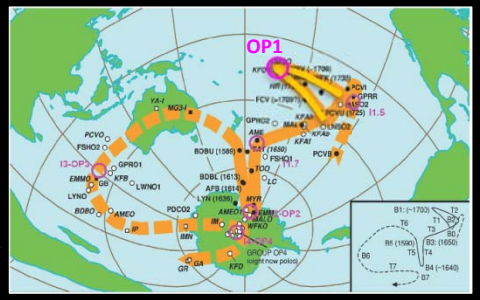
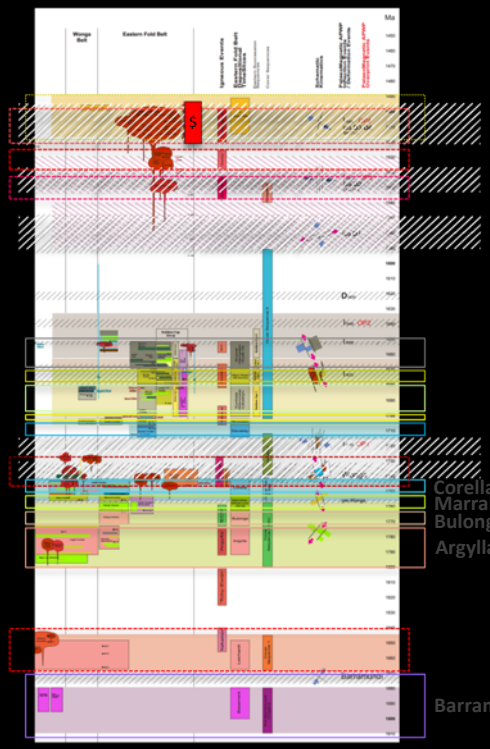
~1710Ma

⇨⇦ OP1 Deformation



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



Wonga MFCV

Kalkadoon Leichardt Volcs

OP1 ⇨⇦

WONGA

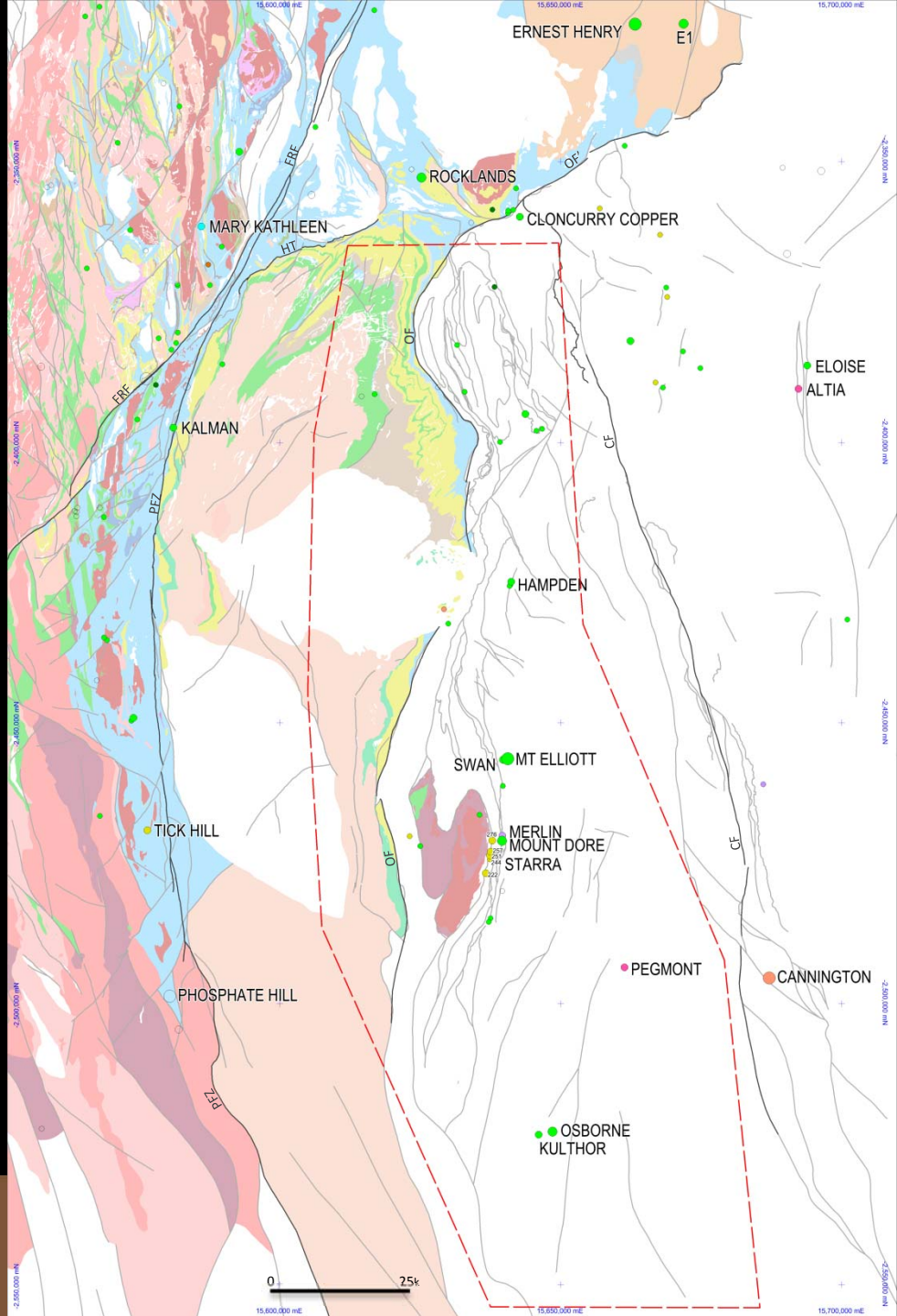
Corella

Marraba-Mitakoodi-DCM

Bulonga

Argylla

Barramundi



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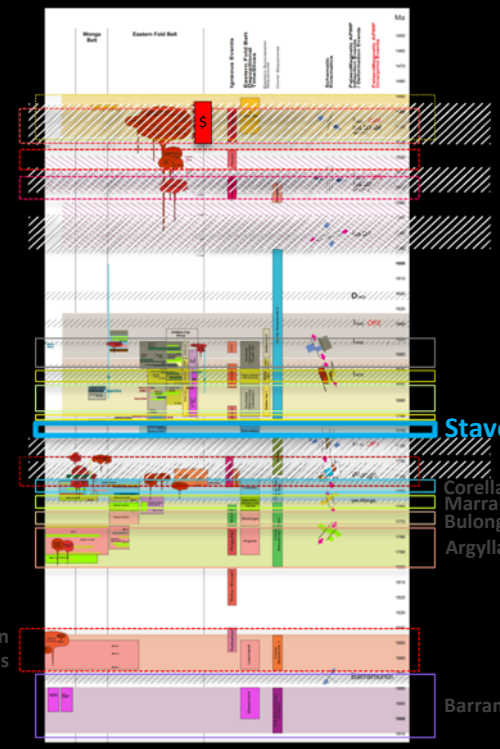
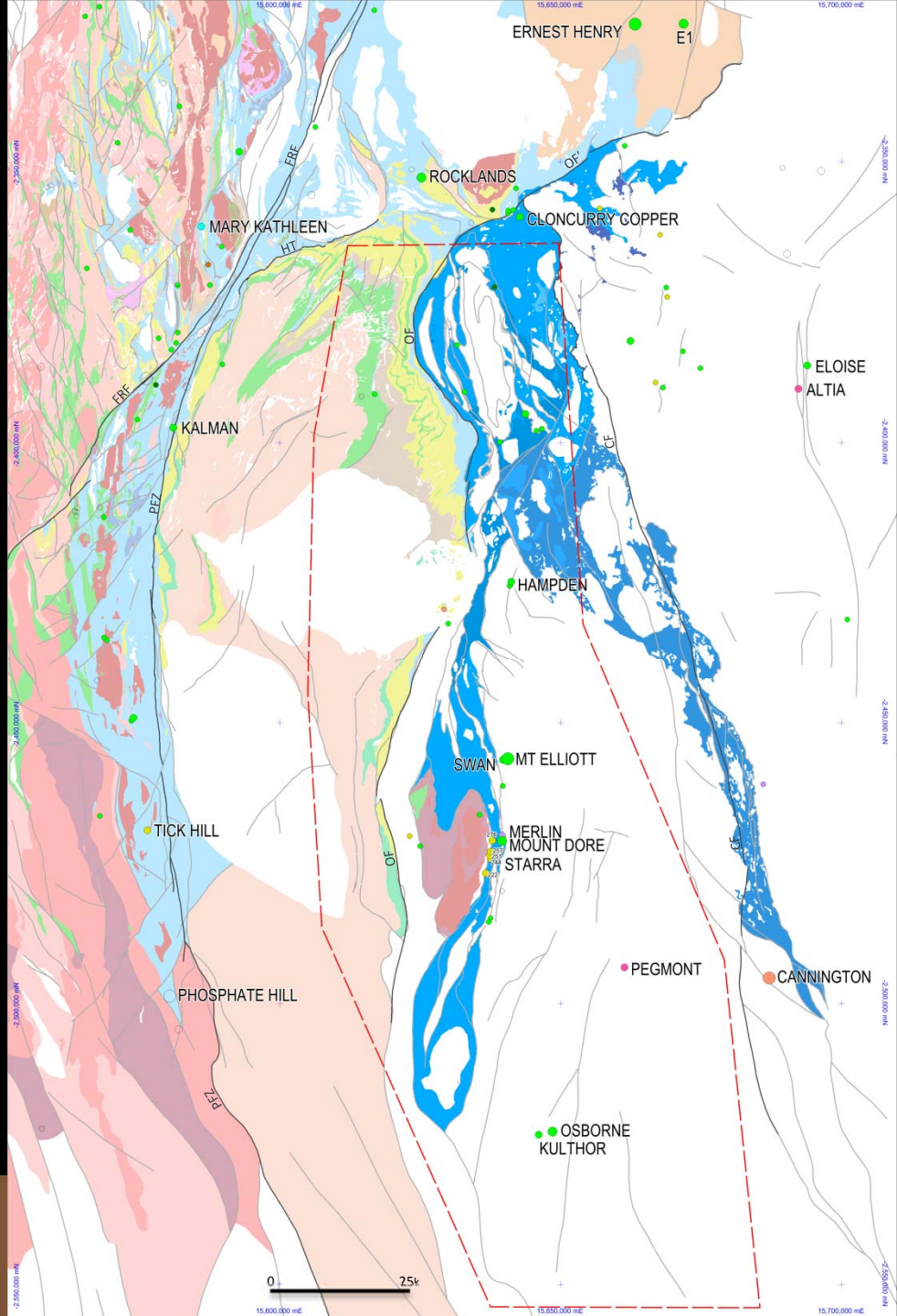
~1715-1710Ma

Staveley





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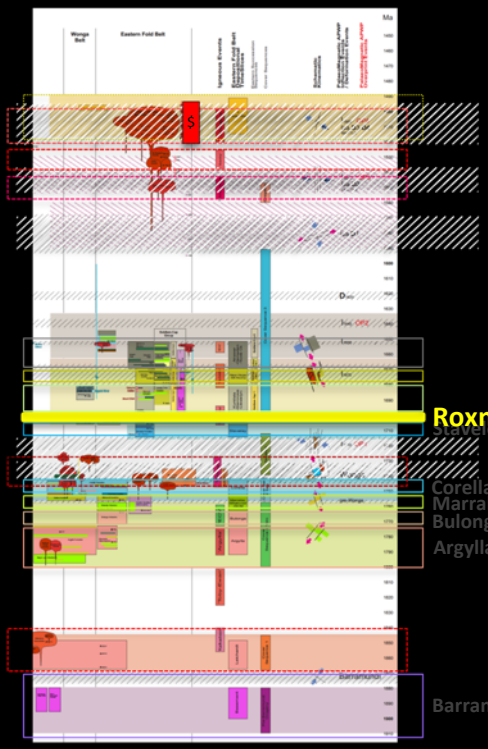
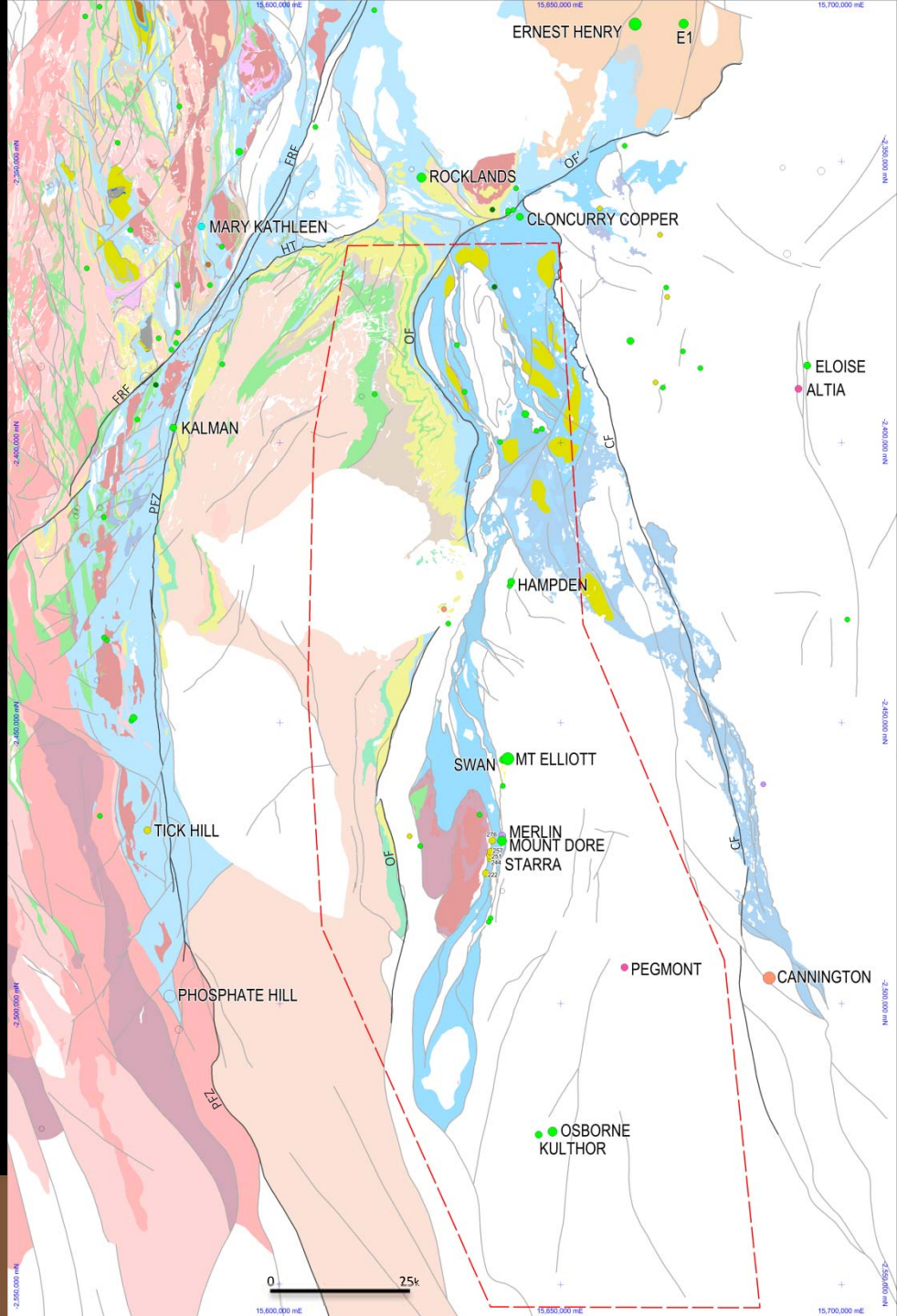
~1710Ma

Roxmere





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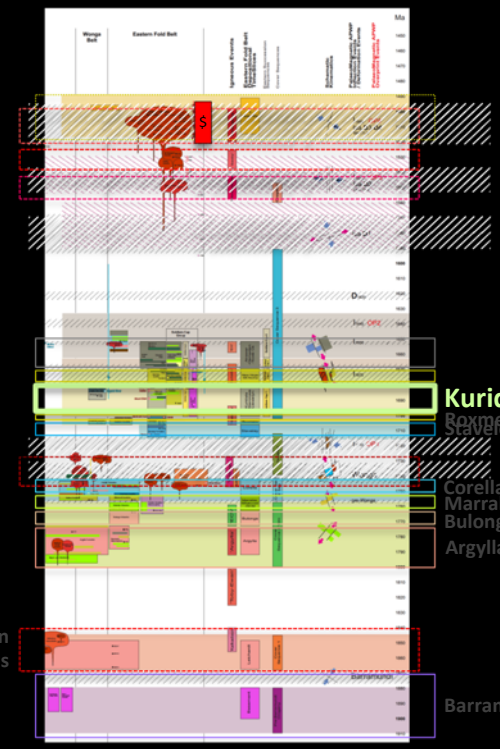
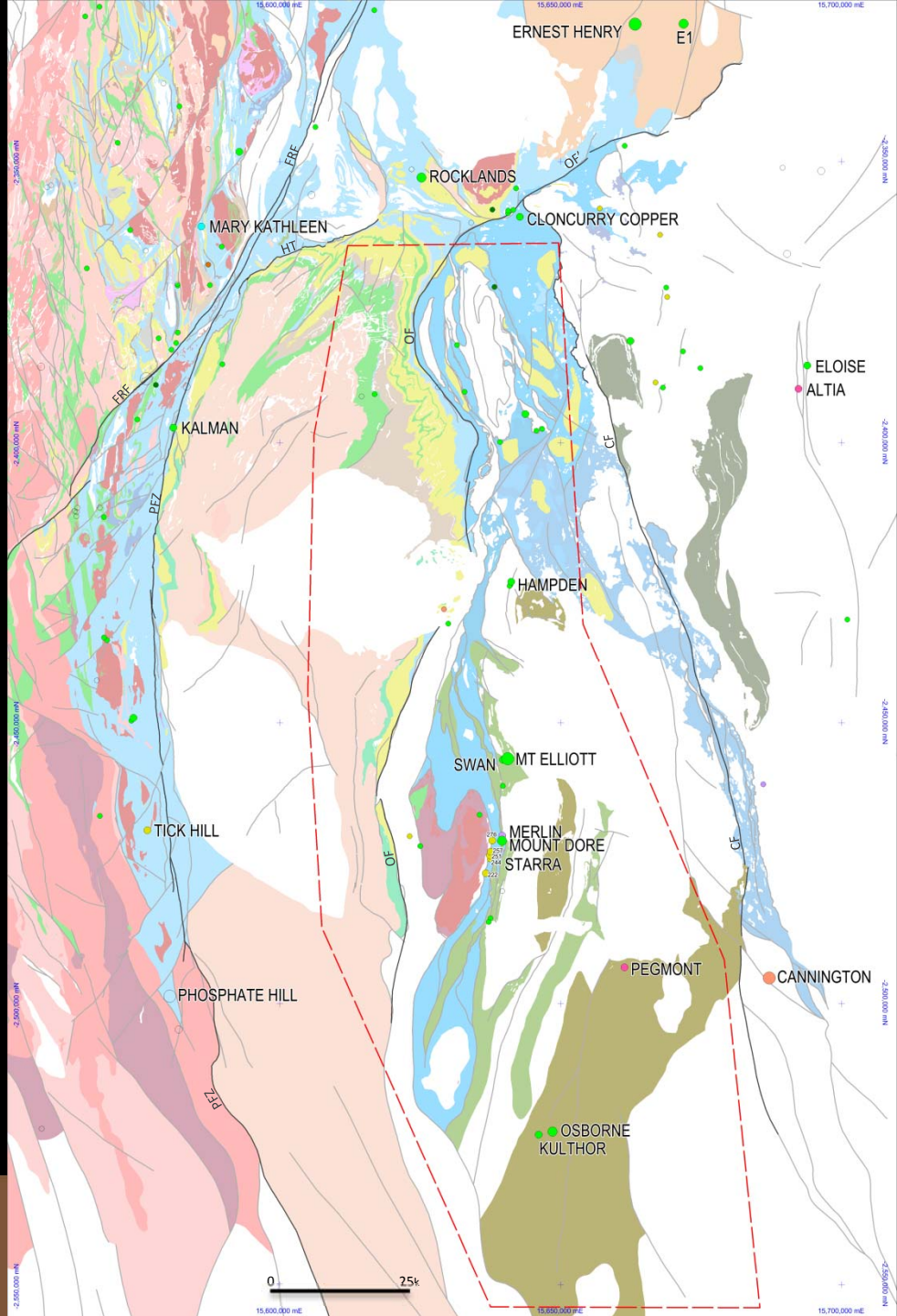
~1710-1680Ma

Kuridala-Starcross-Llewelyn





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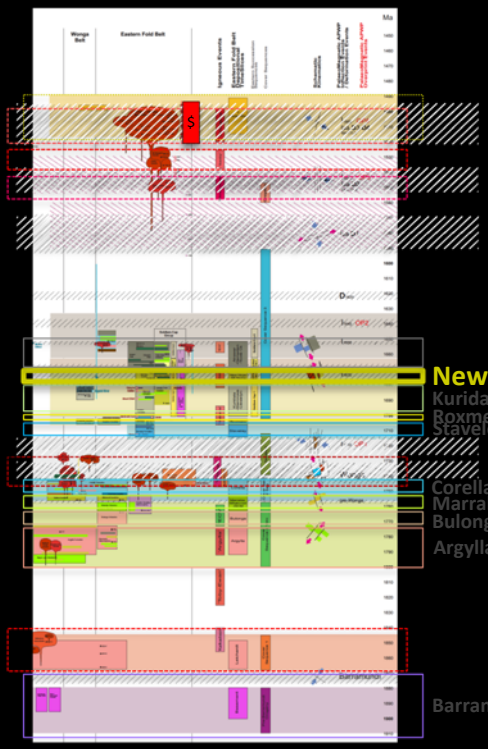
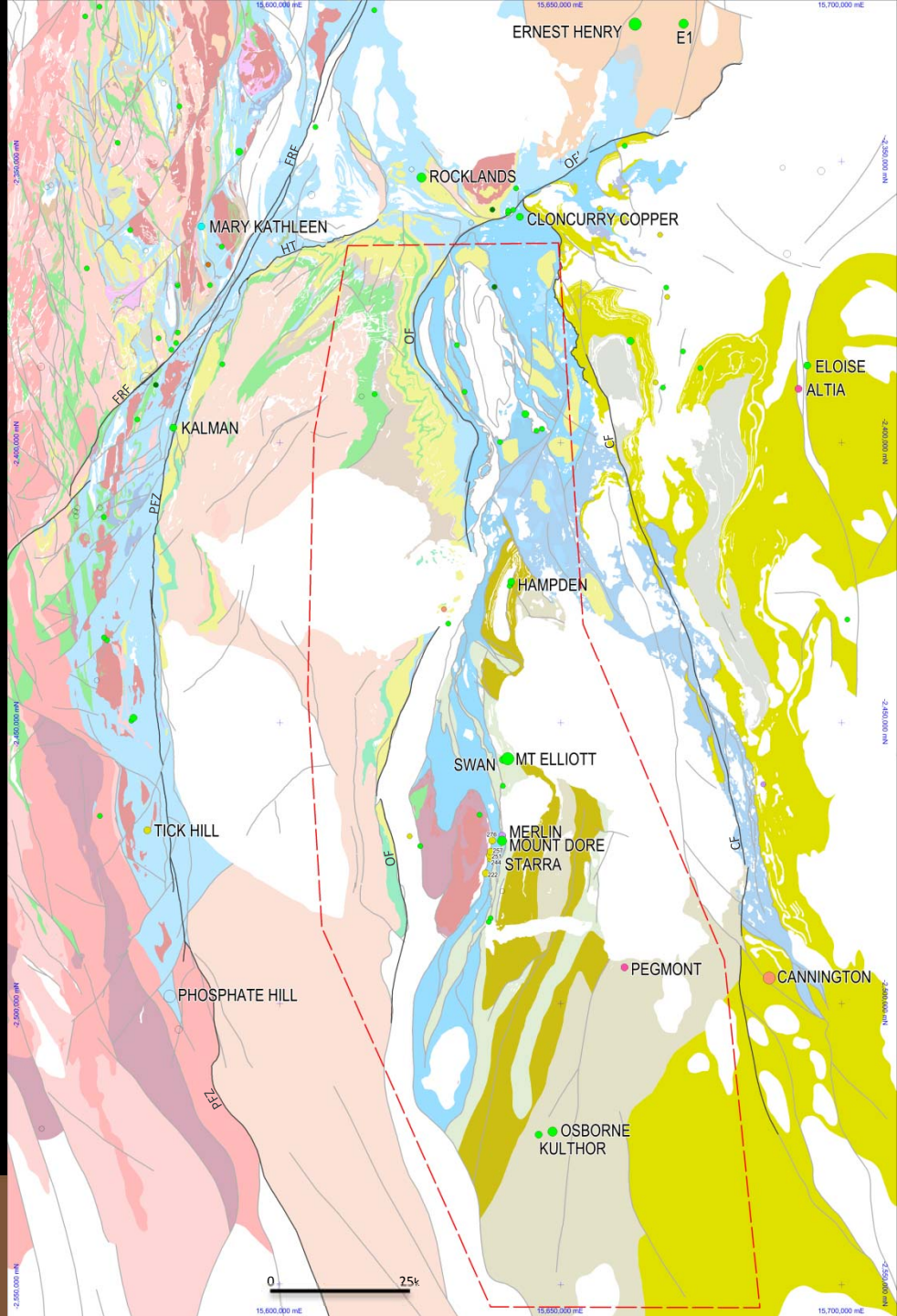
~1680-1670Ma

New Hope-Mt Norna





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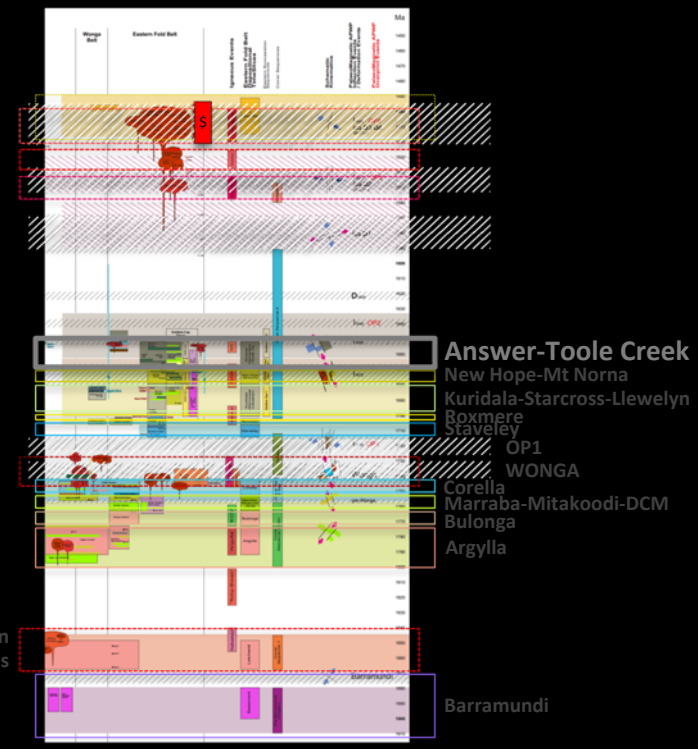
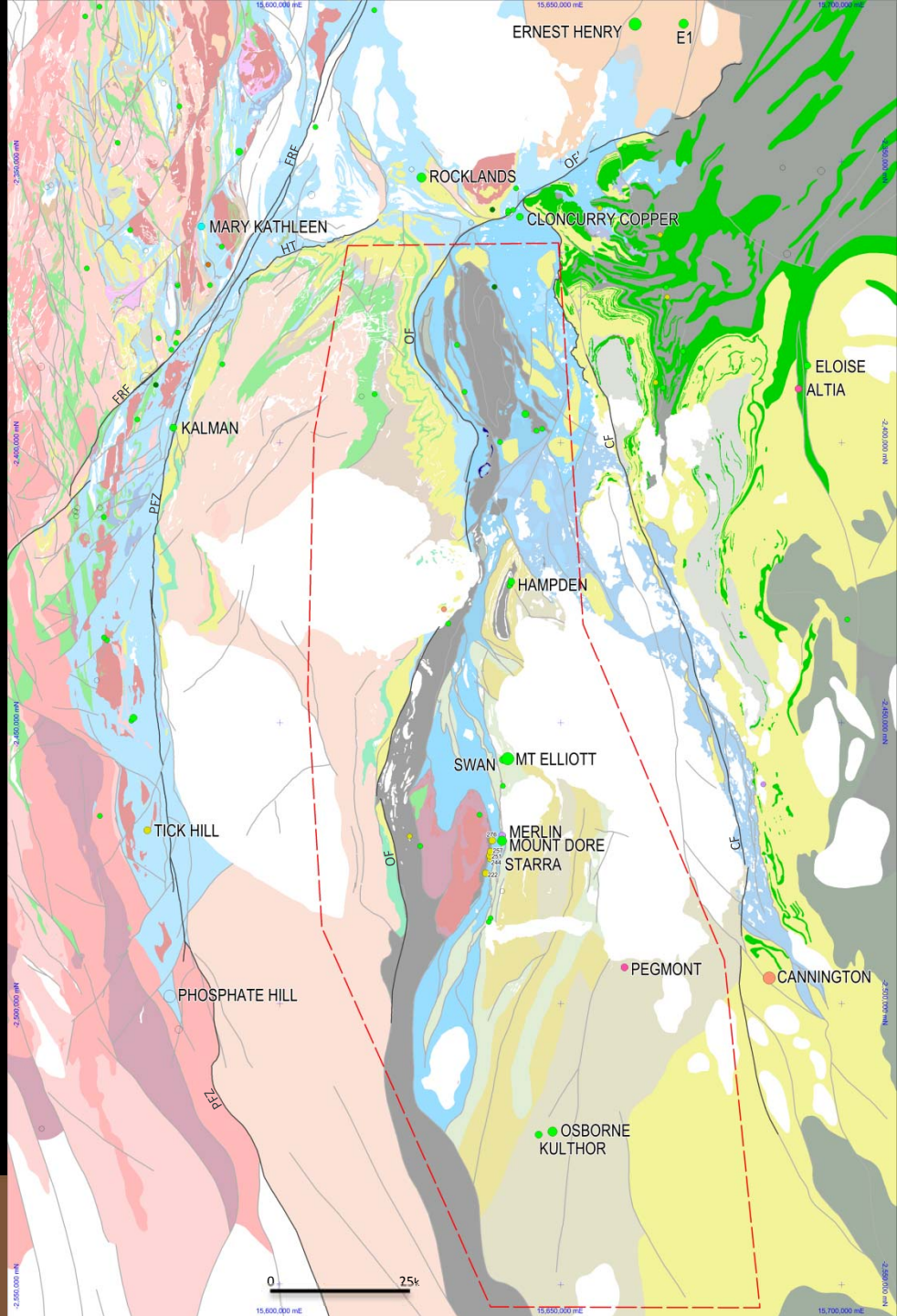
~1670-1650Ma

Answer-Toole Creek





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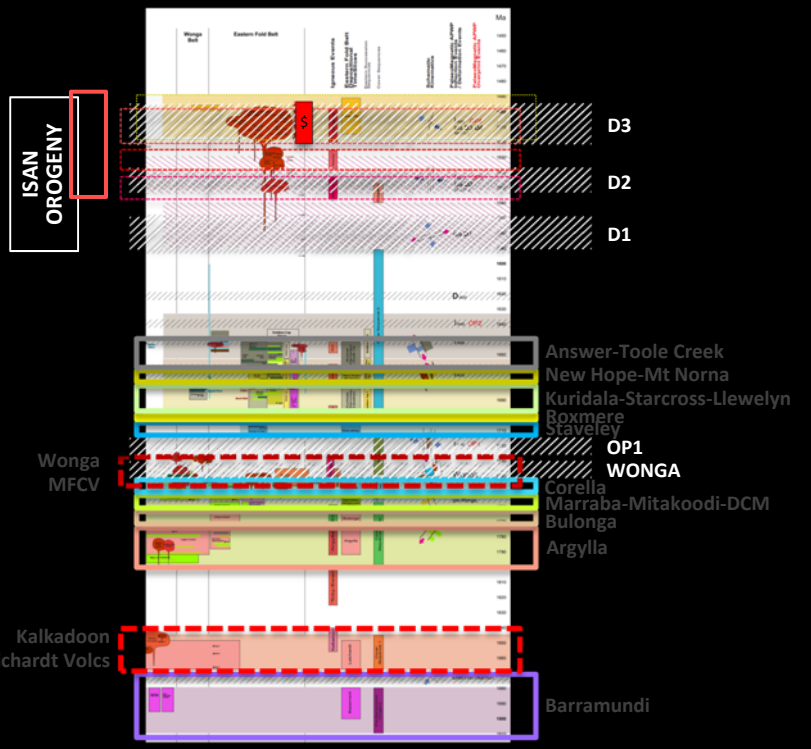
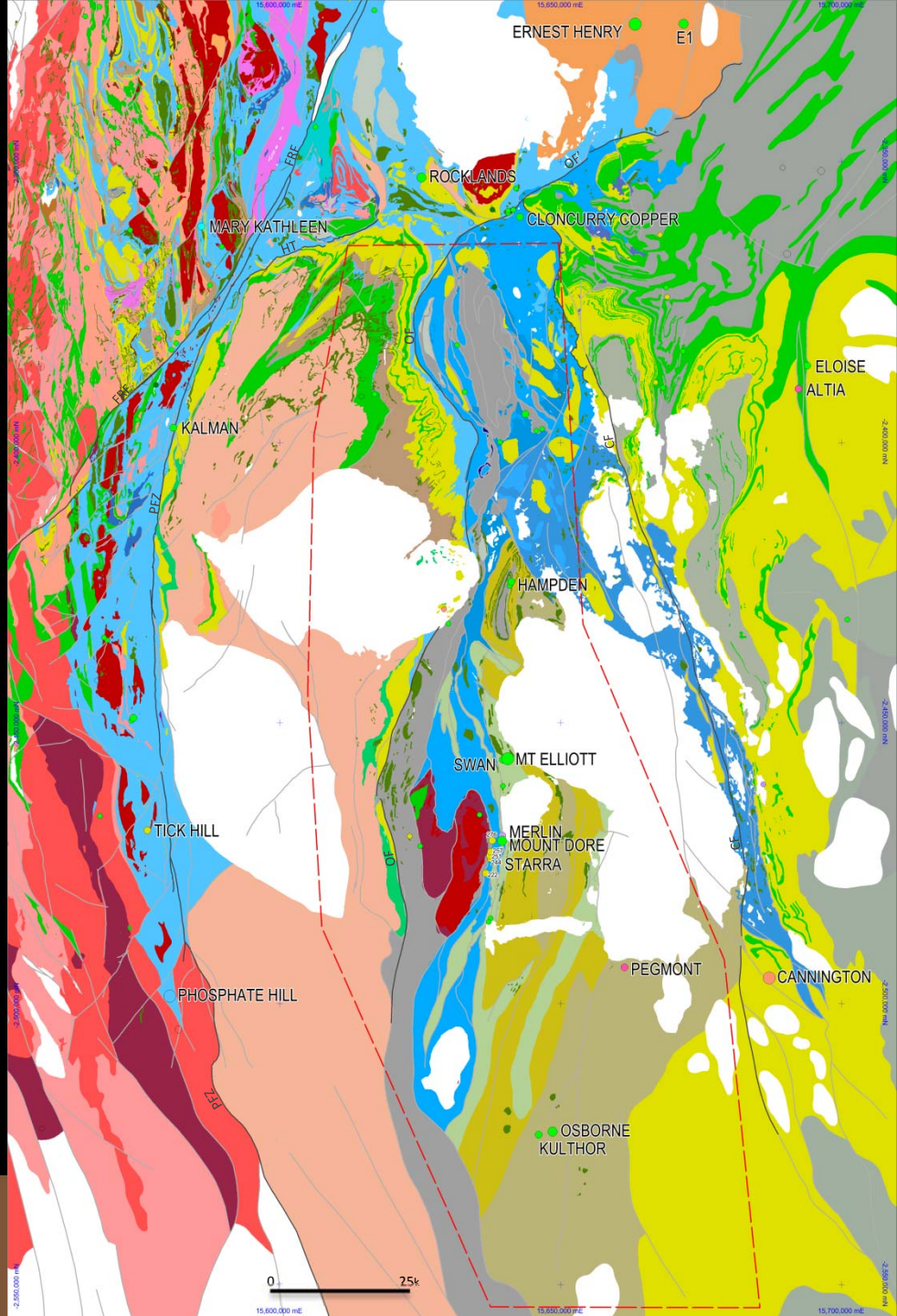
~1650Ma





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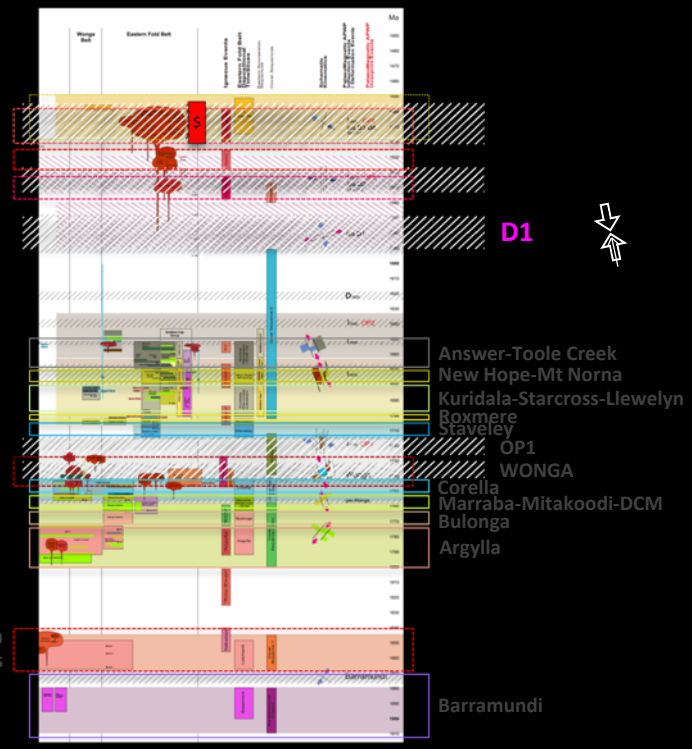
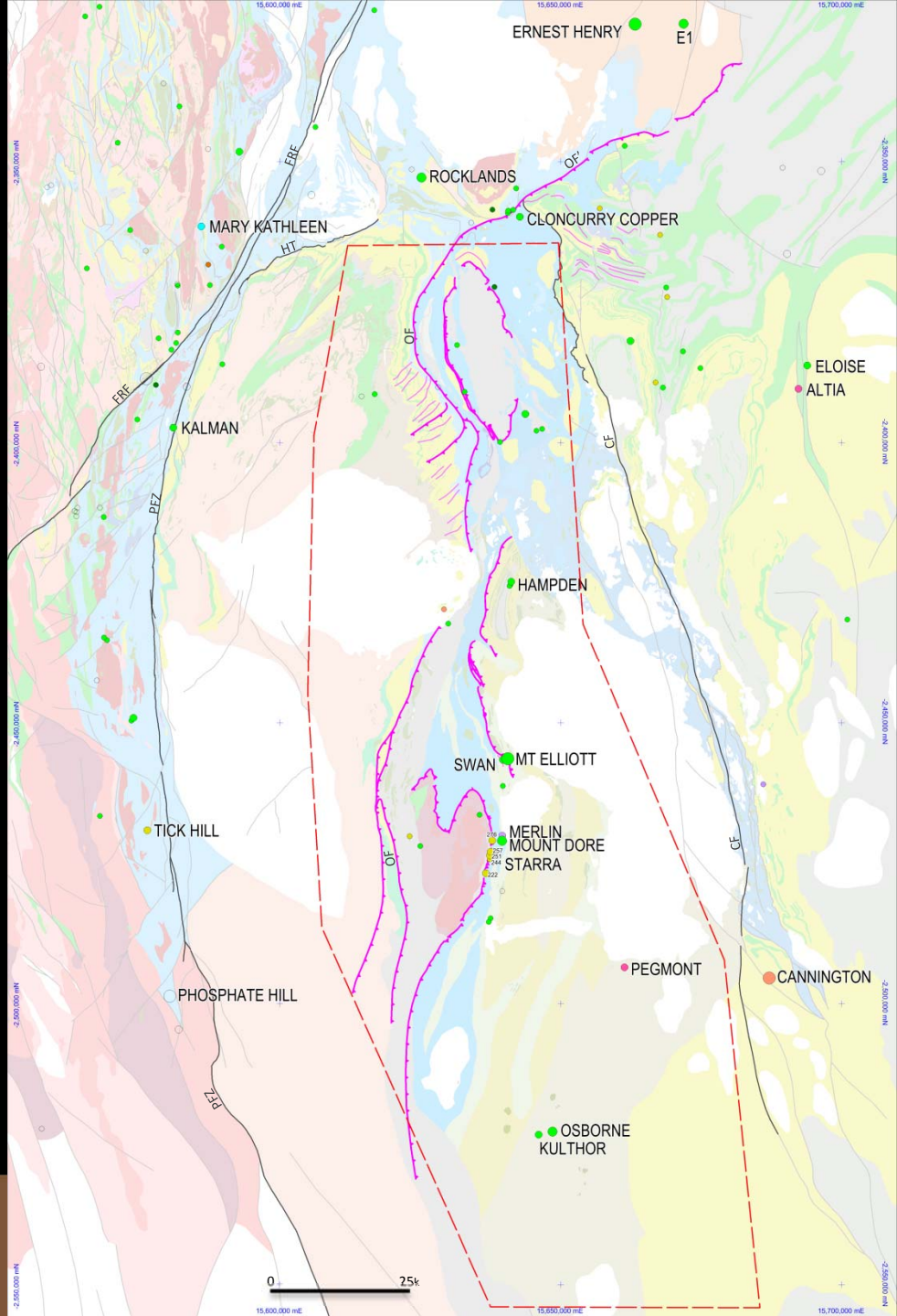
~1590-1575Ma

Isan D1 Folding & Thrusting

THIN-SKINNED





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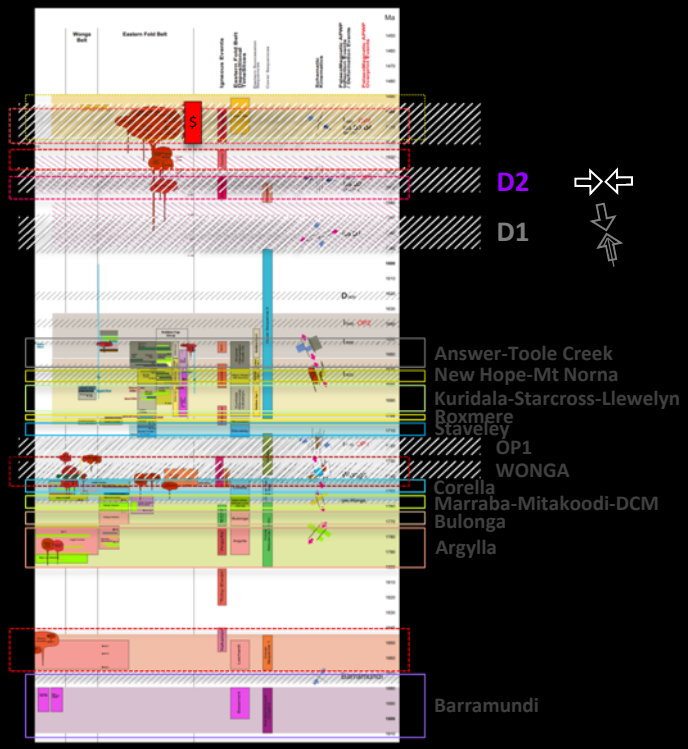
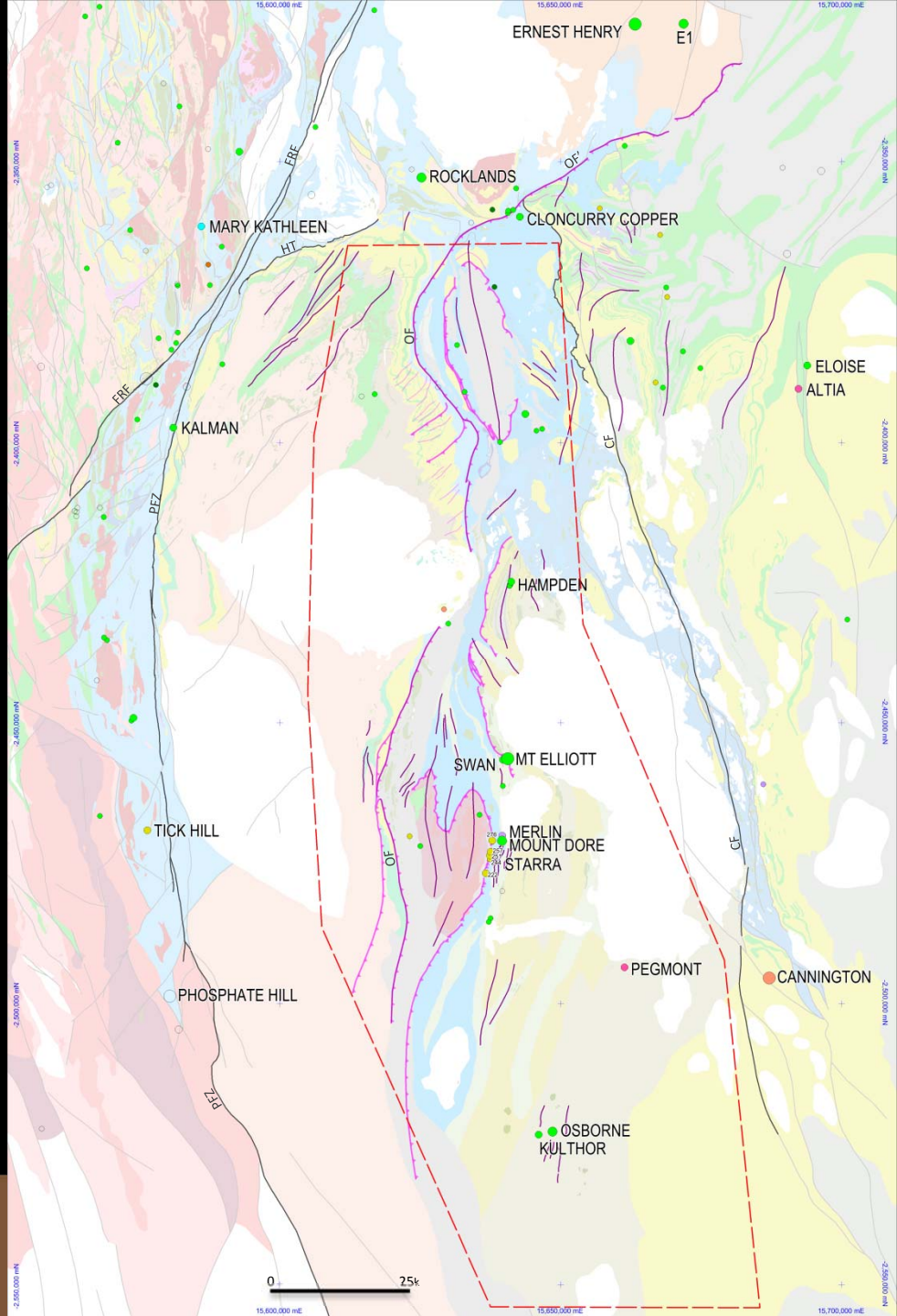
~1555-1535Ma

Isan D2 Folding

THICK-SKINNED





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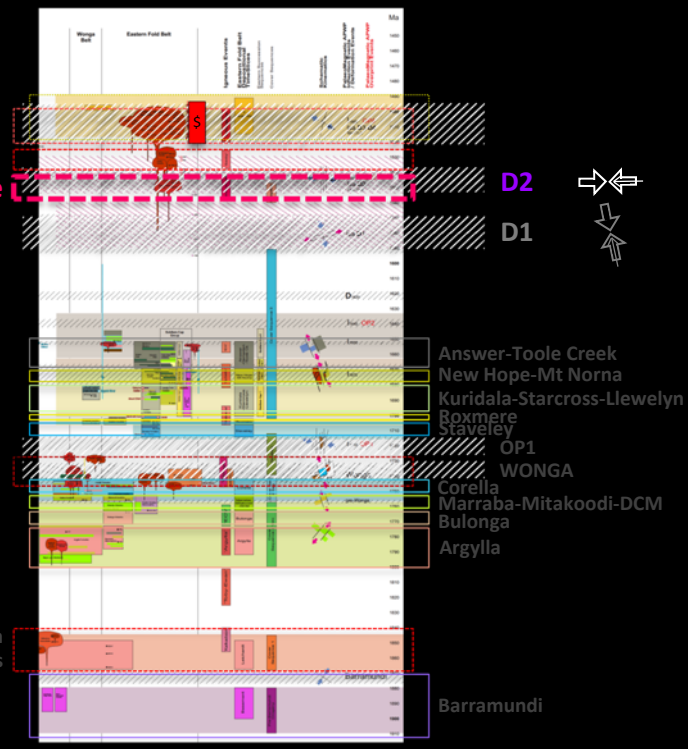
~1555-1535Ma

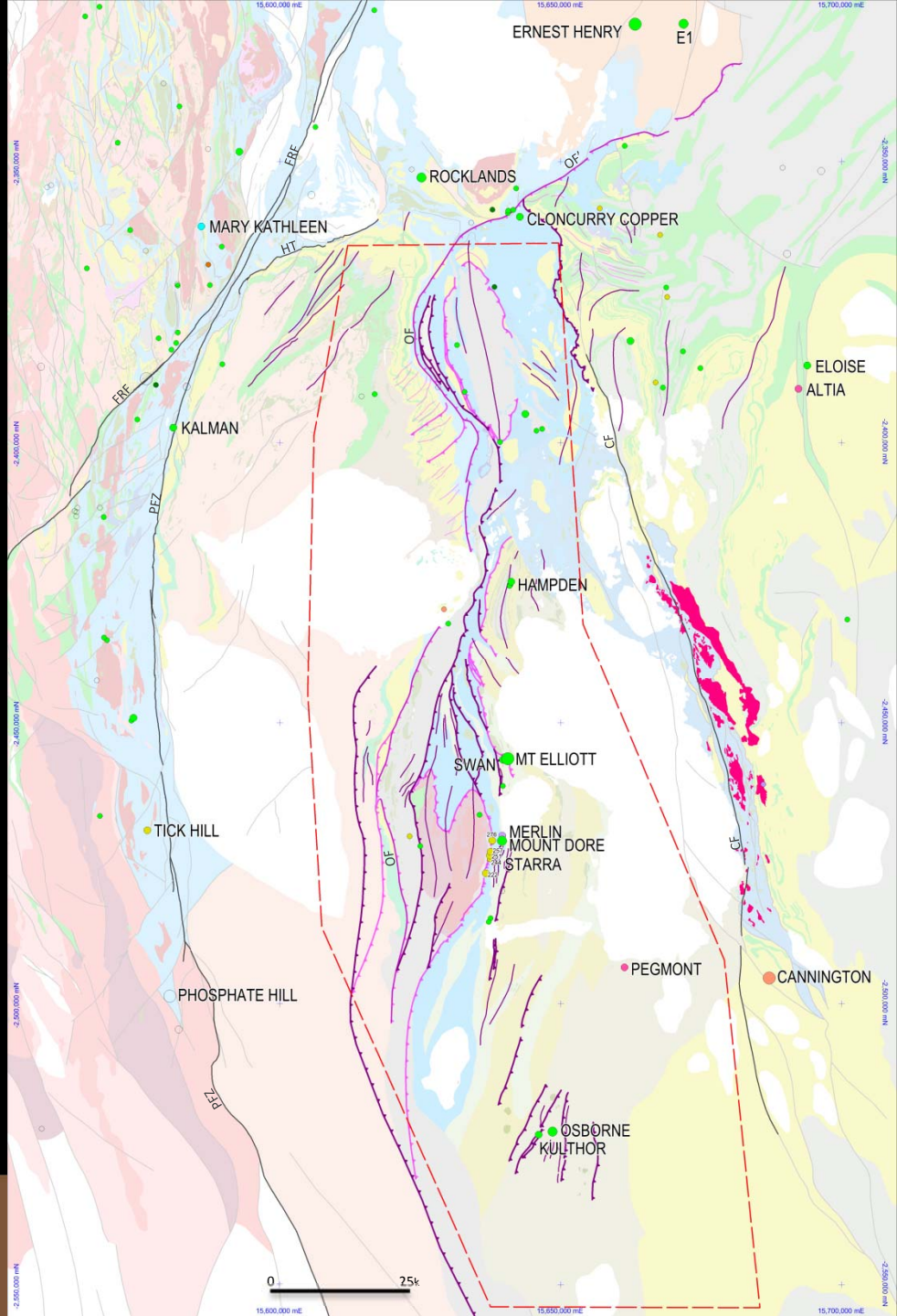
Isan D2 Faulting

THICK-SKINNED

~1545Ma

Maramungee





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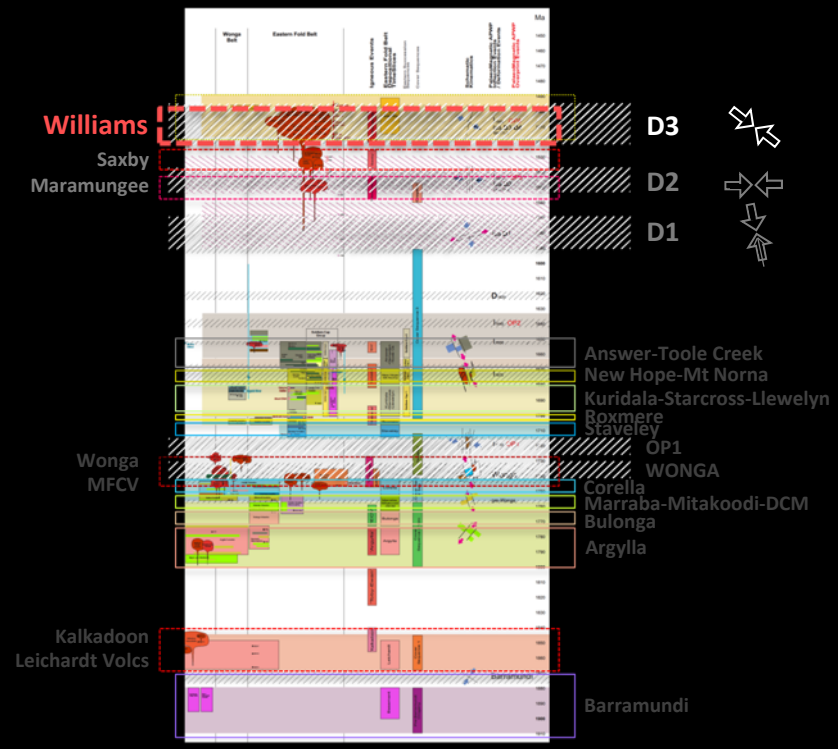
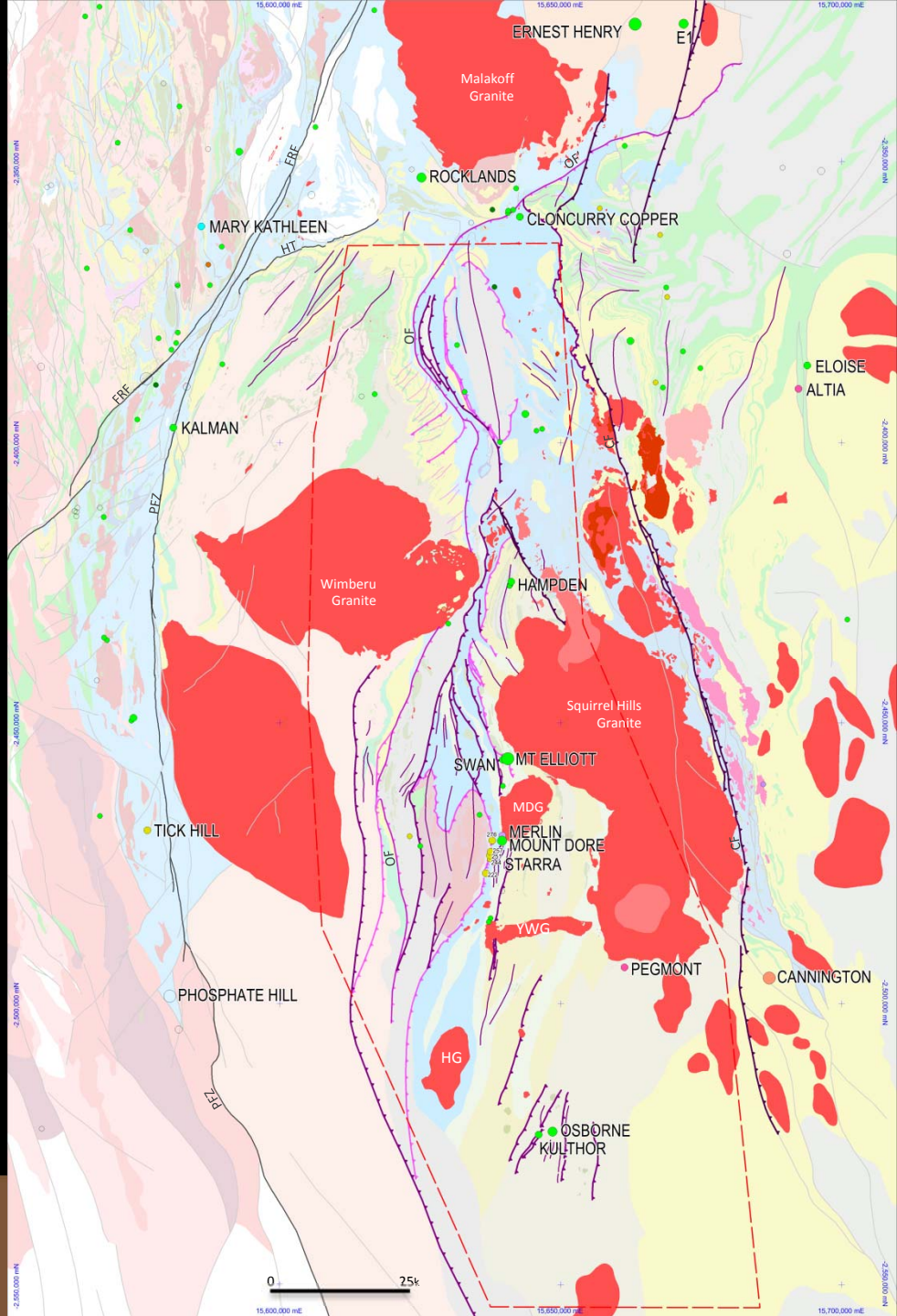
~1515-1500Ma

Williams Suite

~1515-1500Ma

D3 shortening





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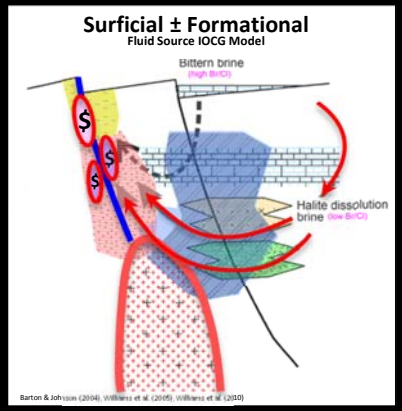


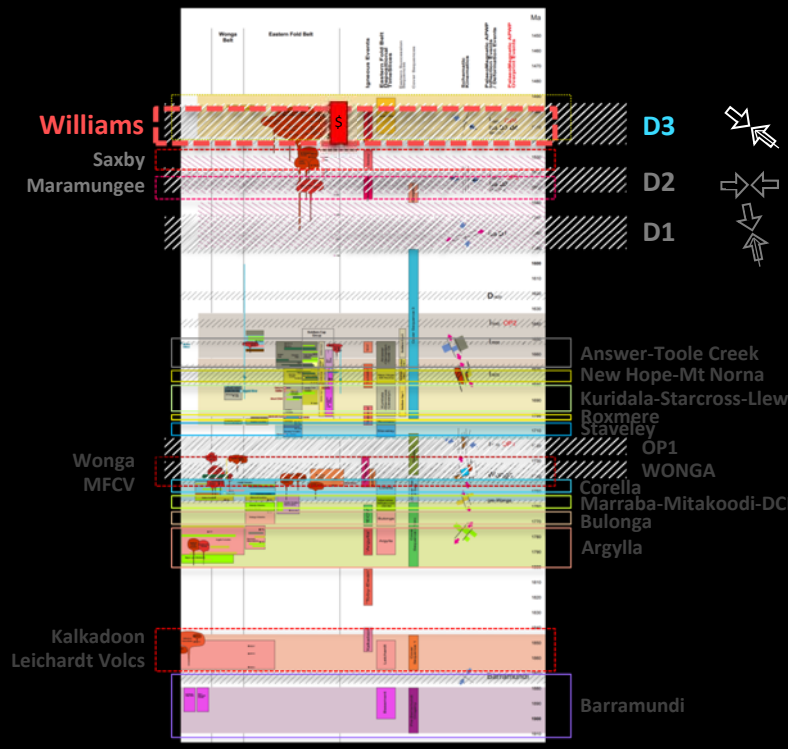
~1515-1500Ma

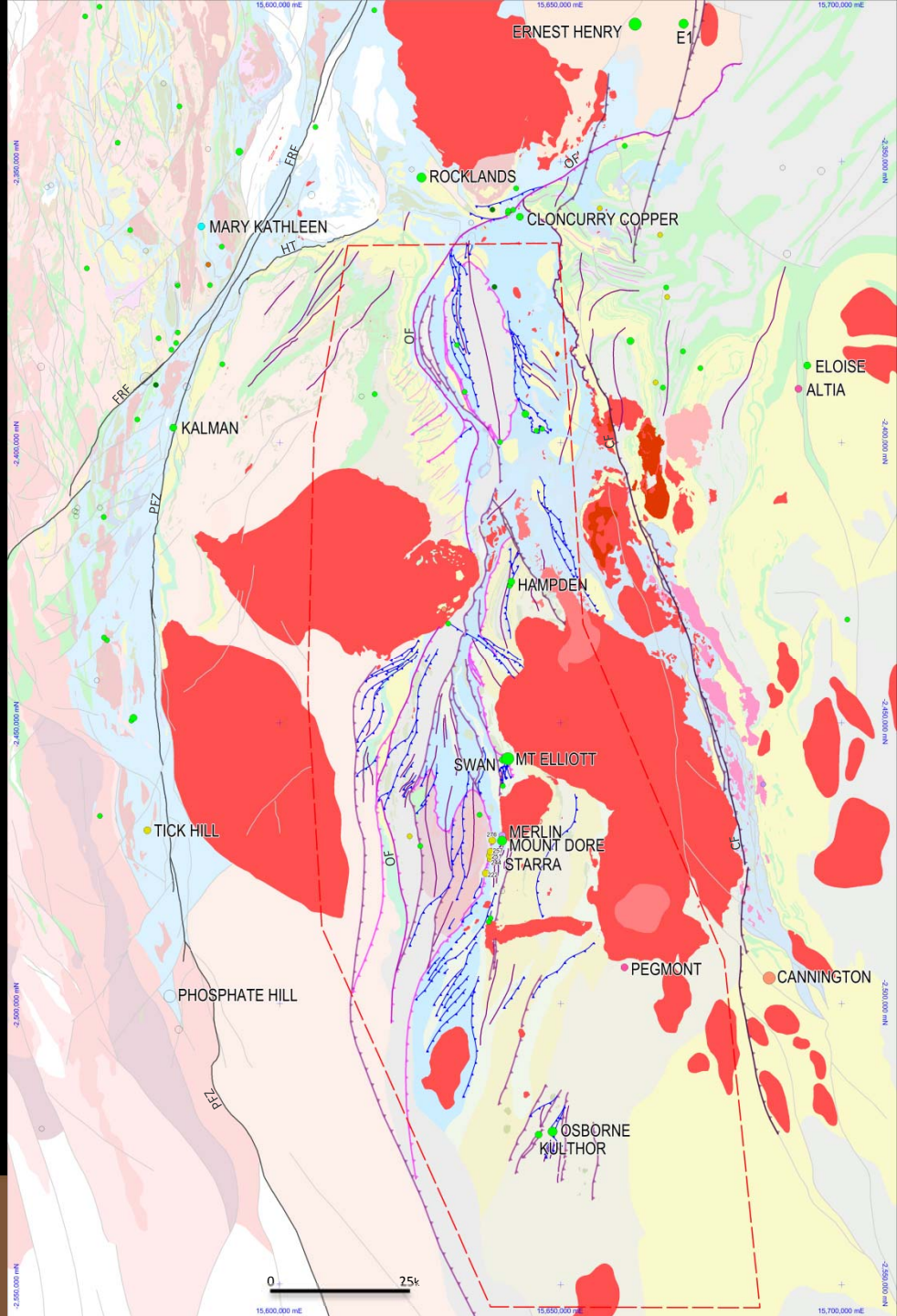
Williams Suite

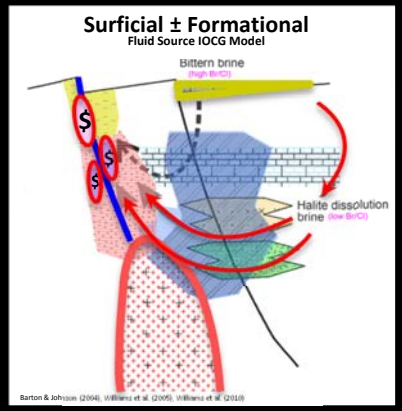
~1515-1500Ma

early D3 Faulting

Cu-Au, Au-Cu, Mo-Cu







~1515-1500Ma

Williams Suite

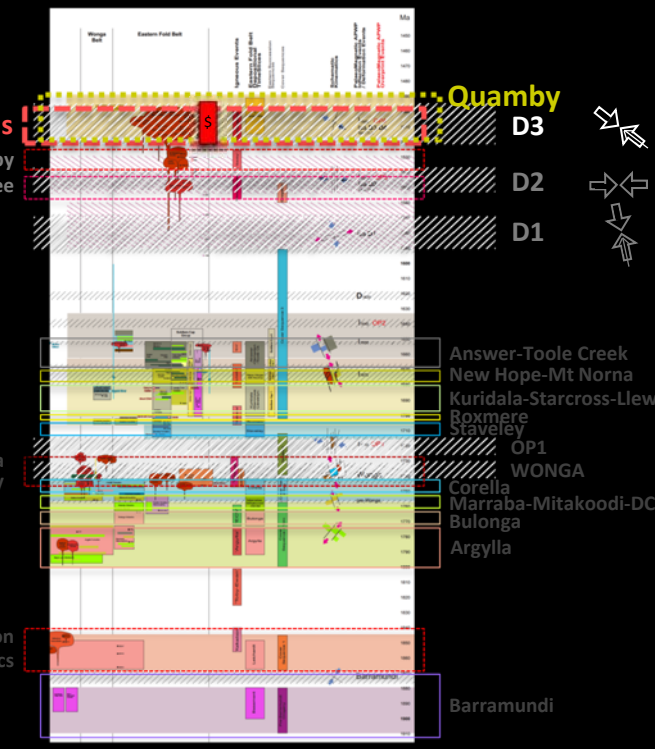
~1515-1500Ma

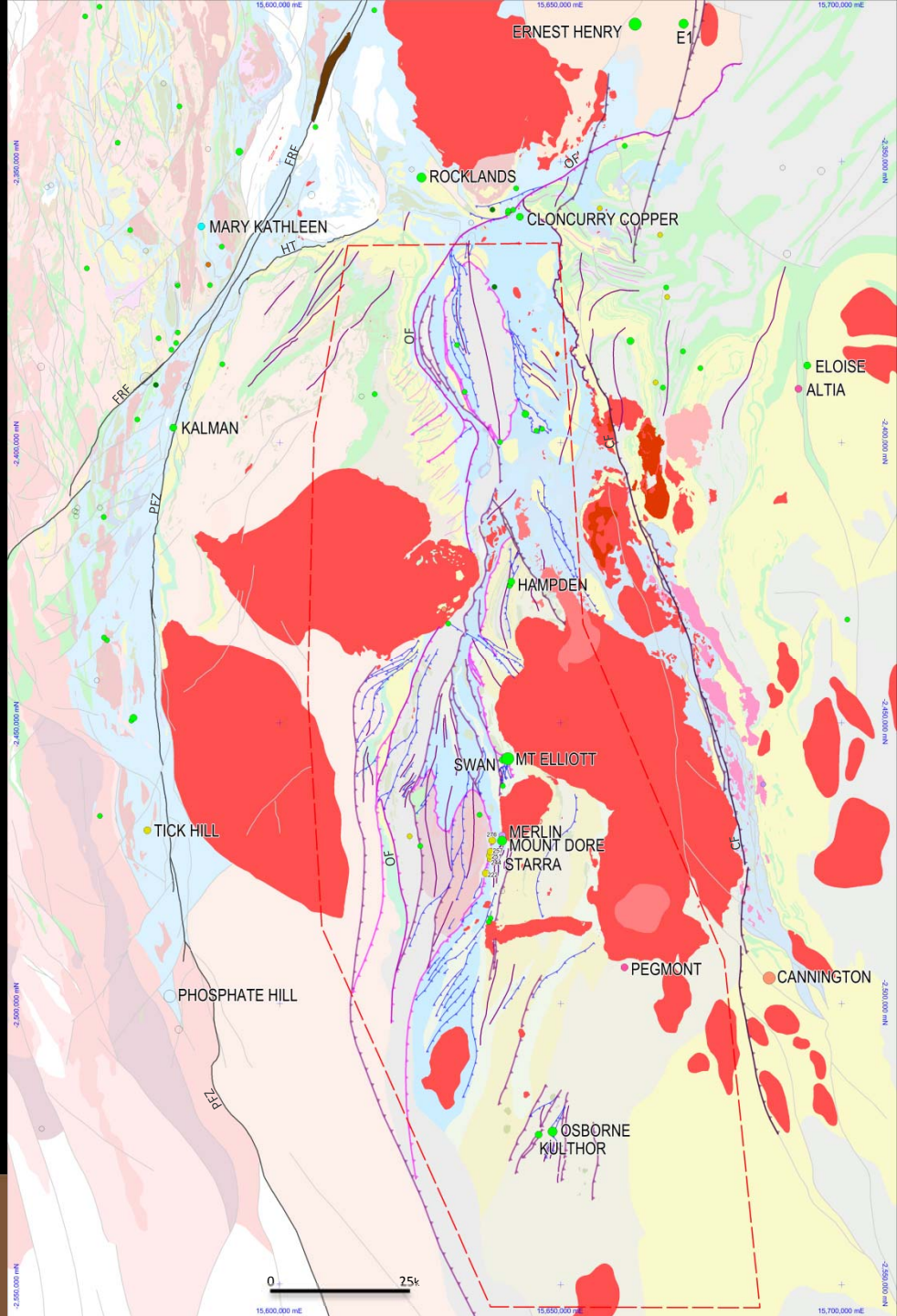
early D3 Faulting

???? Ma

Quamby

Cu-Au, Au-Cu, Mo-Cu





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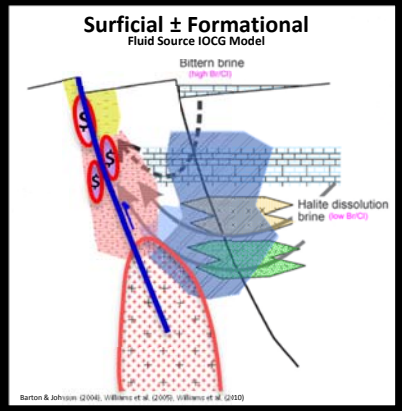
FRF = Fountain Range Fault
PFZ = Pilgrim Fault Zone
HT = Highway Thrust
OF = Overhang Fault
CF = Cloncurry Fault



~1515-1500Ma

Williams Suite

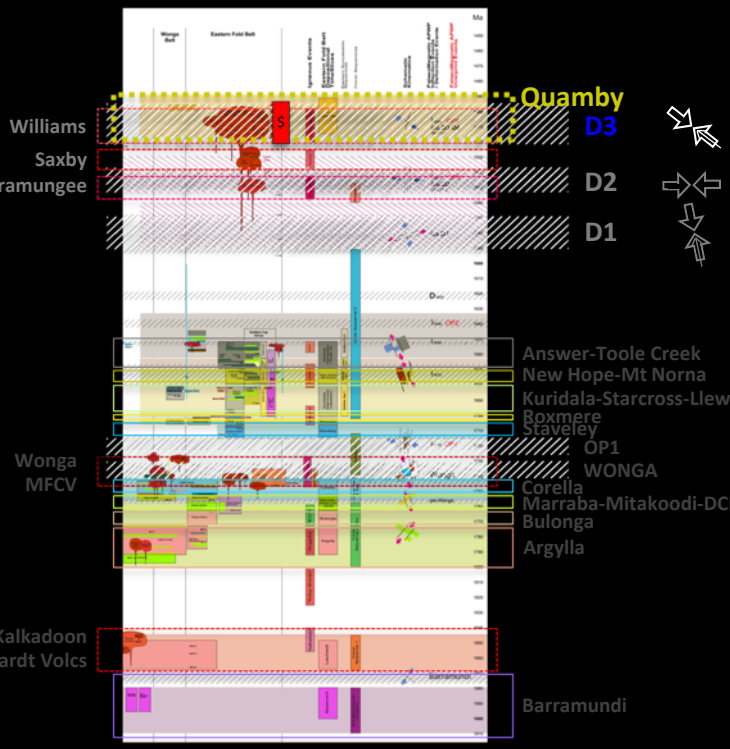
~1505-1490Ma

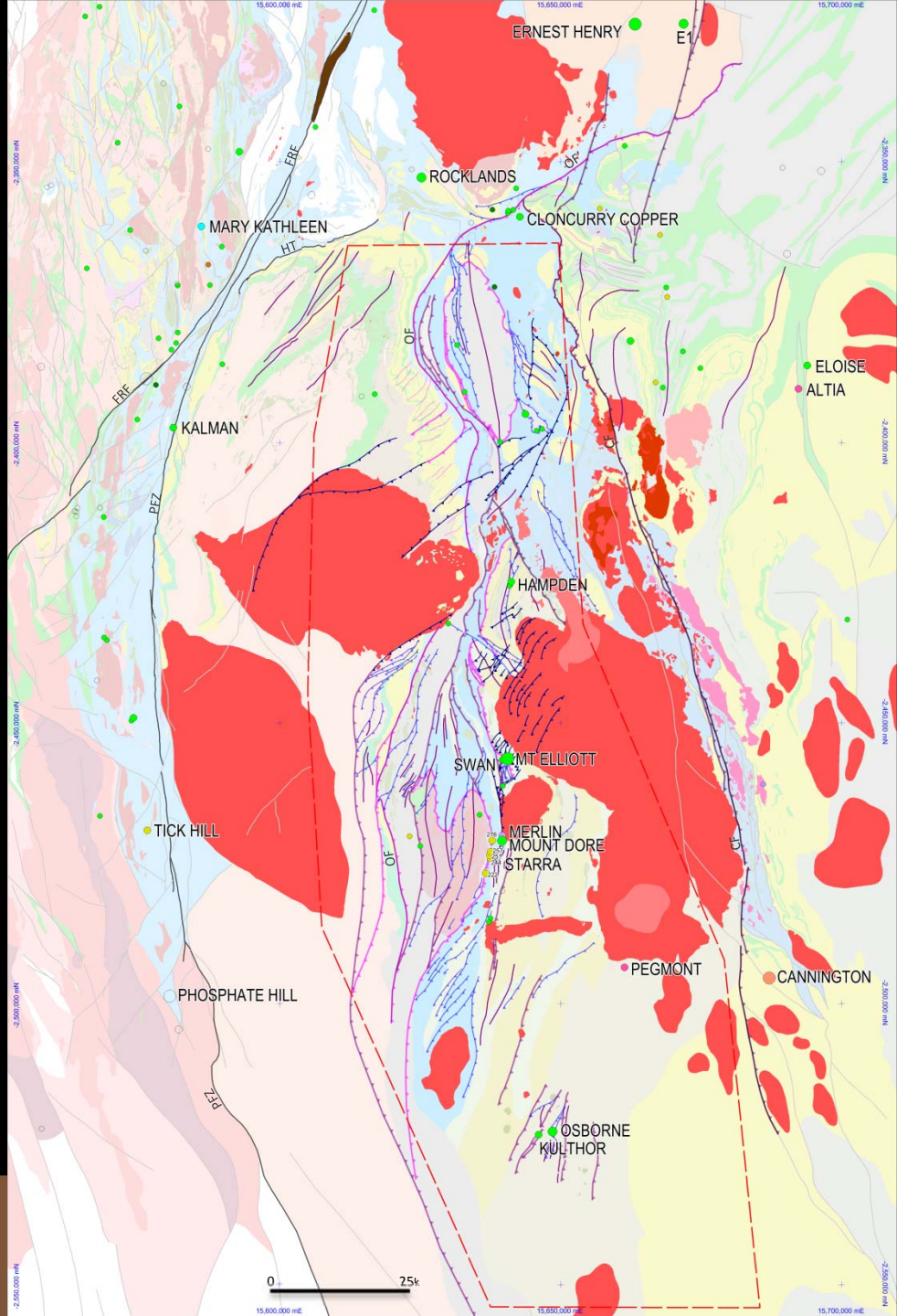
late D3 Faulting

???? Ma

Quamby

Cu-Au, Au-Cu, Mo-Cu





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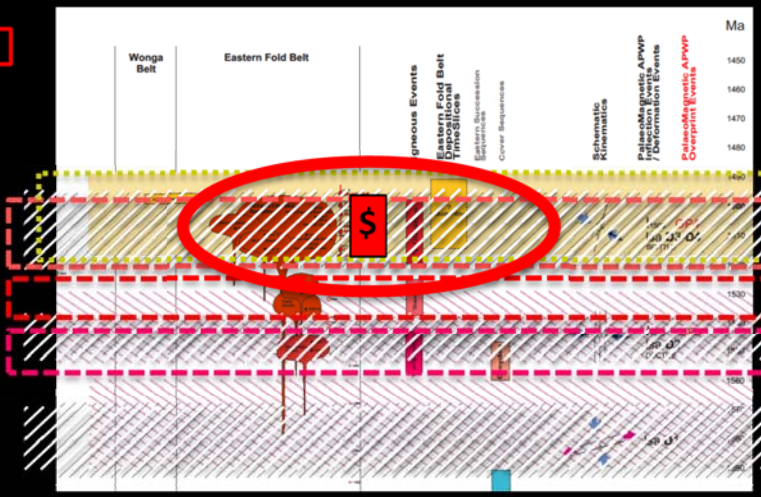
Magmatism

Depositional Timeslices

Deformation



~1515-1500Ma **Williams**

~1530Ma **Saxby**

~1545Ma **Maramungee**

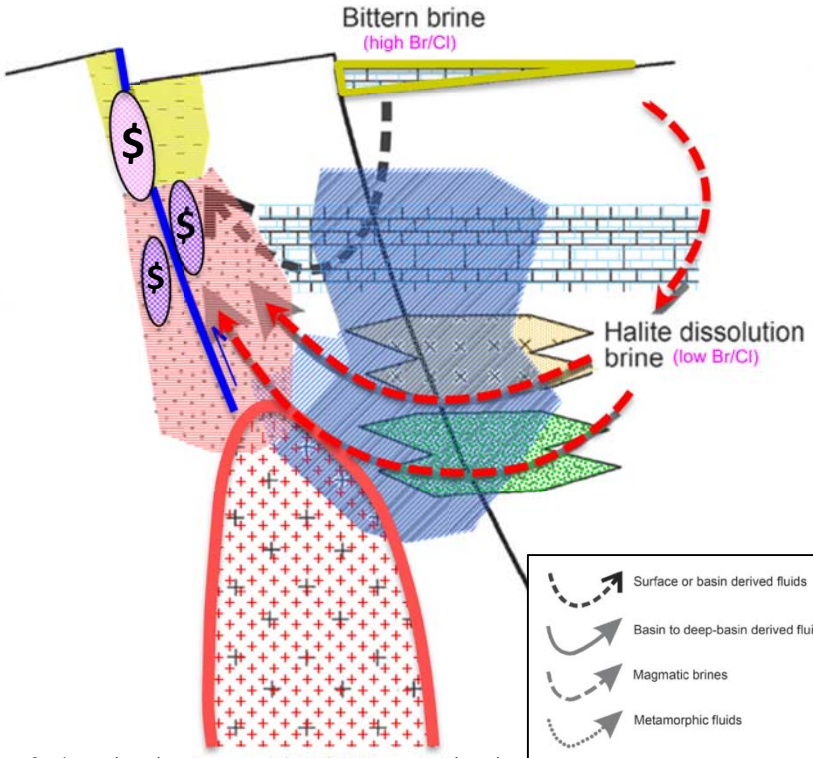
?? Ma **Quamby**

~1520-1490Ma **Isan D3**
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 - BRITTLE, shallow crustal deformation

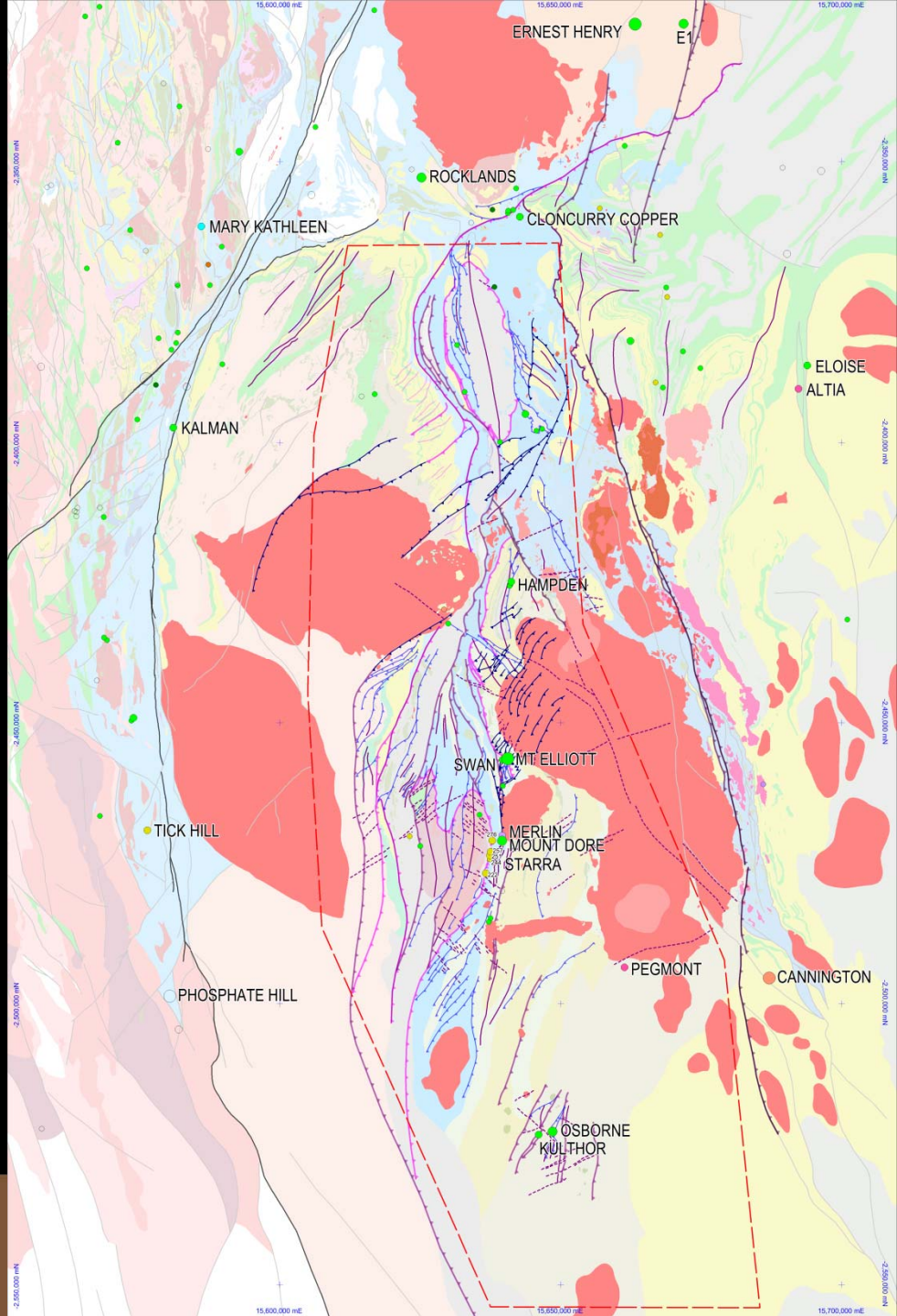
Quamby Basin - continental, oxidised, evaporitic?

>> IOCG Mineralisation

<1500Ma

post Isan Faulting

widespread



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<1500Ma
post Isan Faulting
widespread & appears to reflect ….

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

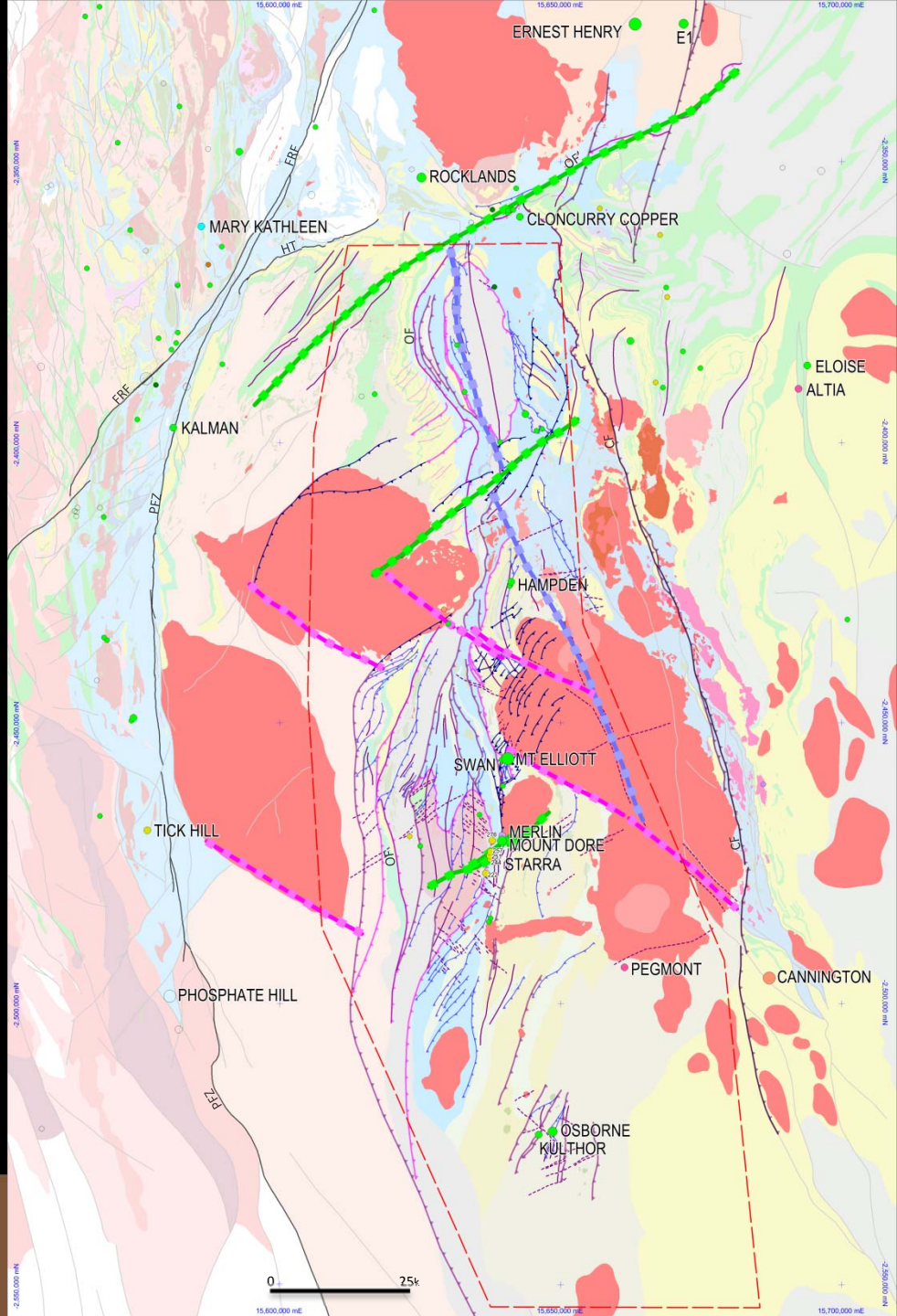
NE architecture
Wonga-reactn>MFCV margin
Mitakoodi culmination D2 folding
D1 & D2 deformation partitioning
post-Williams reactn

NW architecture
Williams margins
D2 deformation partitioning
post-Williams reactn

older NNW architecture
post-Williams reactn

>>> speculated to reflect CoverSeq1 & 2,
and **pre-Barramundi** (?Archaean)
depositional architectures

>>> significant influence on IOCG mineral system geometry and ultimate sites of metal accumulation in D3



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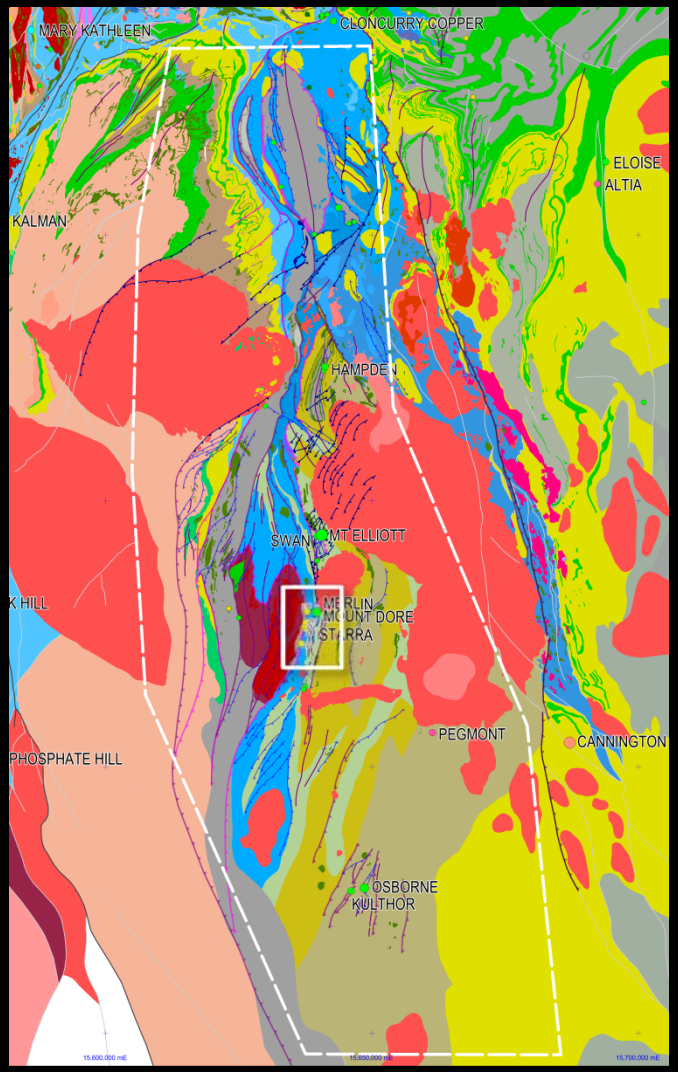
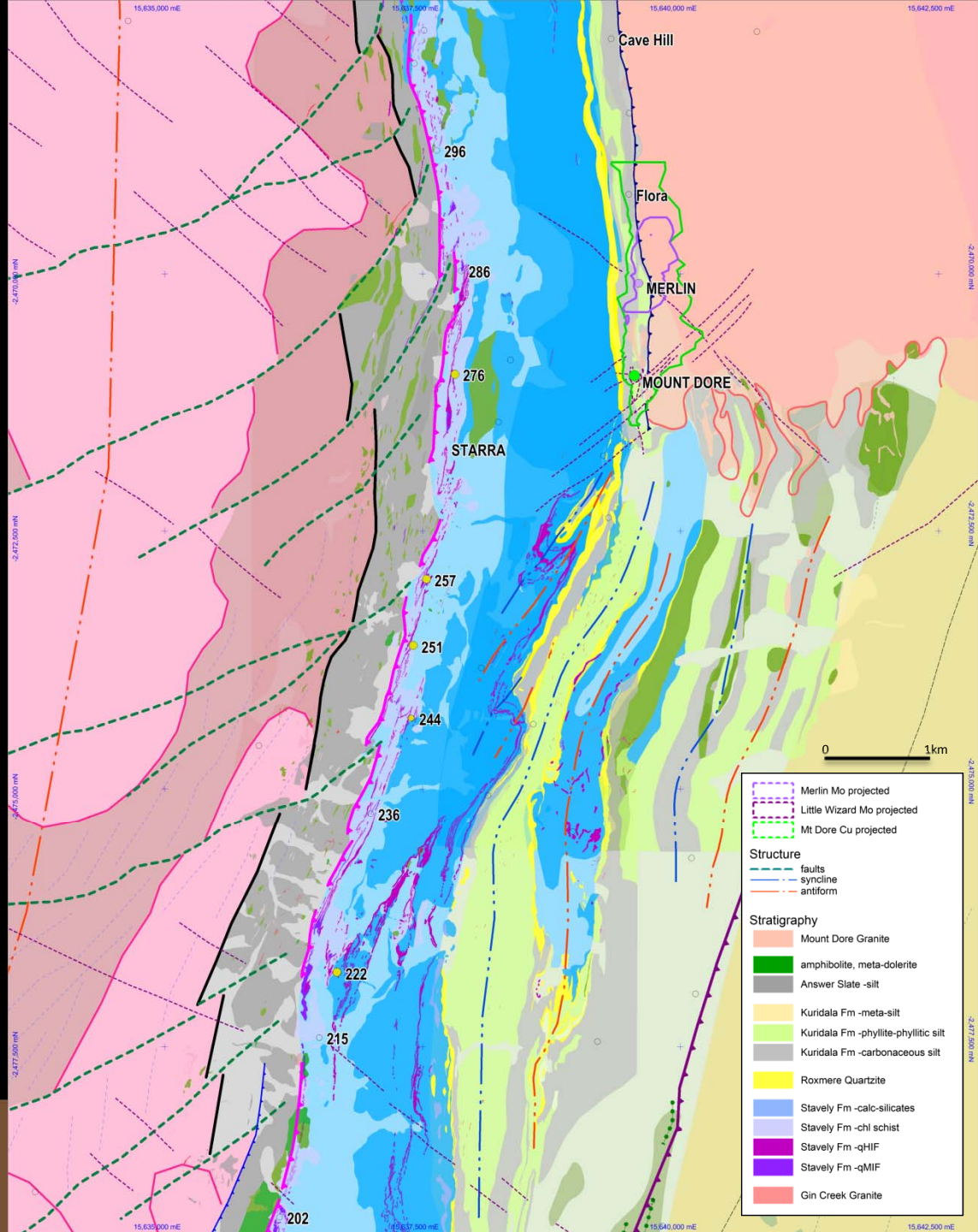
Starra-Merlin-Mount Dore





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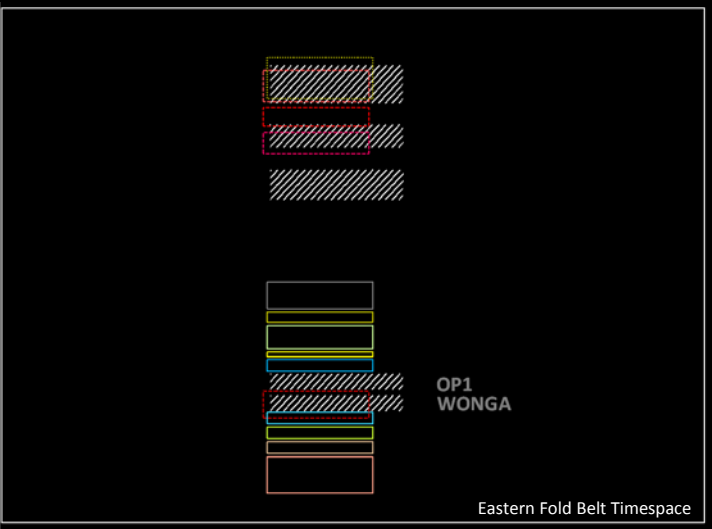
Starra-Merlin-Mount Dore

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



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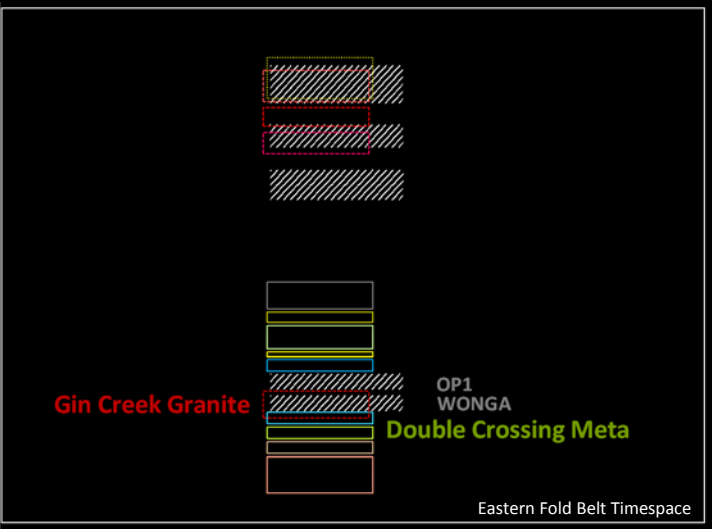

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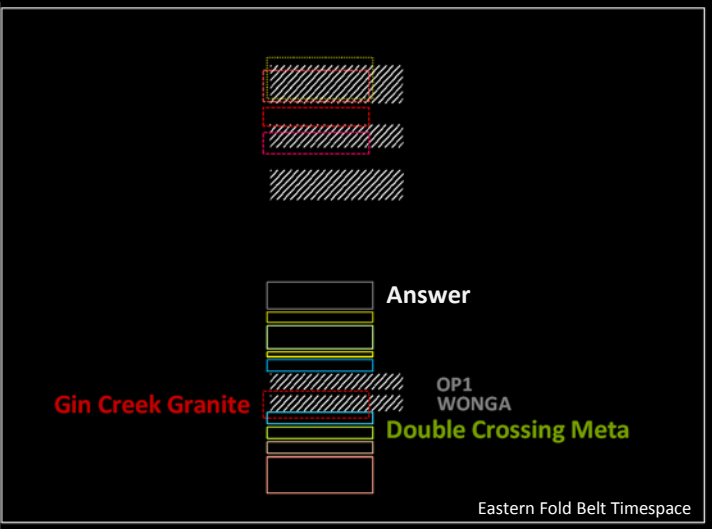

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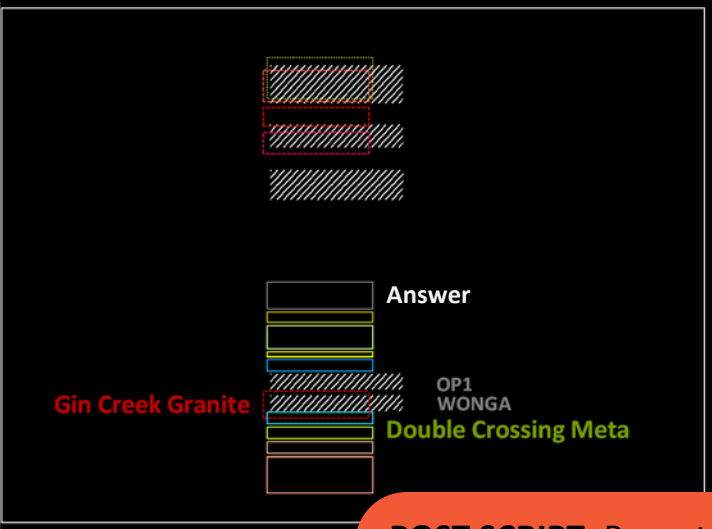

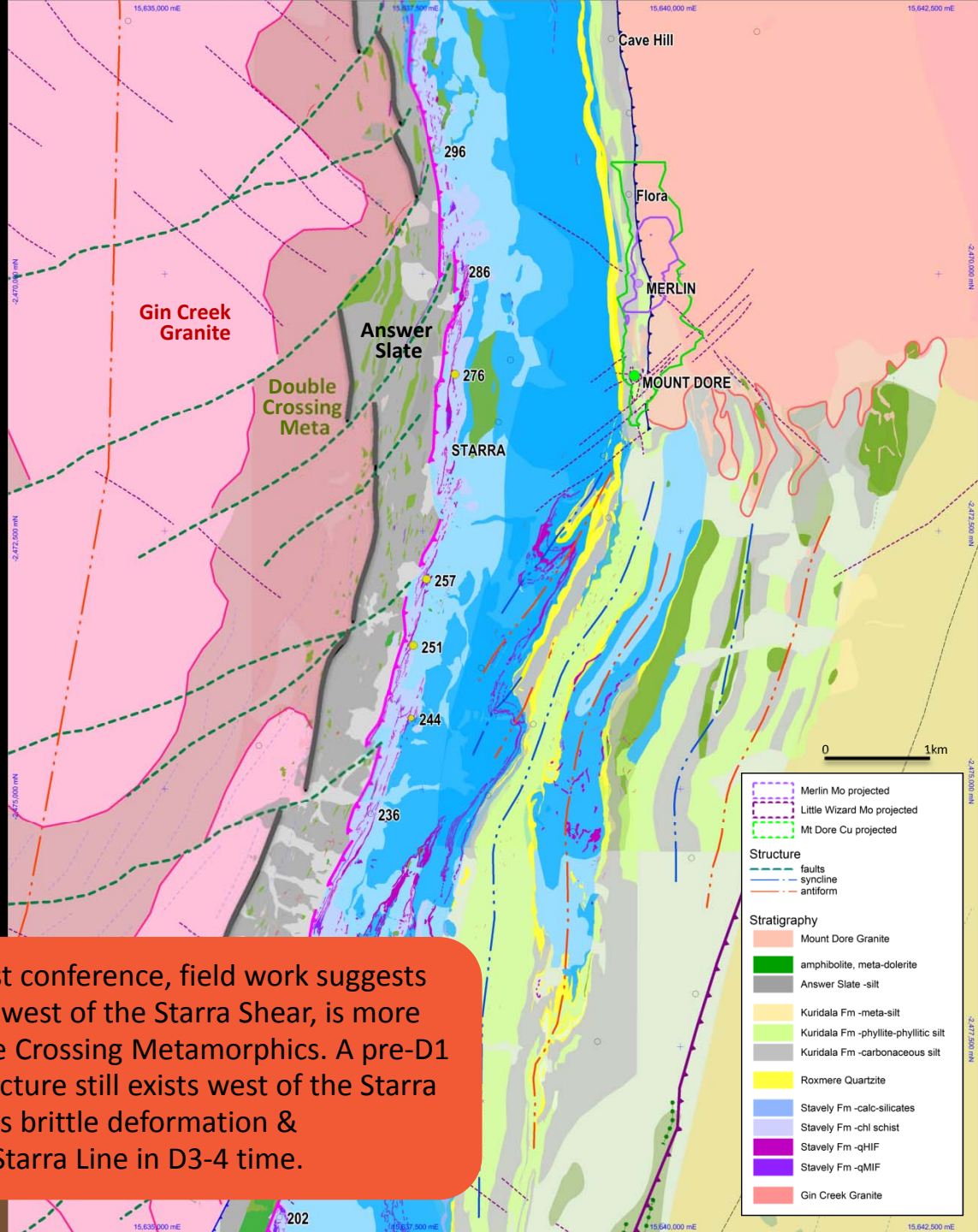

POST SCRIPT: Recent, post conference, field work suggests Leishman's Answer Slate, west of the Starra Shear, is more likely lower-grade, Double Crossing Metamorphics. A pre-D1 Starra Shear block architecture still exists west of the Starra Line and likely still impacts brittle deformation & mineralisation along the Starra Line in D3-4 time.

Starra-Merlin-Mount Dore

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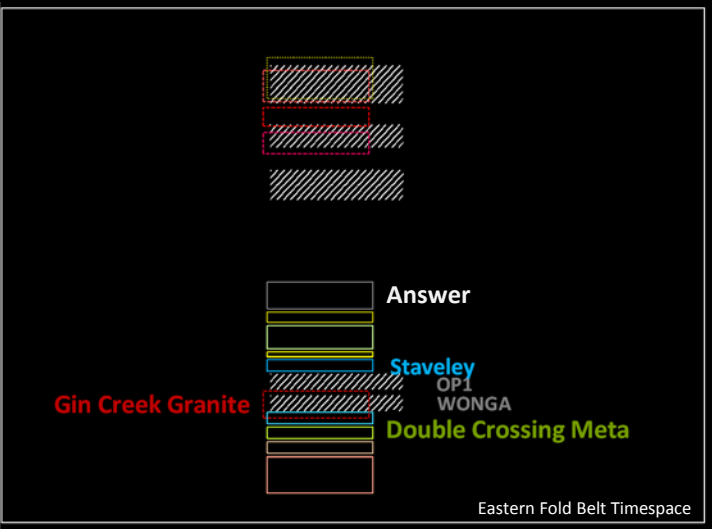

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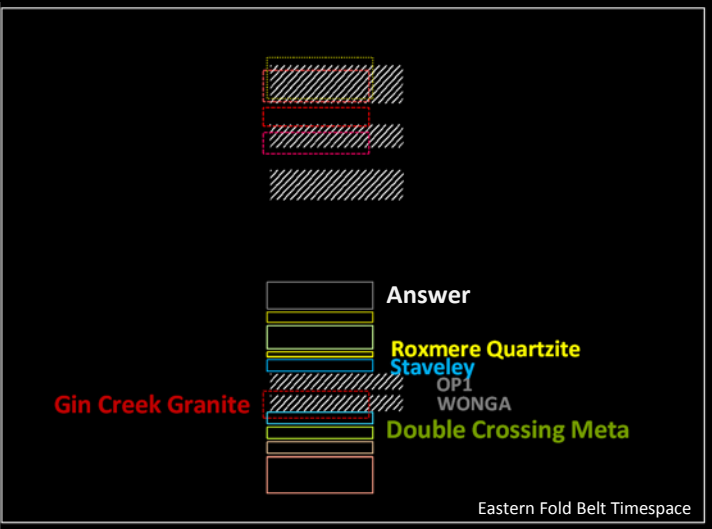

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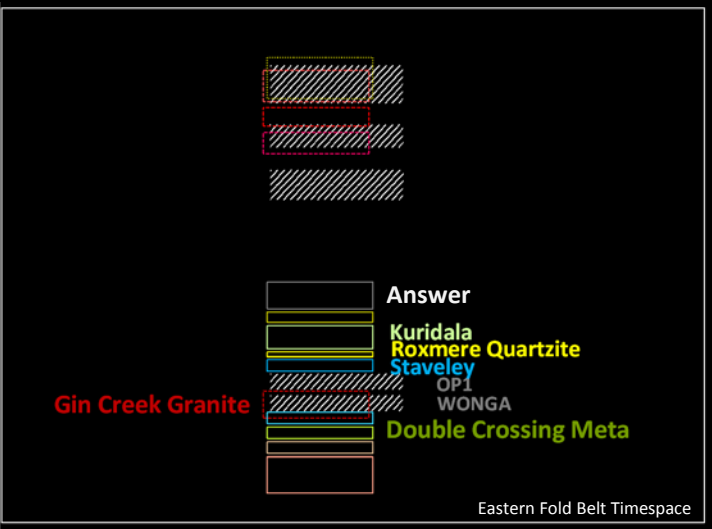

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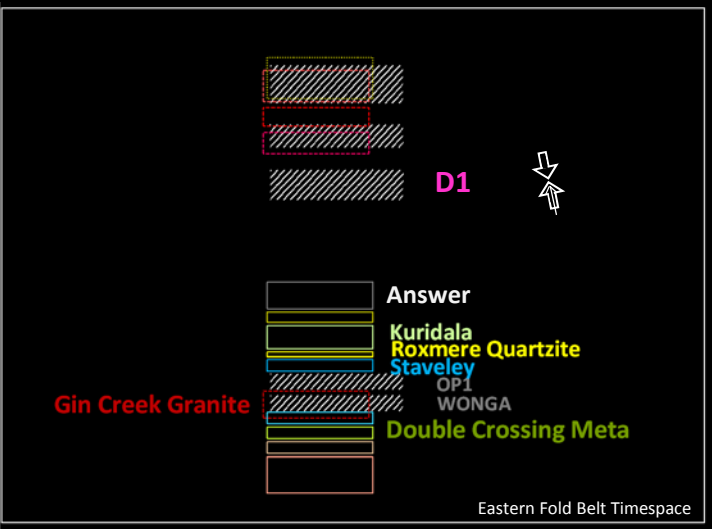

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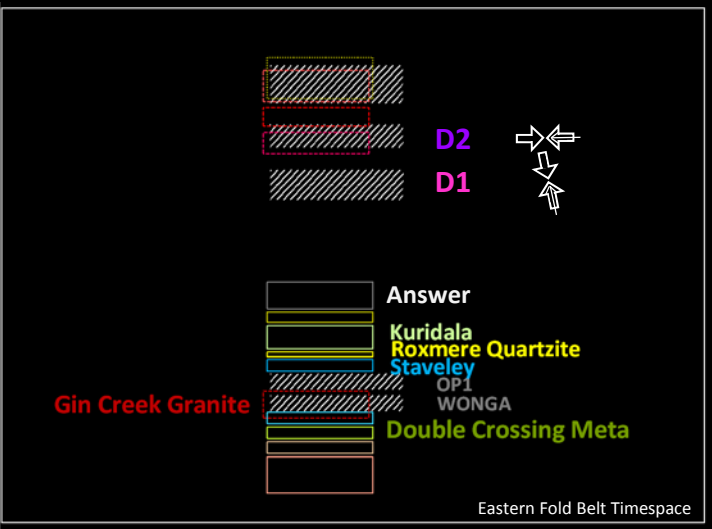

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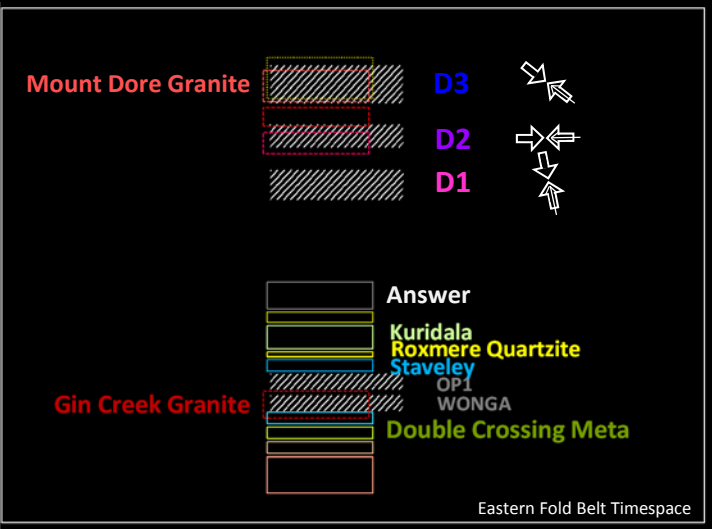
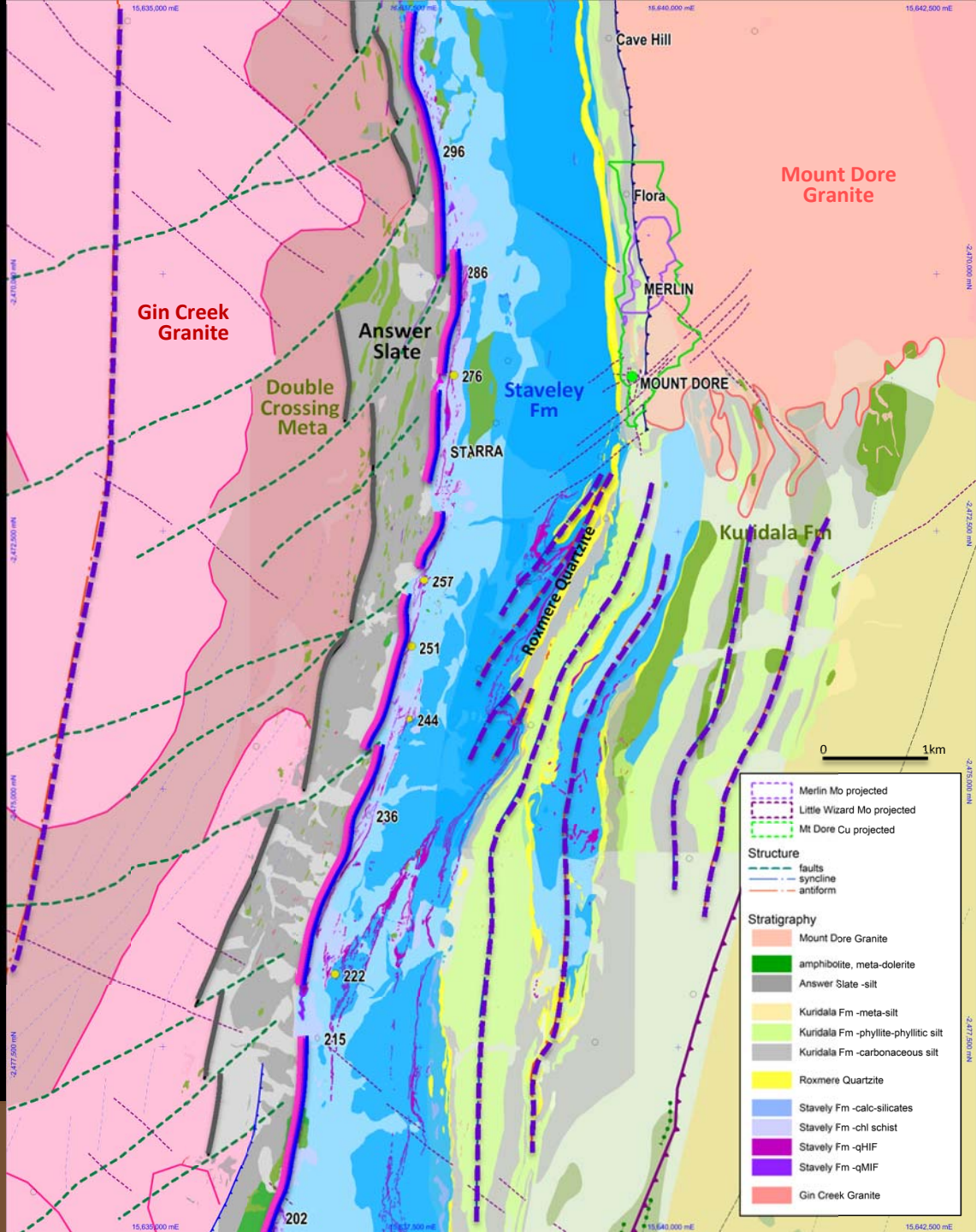
  > at Starra, footwall architecture contribution to fract-bx
  > at Merlin-Mt Dore, strain intensification





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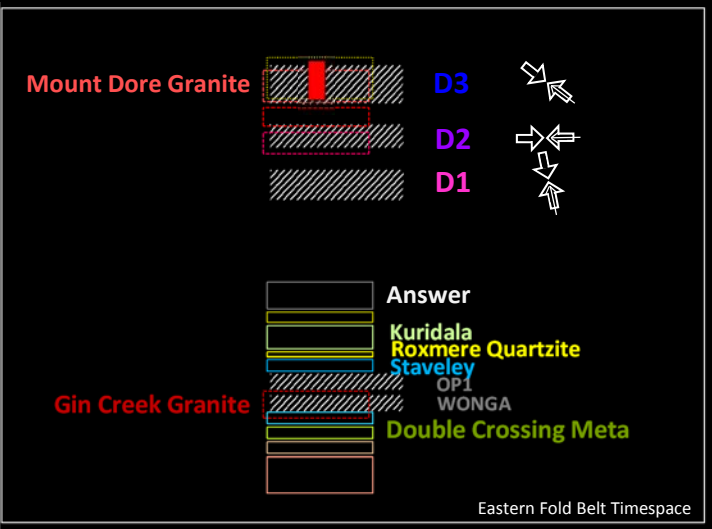

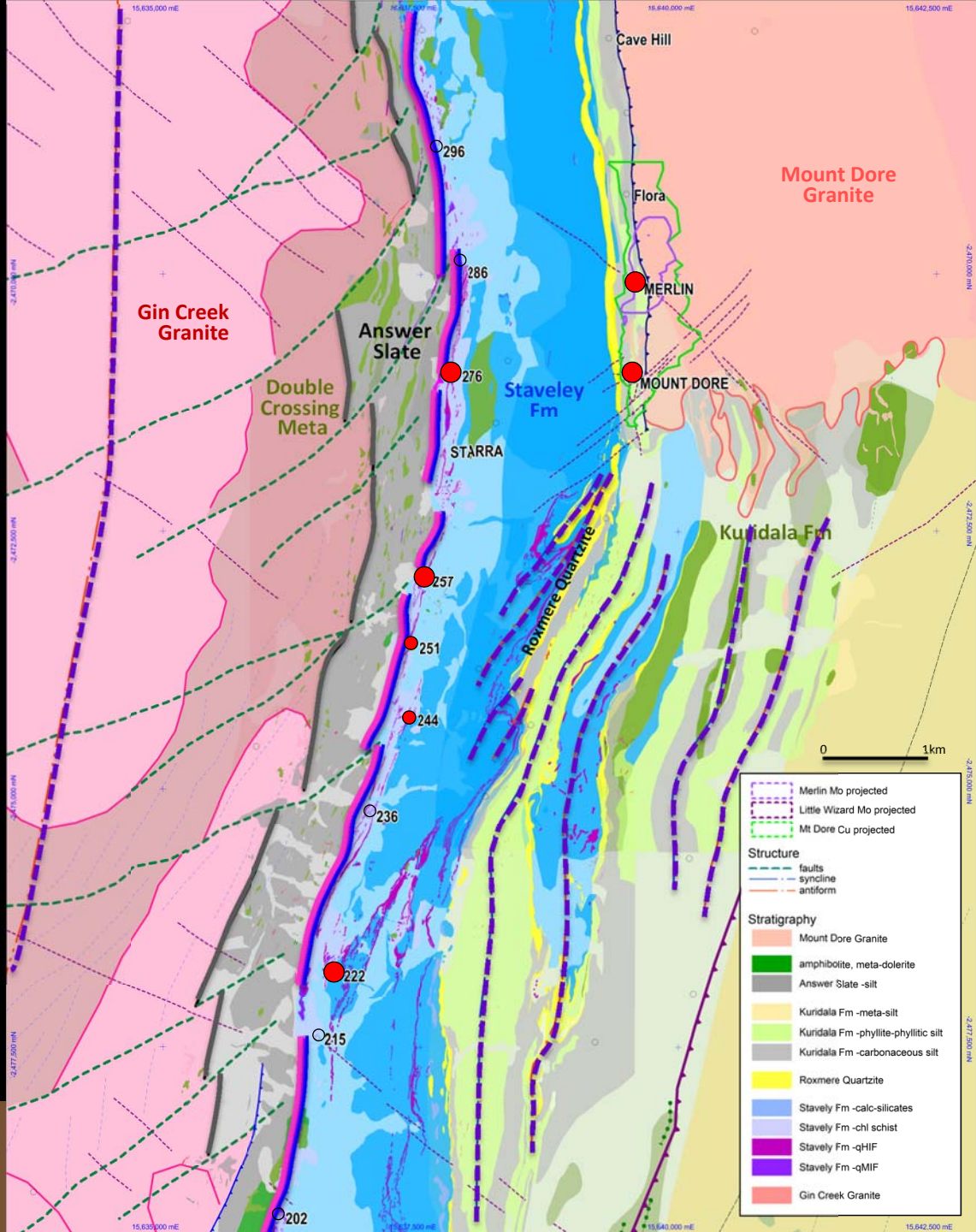

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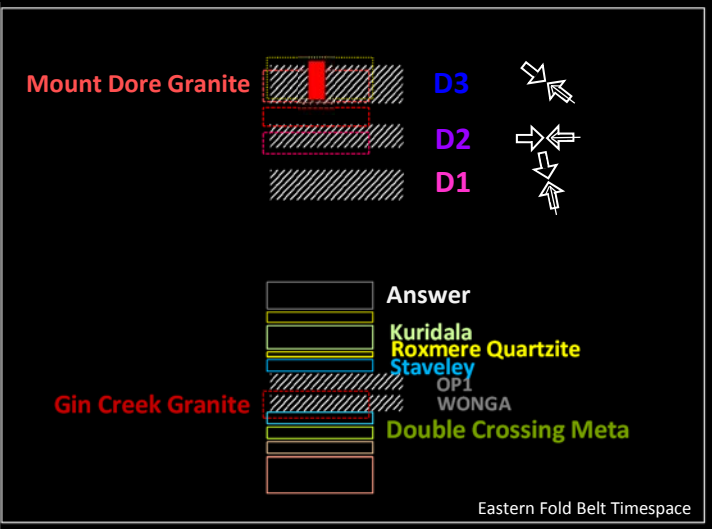
- **post-mineral reverse faulting of MDG over M-MD**



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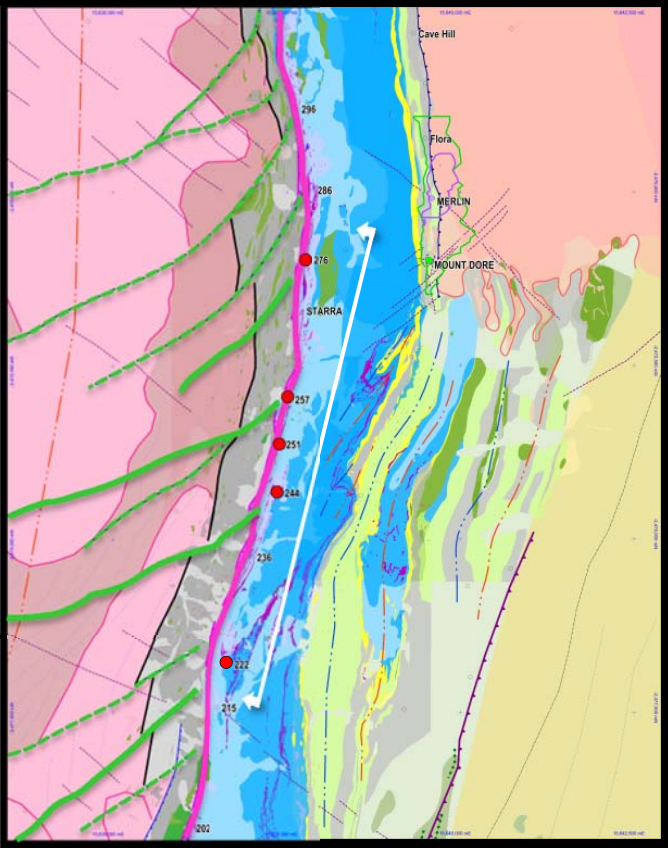
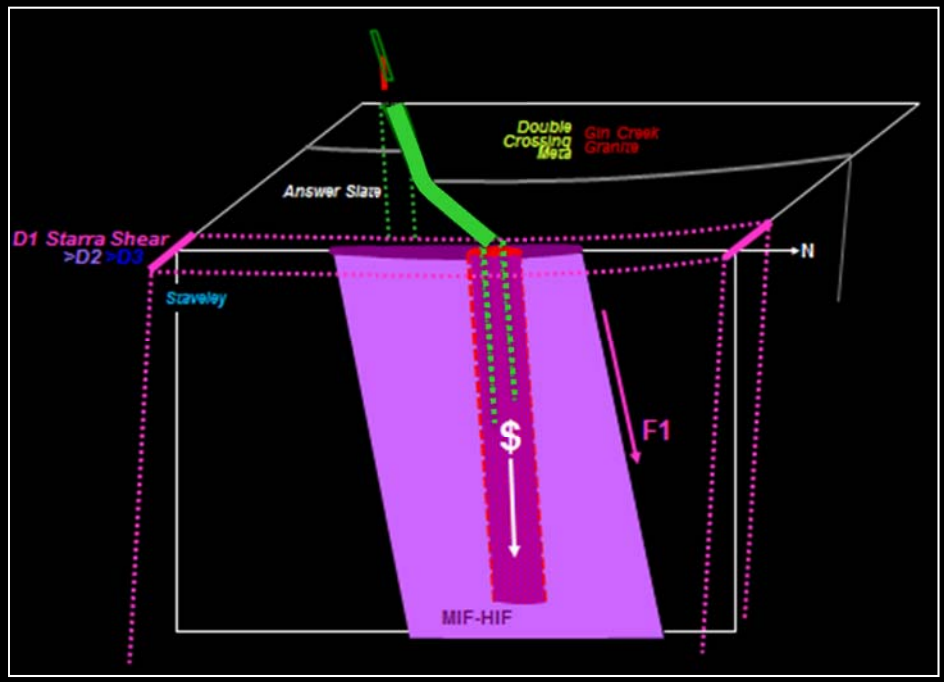
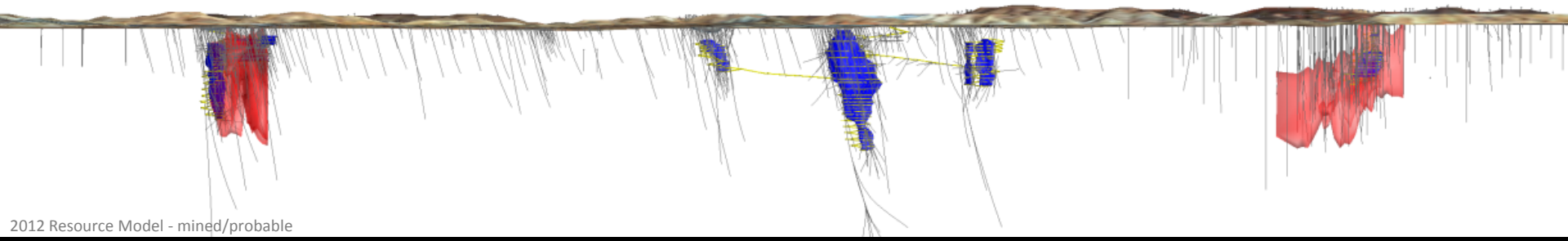
Starra Line - Long Section



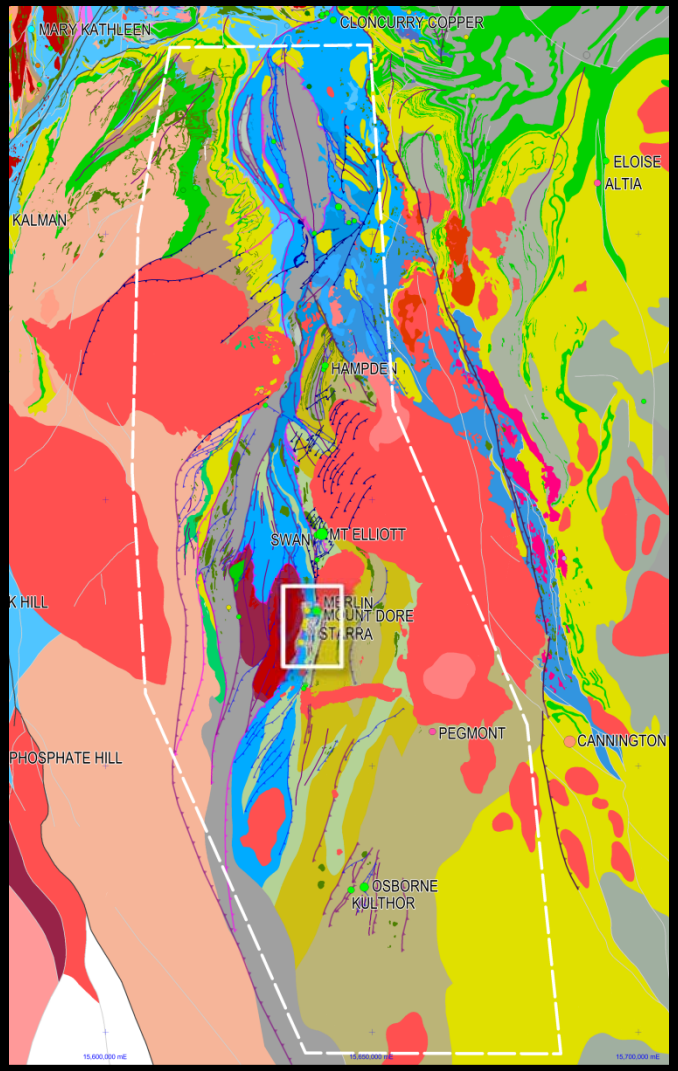


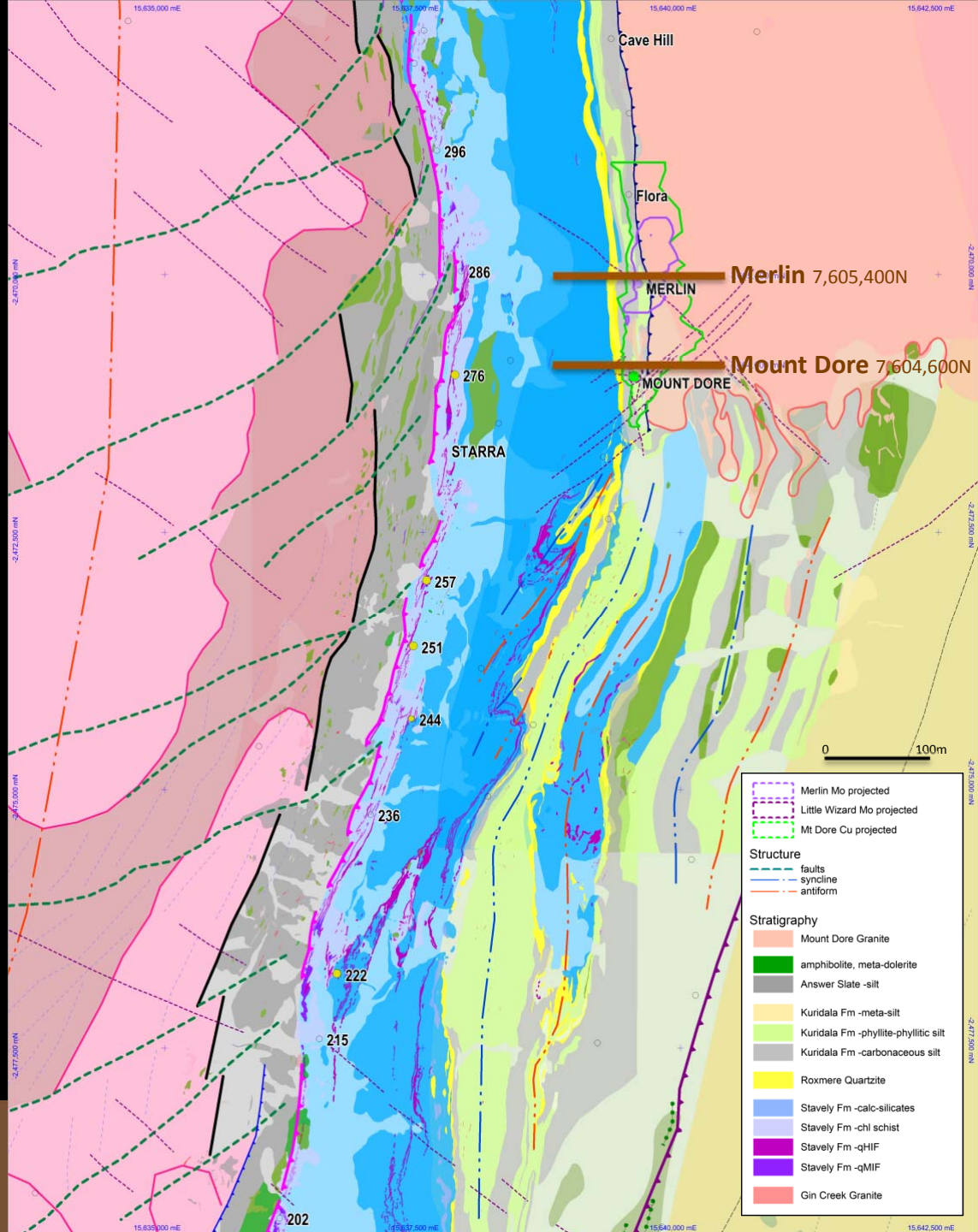
S 222 236 244 251 257 276 N



2012 Resource Model - mined/probable

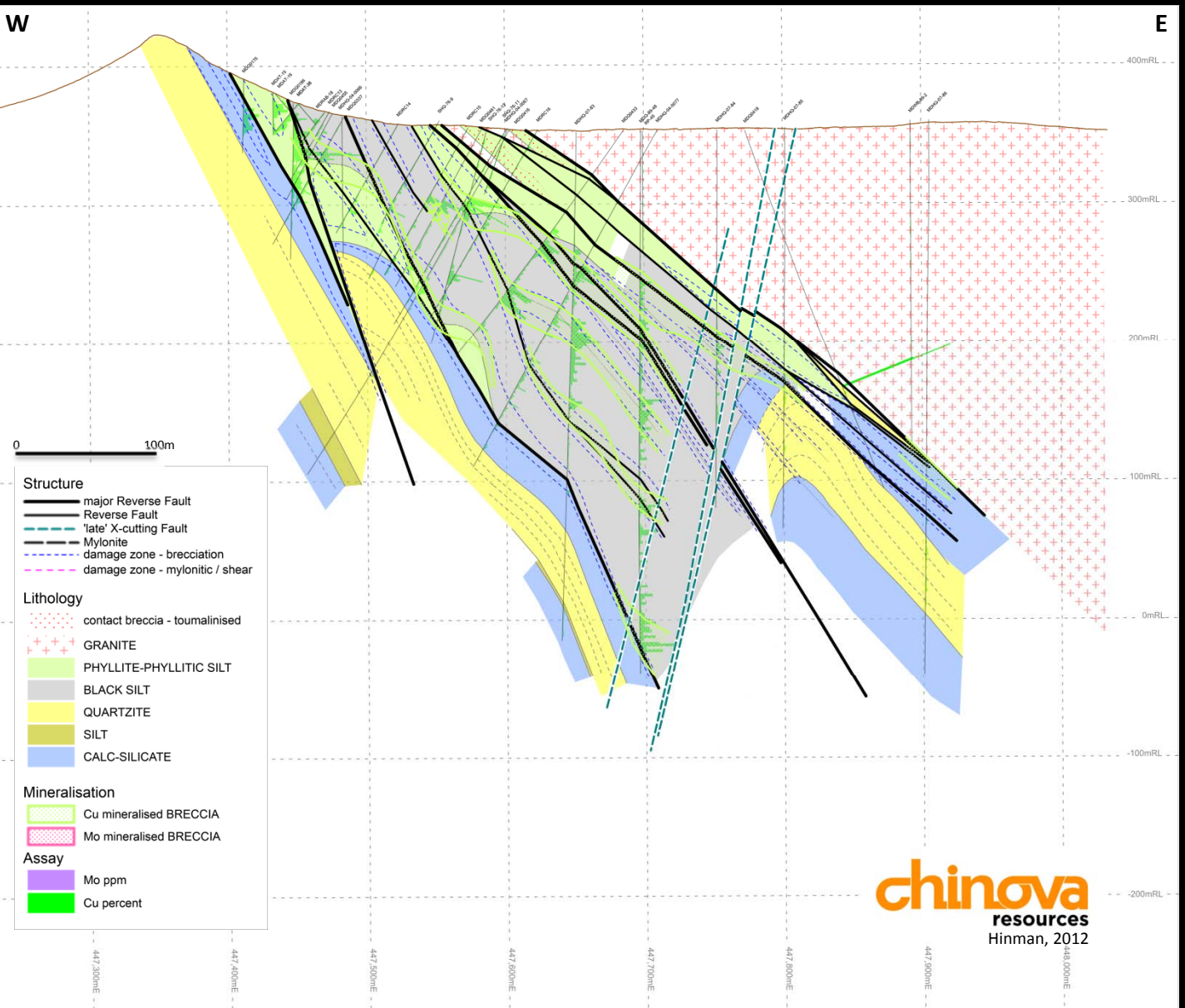
Mount Dore-Merlin





Mt Dore - Cross Section

7,604,600N



chinova resources

Hinman, 2012

Gradational stratigraphy:

Staveley-Roxmere-(SF)-Kuridala

Kuridala: carb silt dominant

Mt Dore - Cross Section

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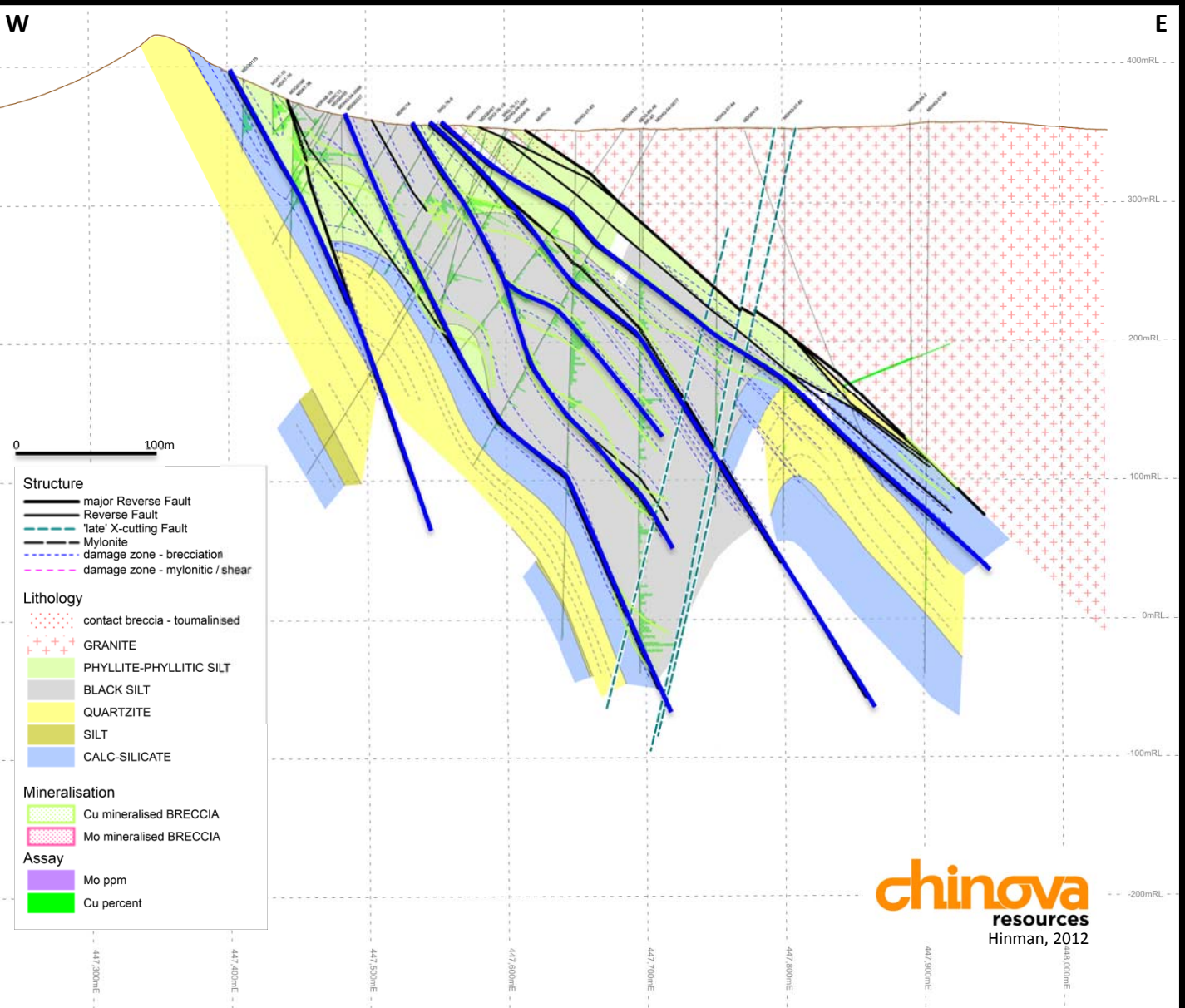

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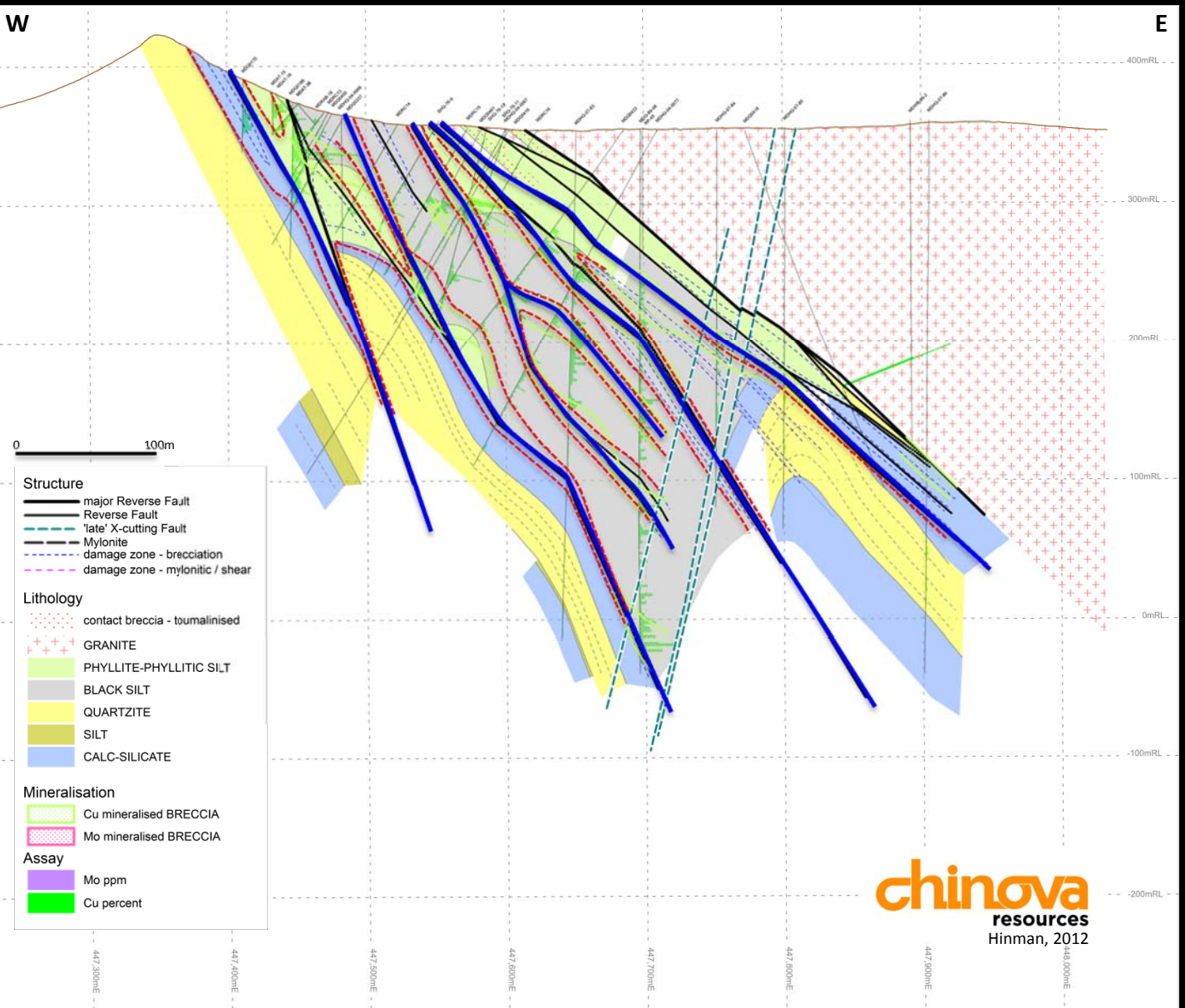

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Brittle, fracture & breccia Damage Zones …

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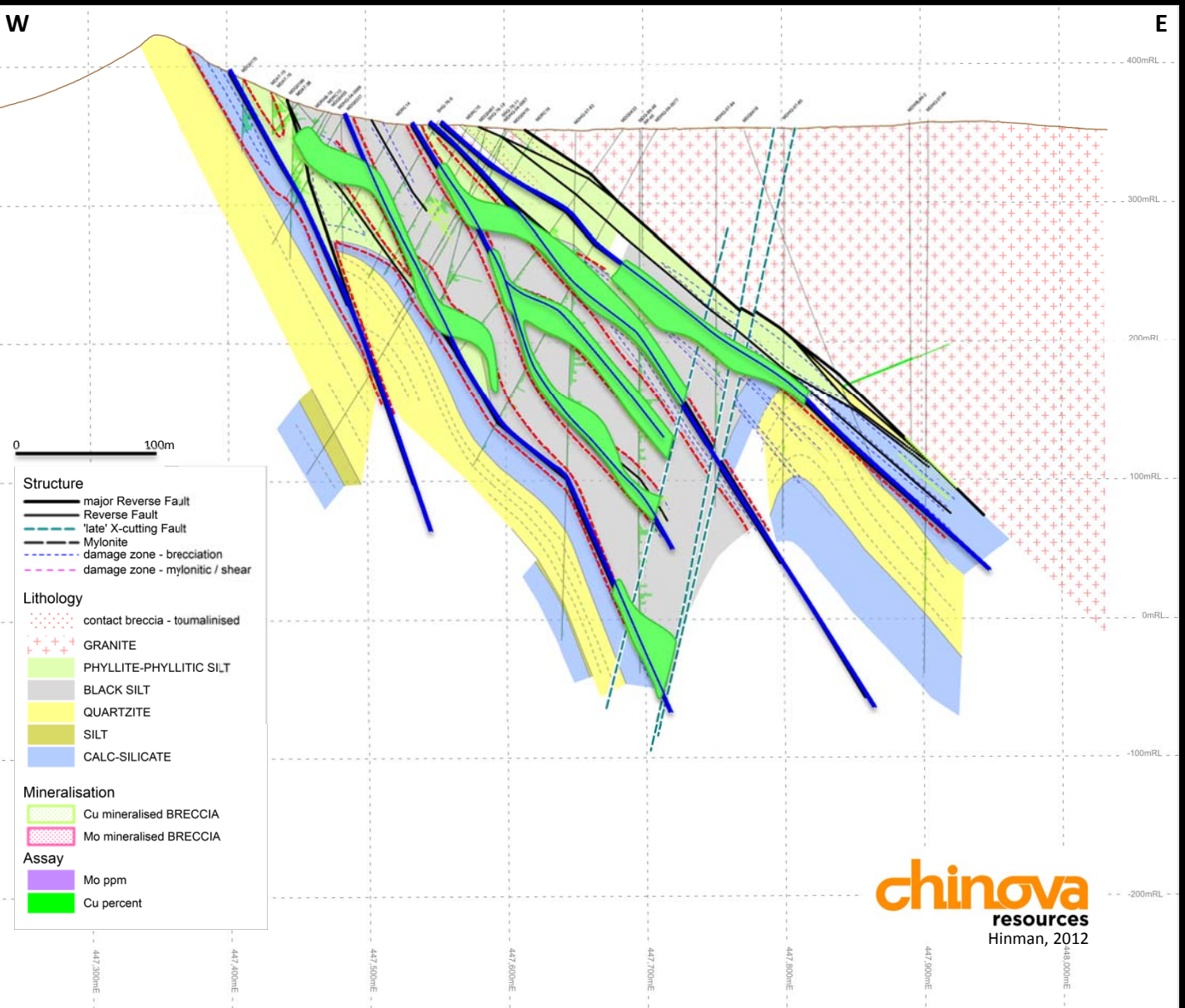

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… in carbonaceous silts
& along reactivated contacts
.. host Cu mineralisation

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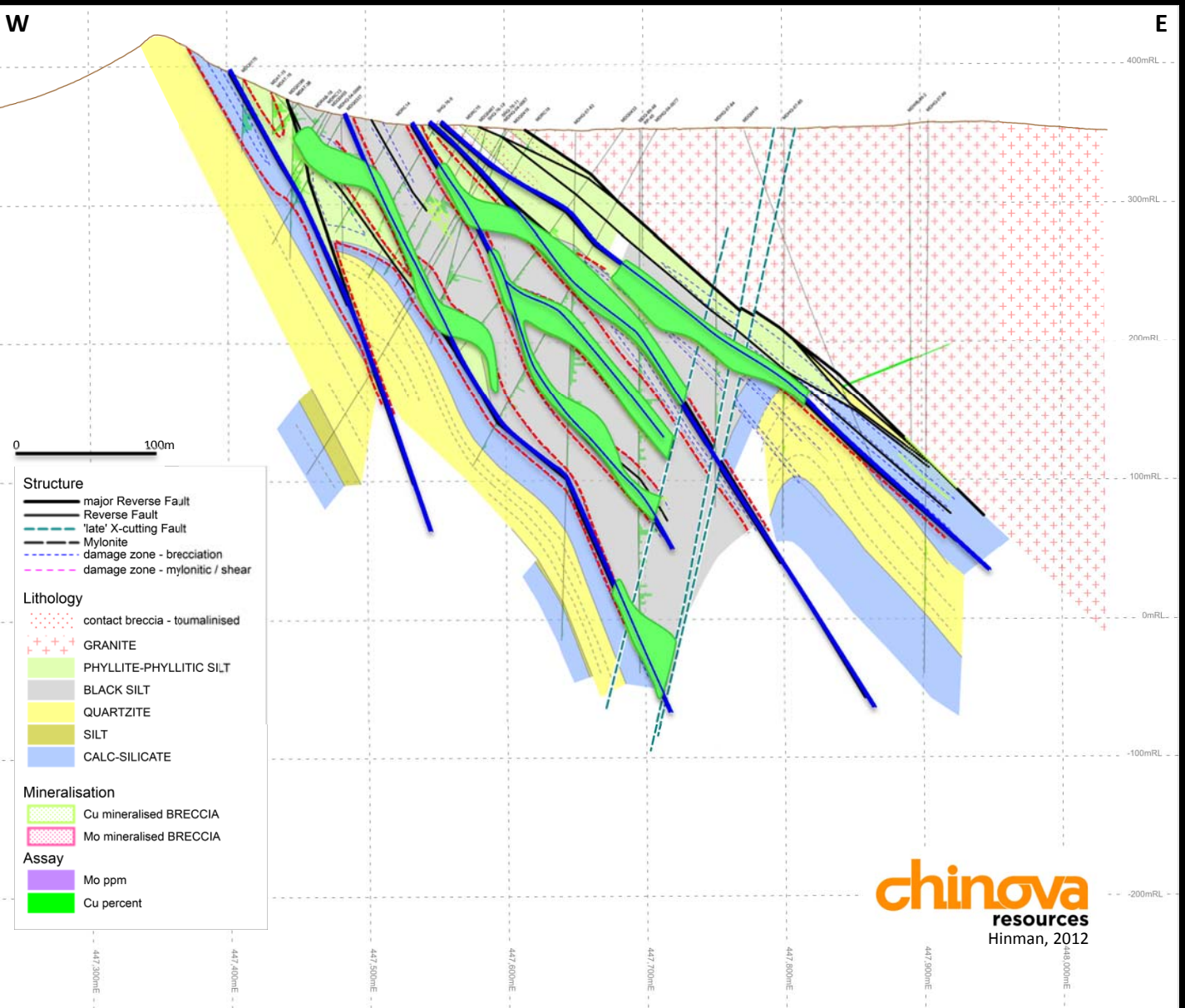

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D3 Faults … small throws!
NOT Regional Structures

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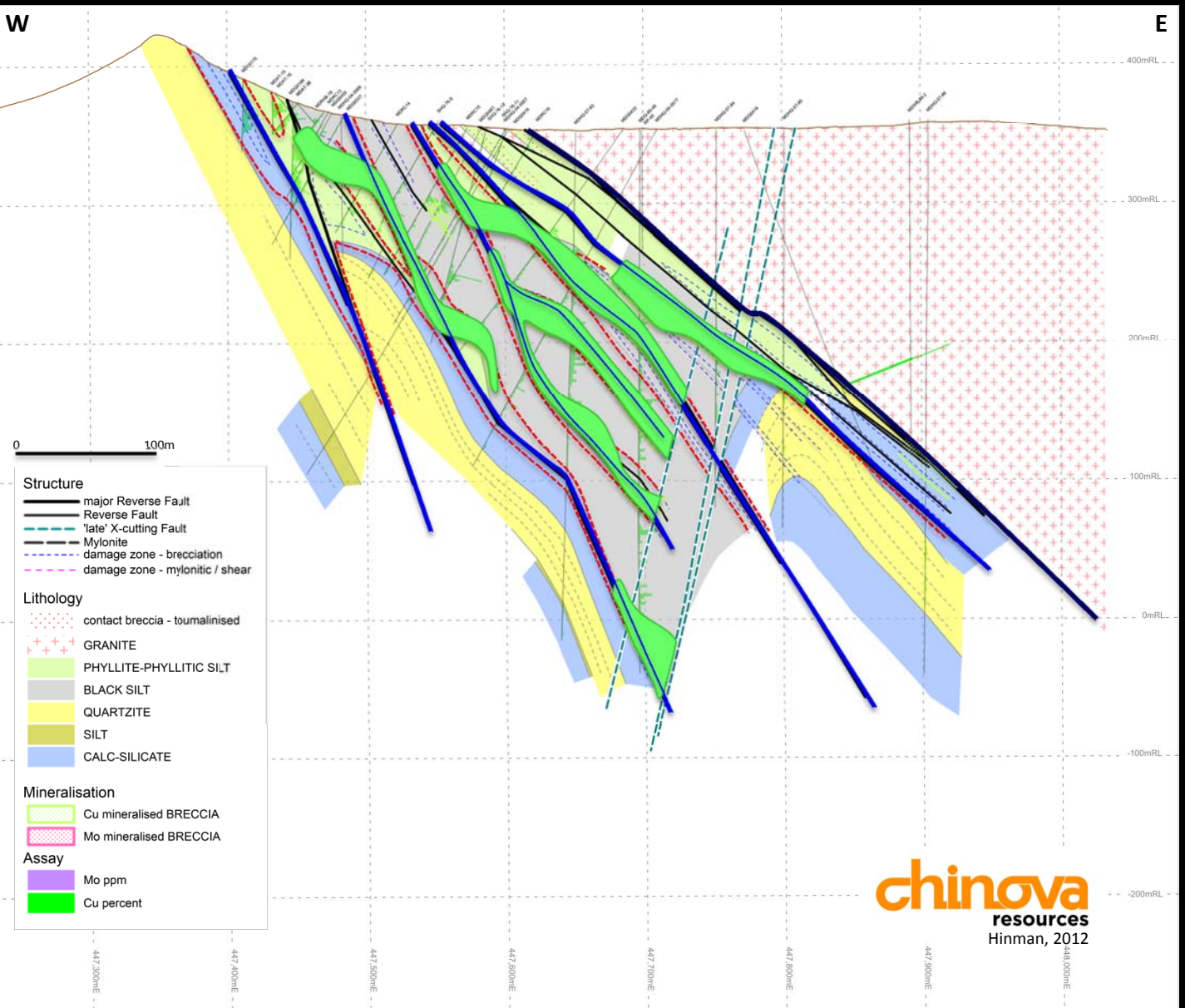

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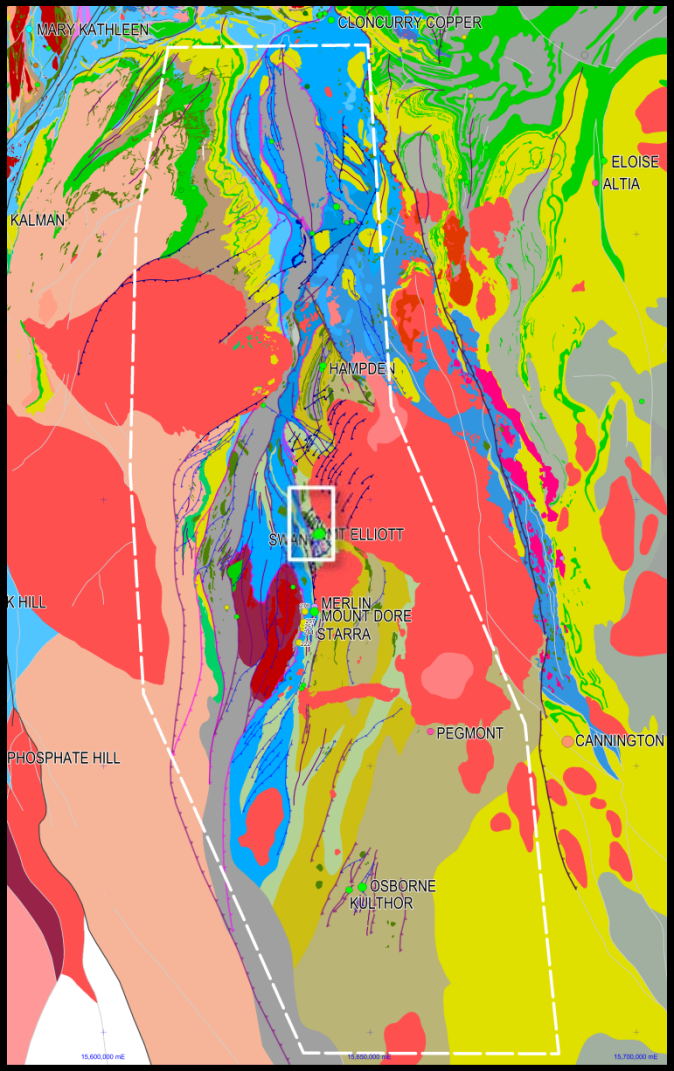
D3 Faults … small throws! NOT Regional Structures

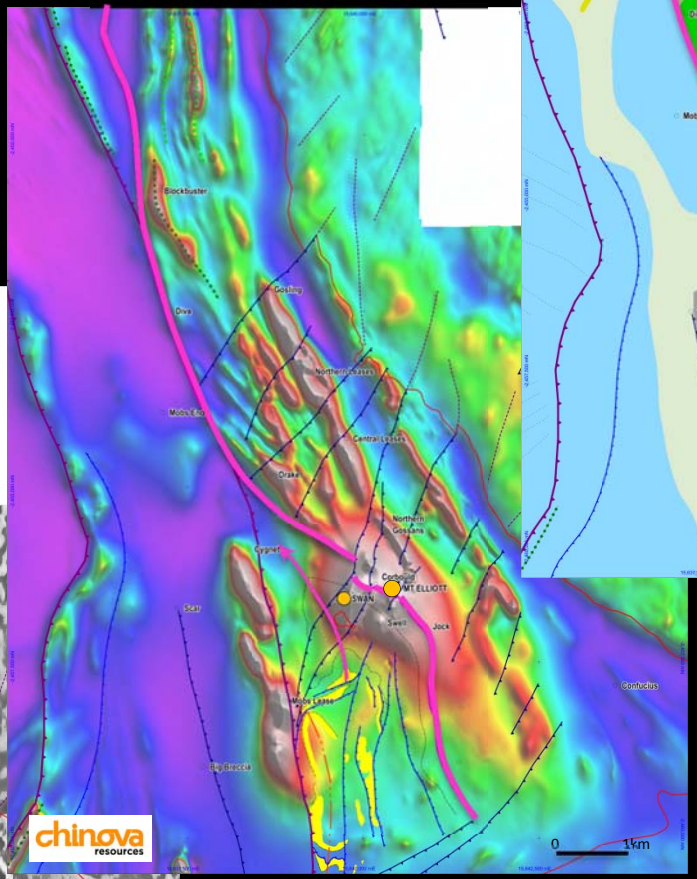
Granite Reverse Fault
highly planar, post-mineral, significant throw

Mount Elliott - SWAN

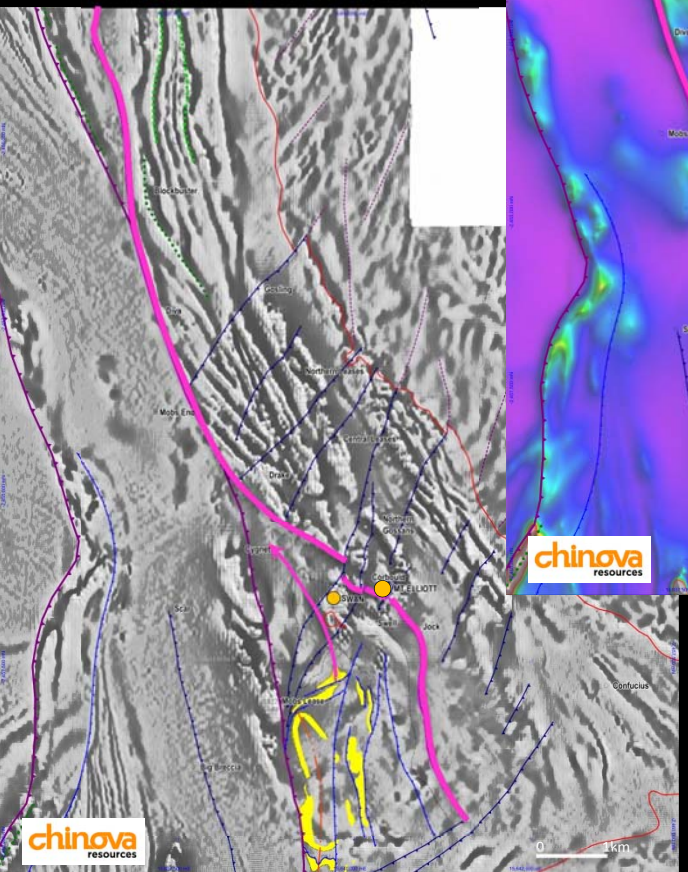


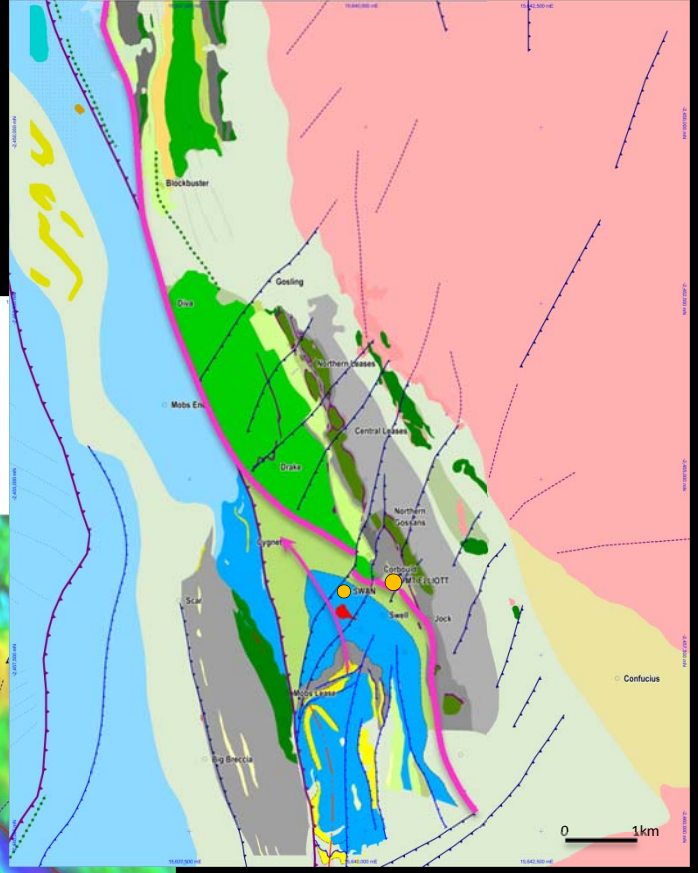
Mount Elliott - SWAN

detmag tmi-rtp



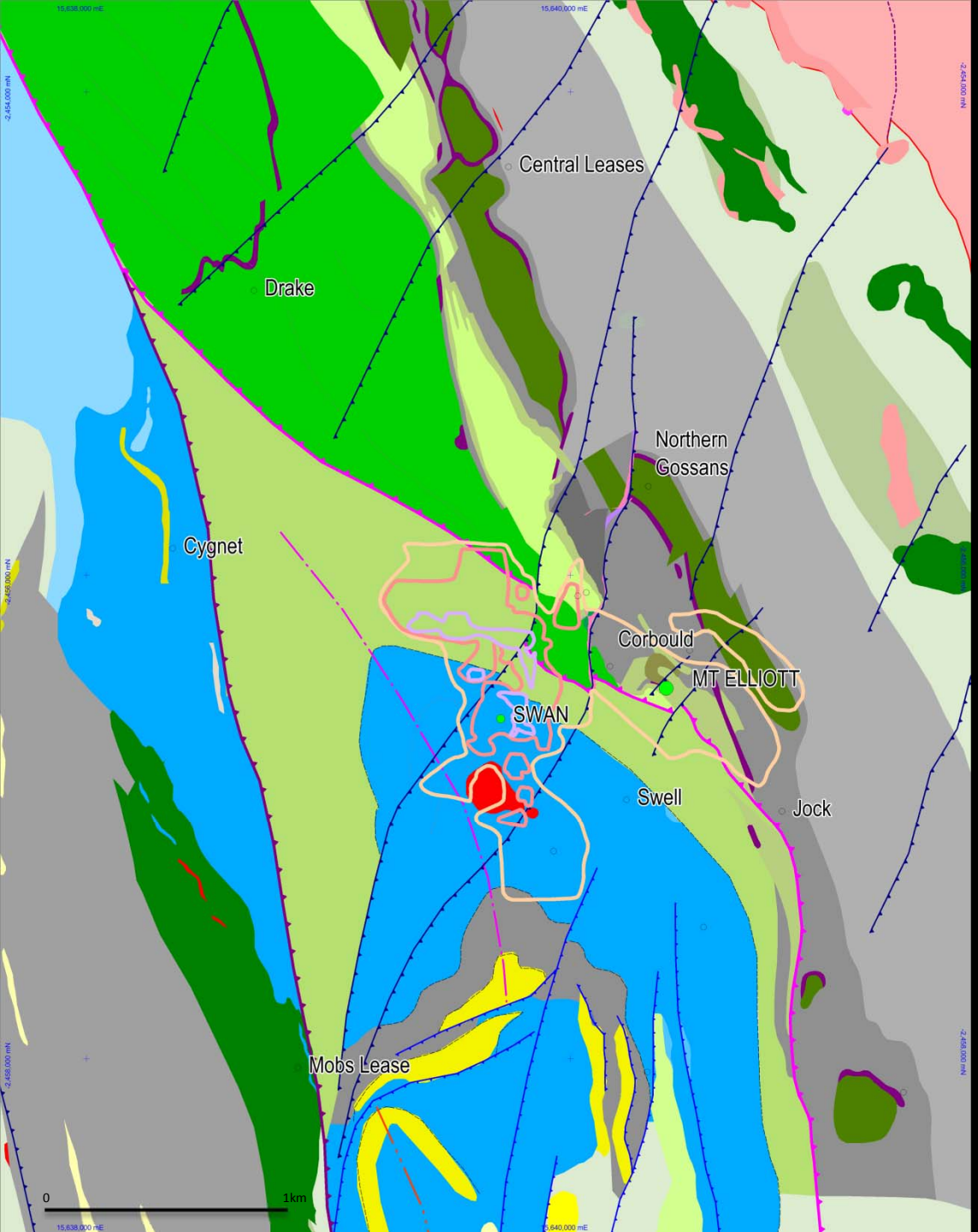
detmag vrmi-2vd

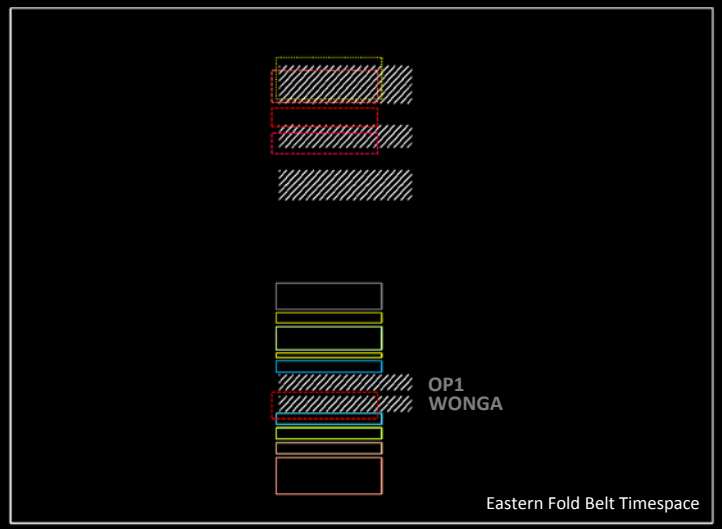




Close proximity to ?D1 structure

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





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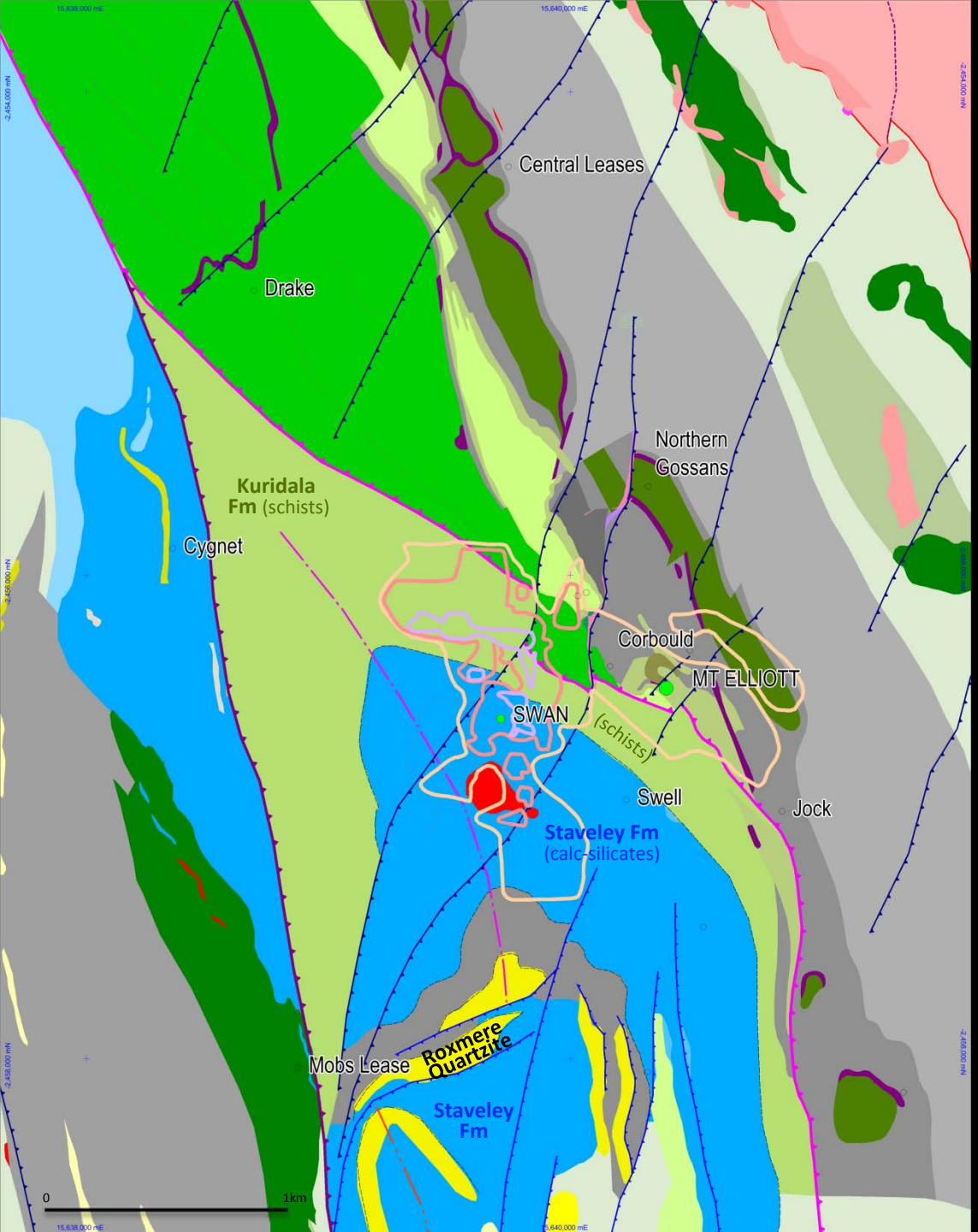

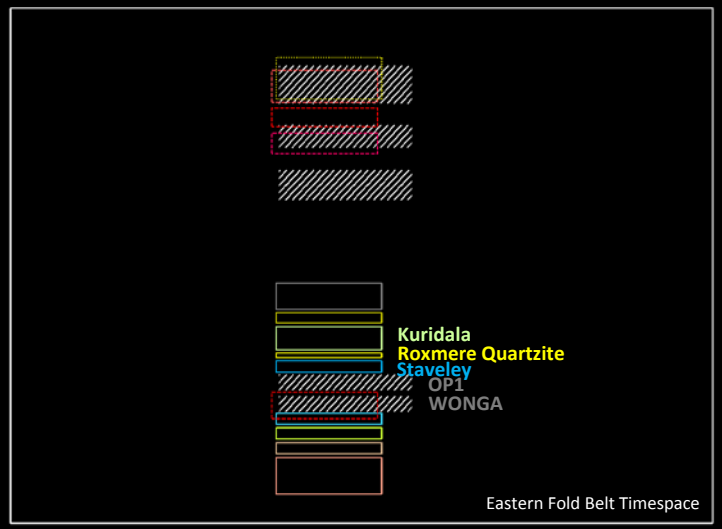

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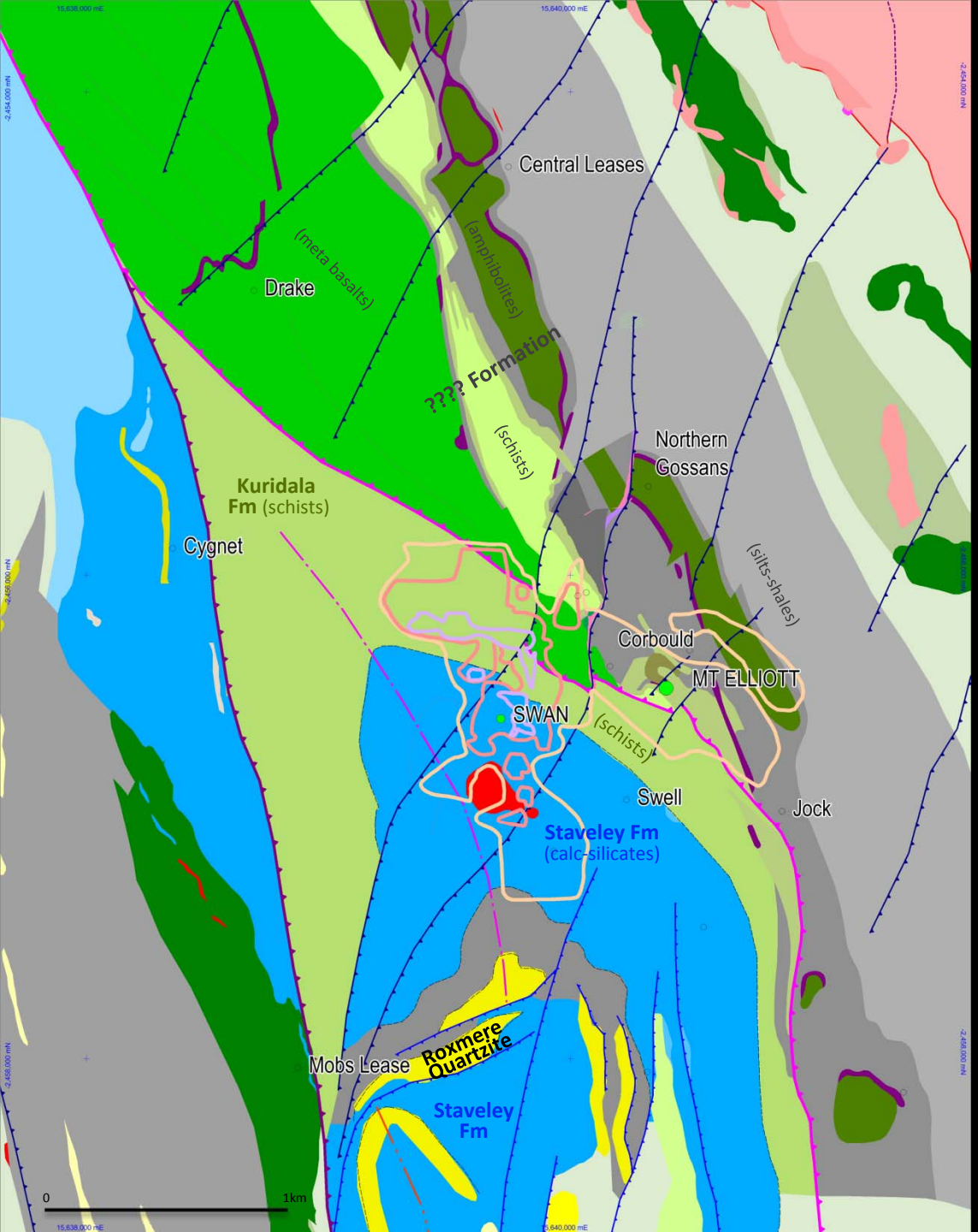

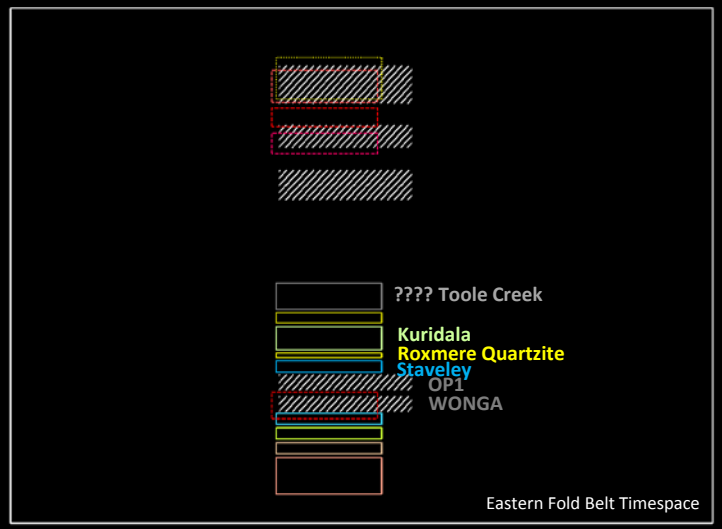

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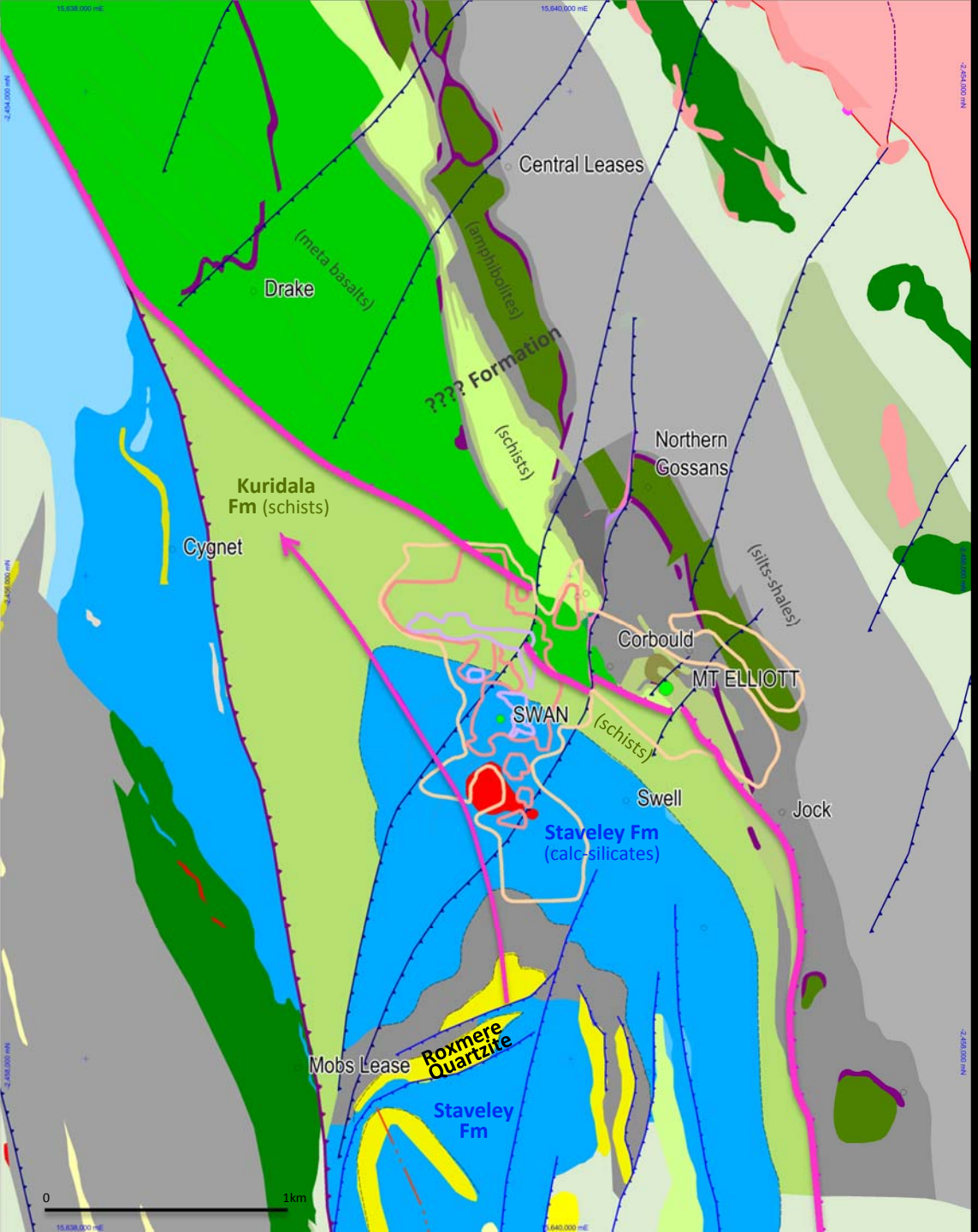

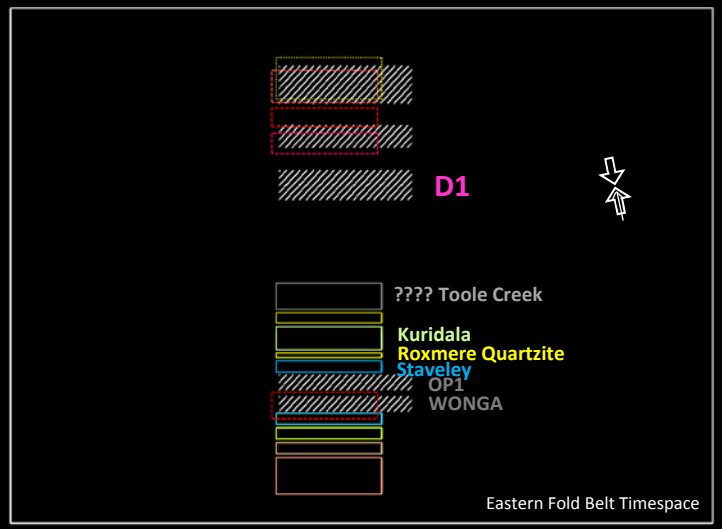

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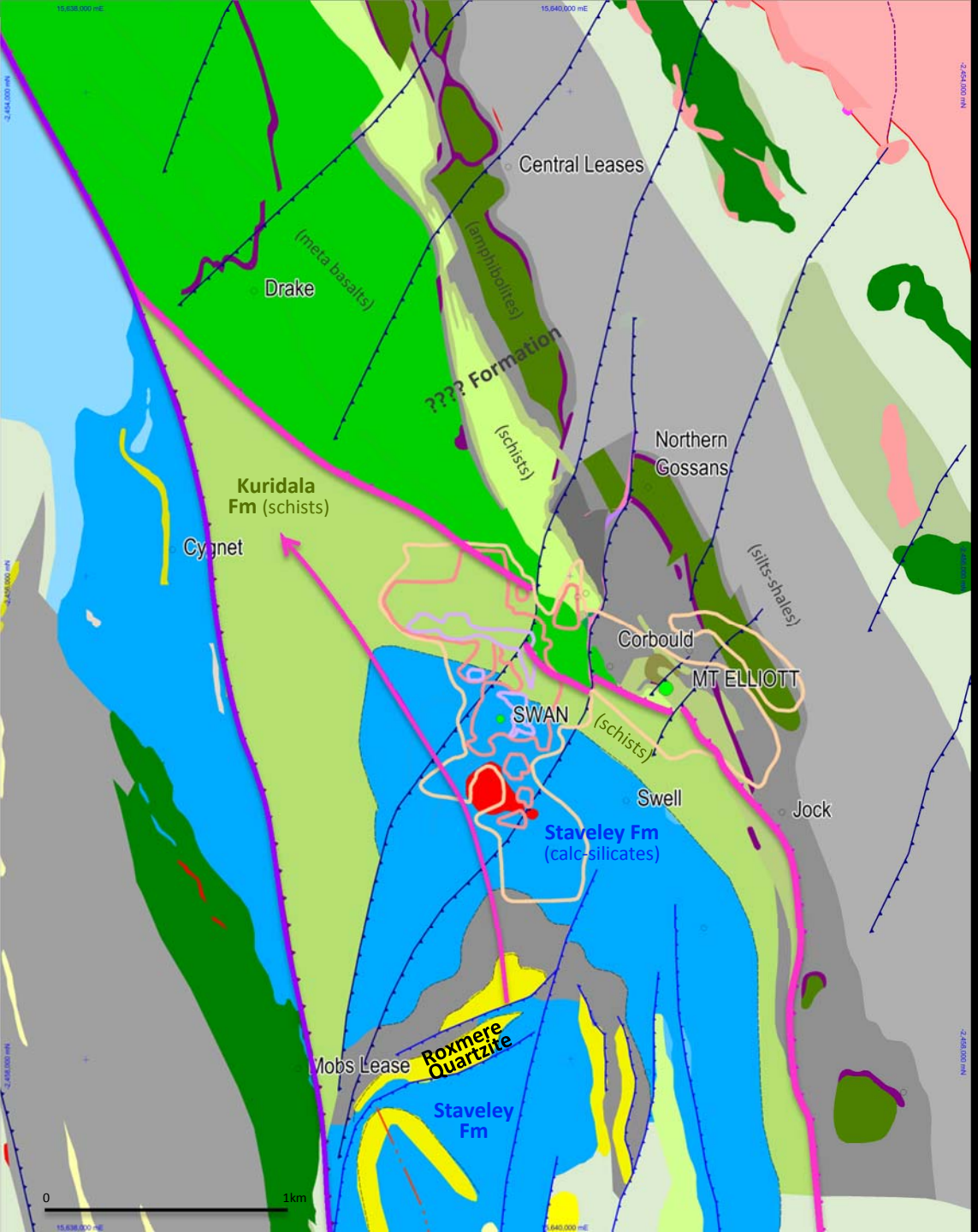

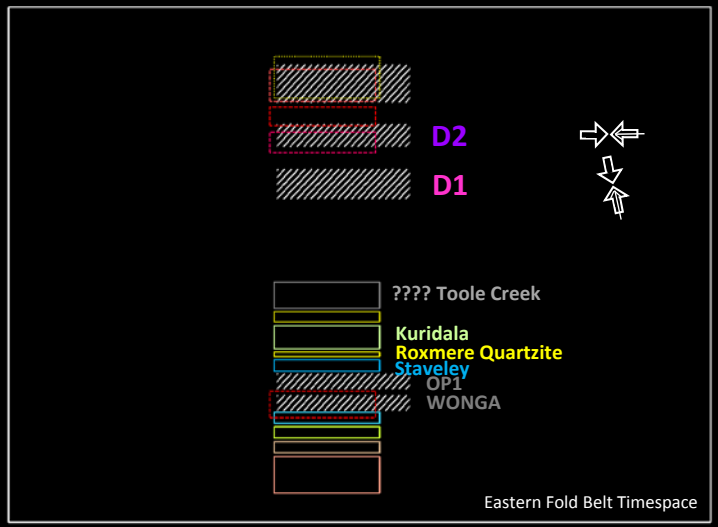

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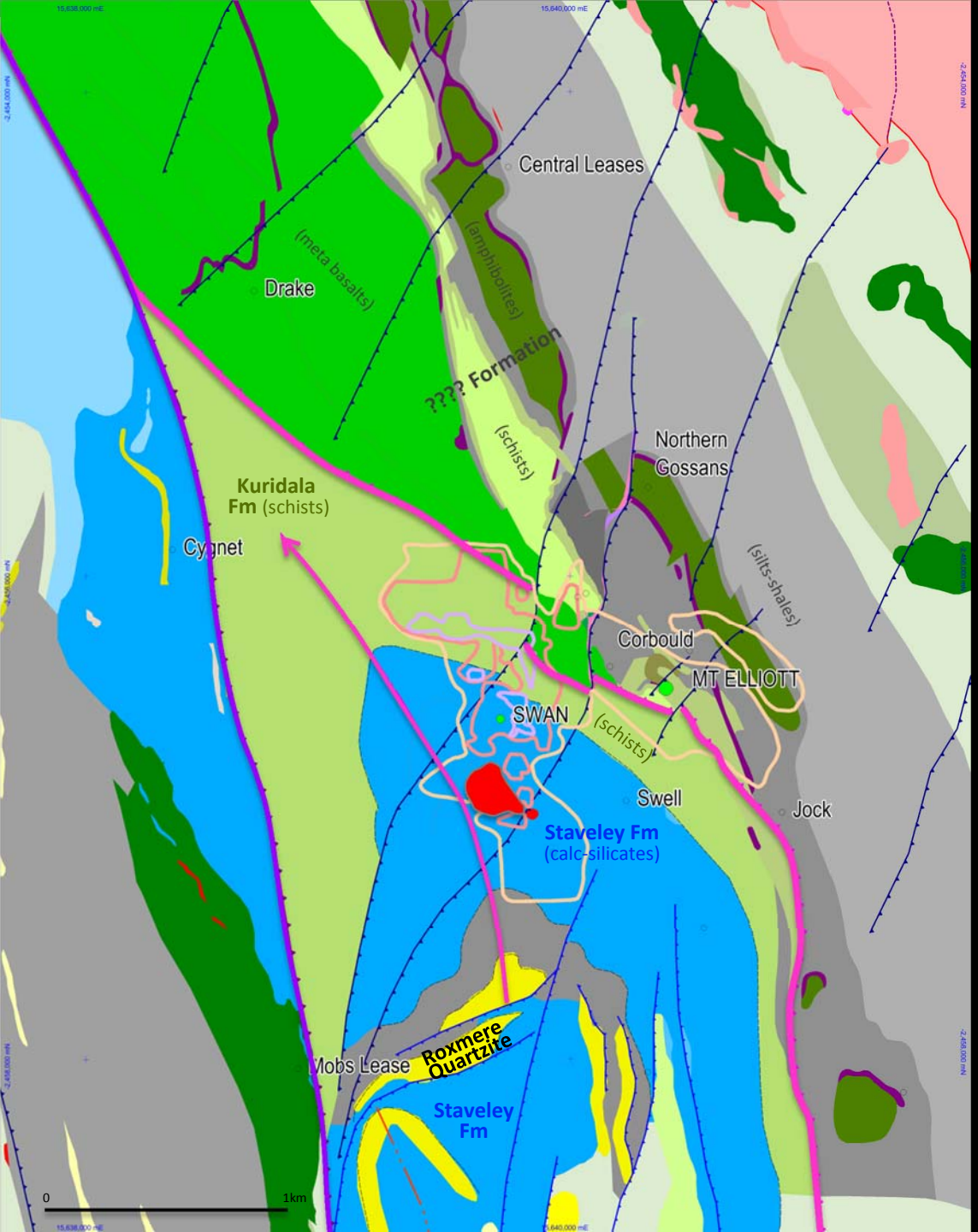

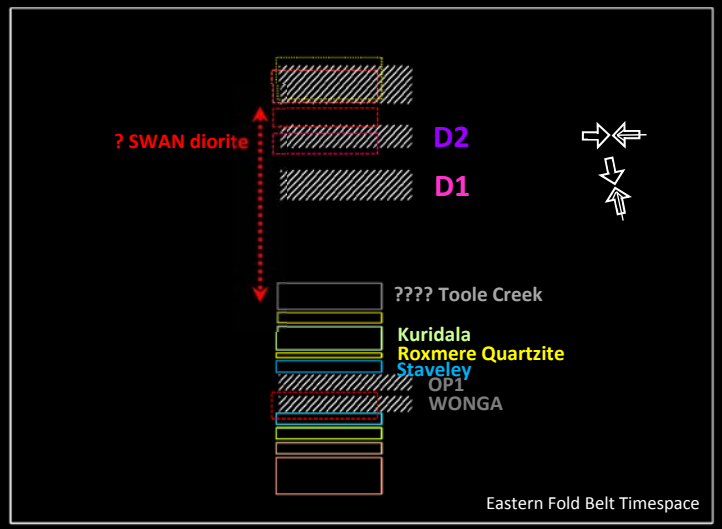

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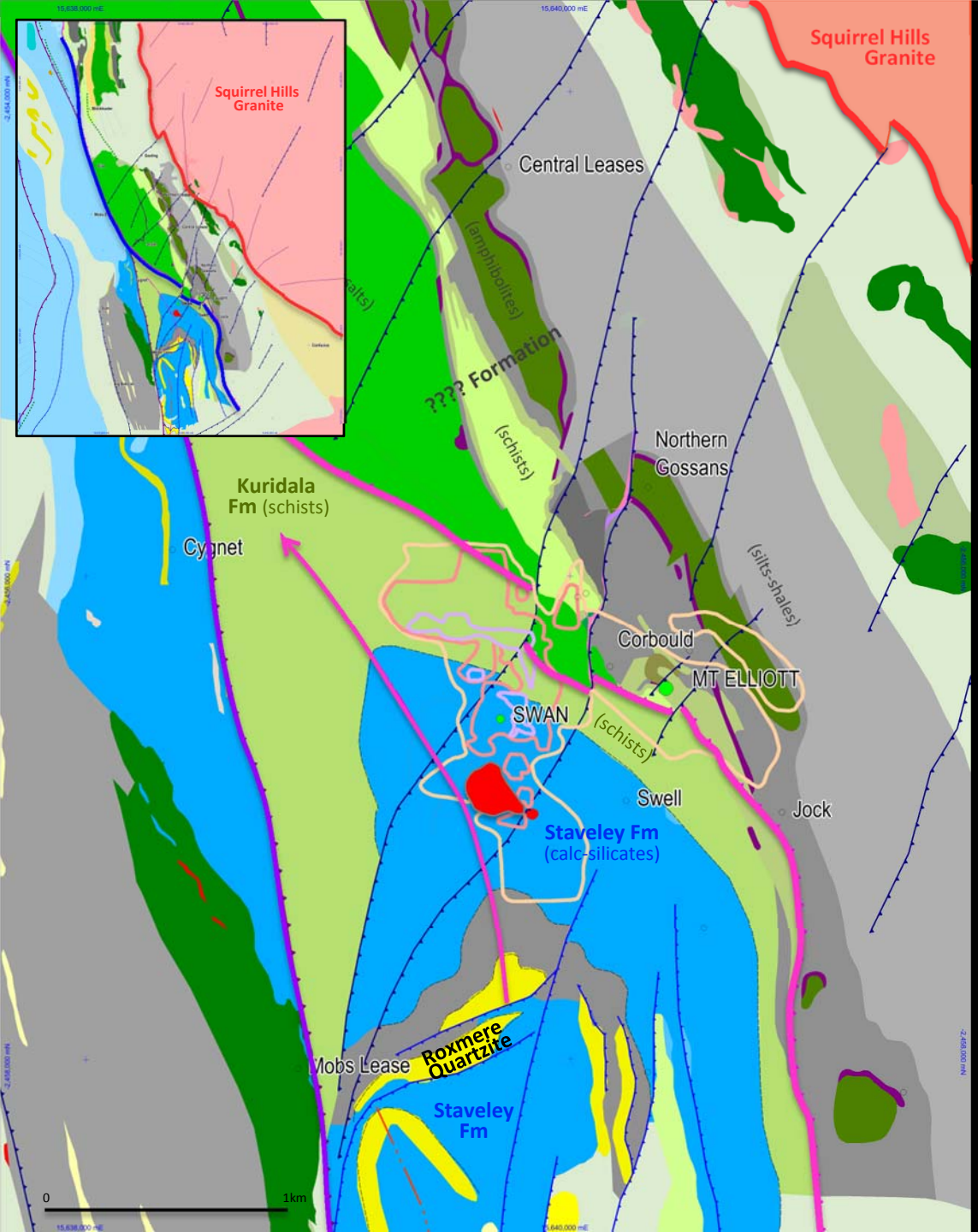

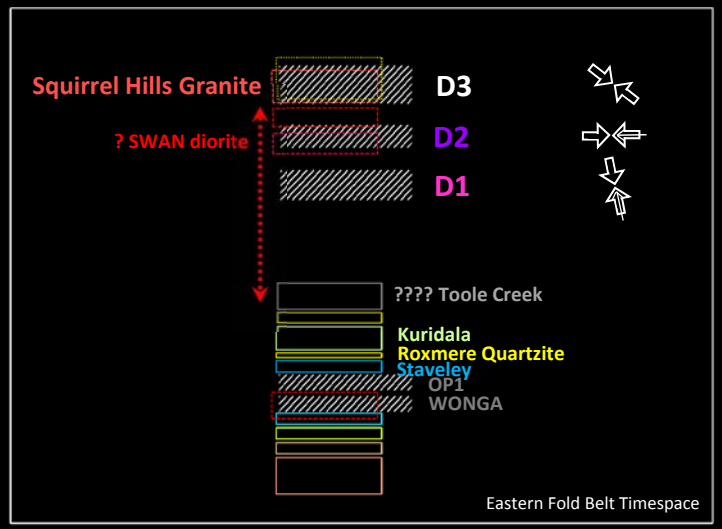

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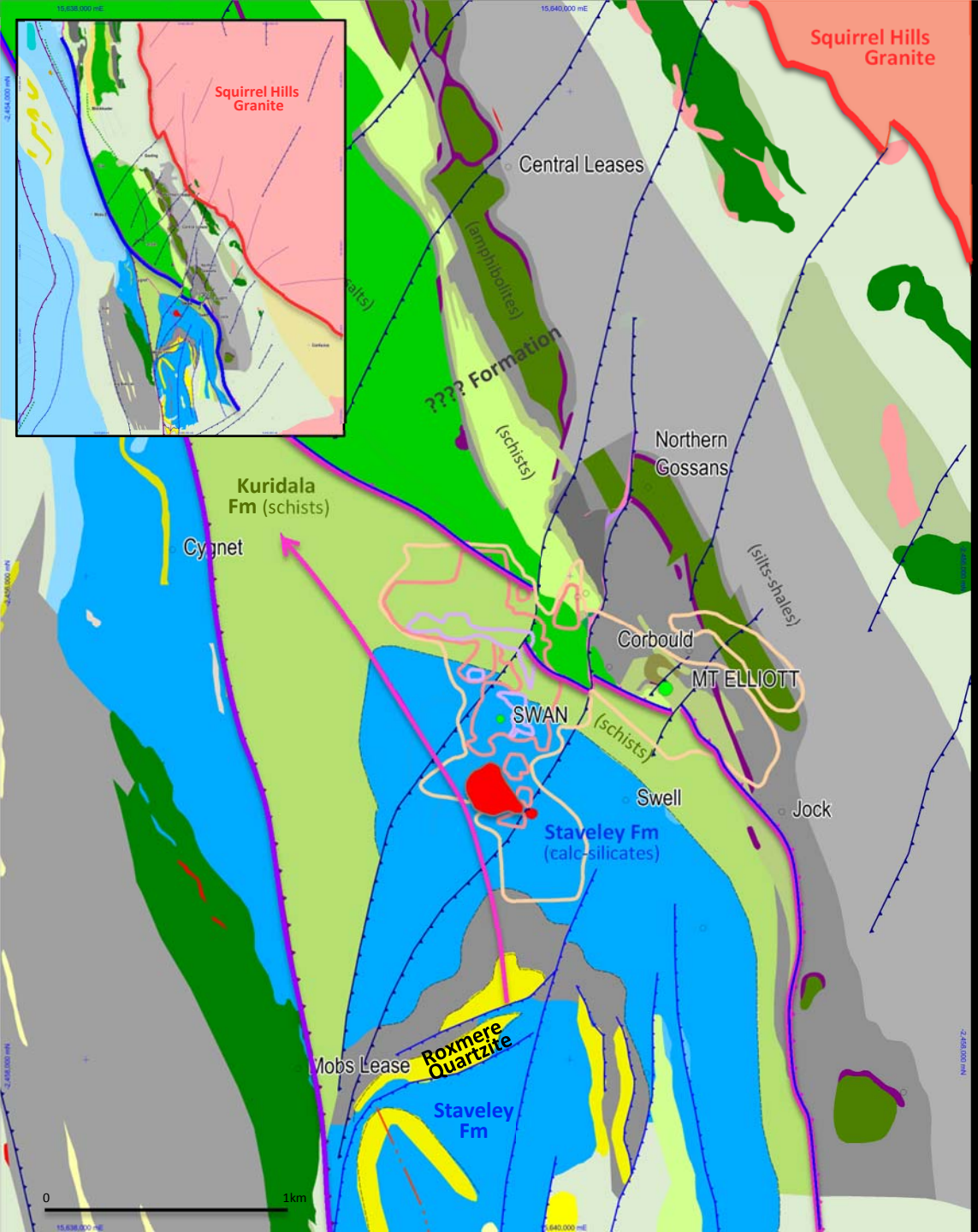
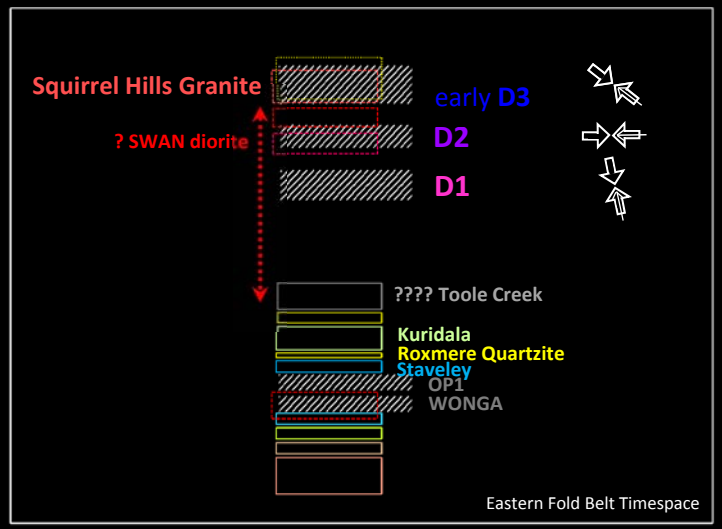
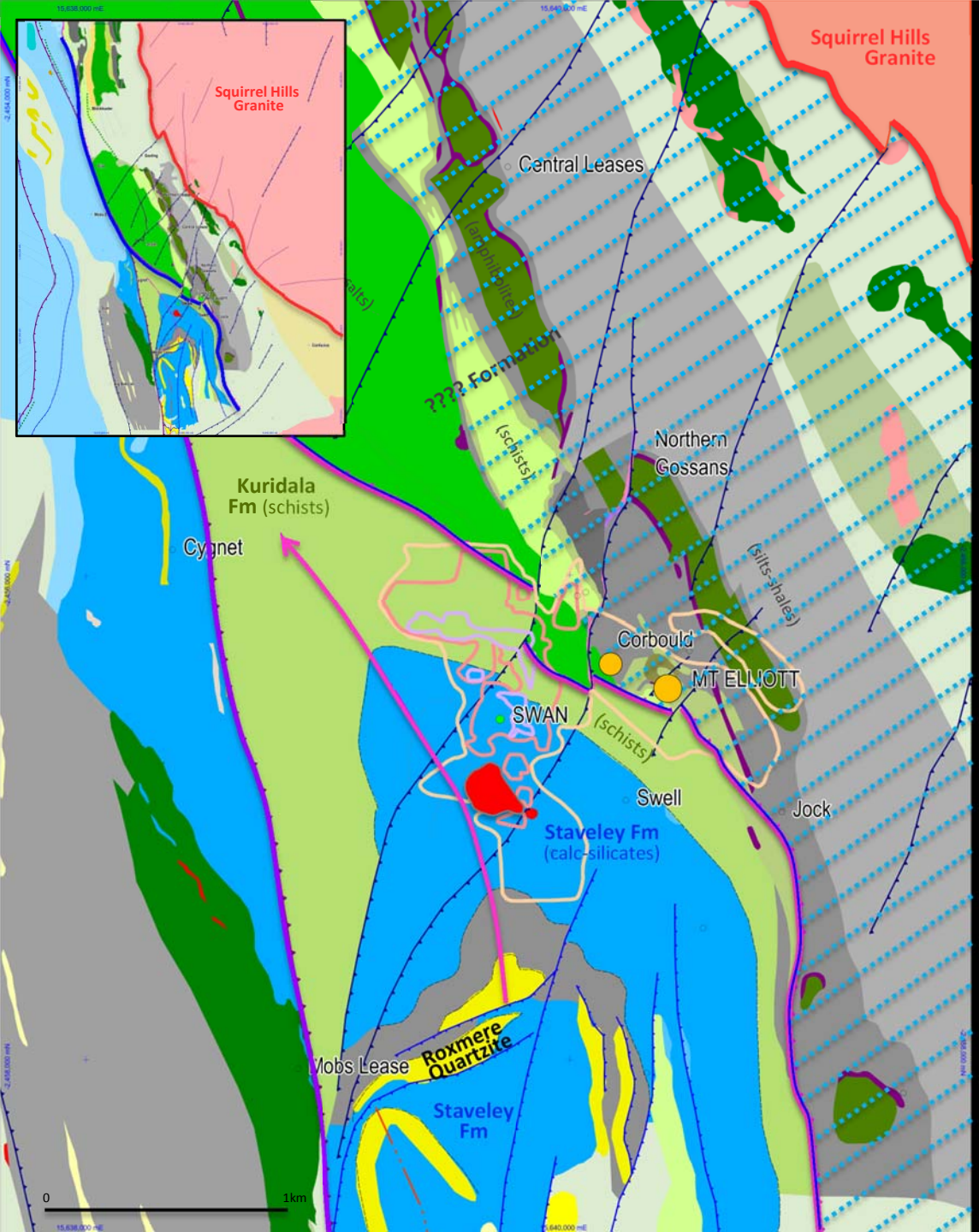

Squirrel Hills Granite
Central Leases
(amphibolites)
???? Formation
(schists)
Northern Gossans
(silts-shales)
Kuridala Fm (schists)
Cygnet
Corbould
MT ELLIOTT
SWAN
(schists)
Swell
Jock
Staveley Fm (calc-silicates)
Mobs Lease
Roxmere Quartzite
Staveley Fm
0
1km


Squirrel Hills Granite
? SWAN diorite
early D3
D2
D1
???? Toole Creek
Kuridala
Roxmere Quartzite
Staveley
OP1
WONGA
Eastern Fold Belt Timespace


> 0.25eq%Cu
> 1.0eq%Cu
> 2.0eq%Cu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Central Leases
(amphibolites)
???? Formation
(schists)
Northern Gossans
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(silts-shales)
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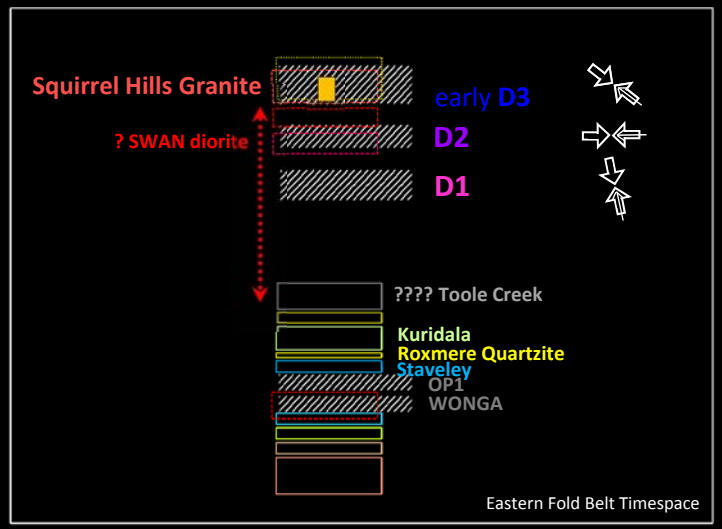
0
1km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? SWAN diorite
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Staveley
OP1
WONGA
Eastern Fold Belt Timespace


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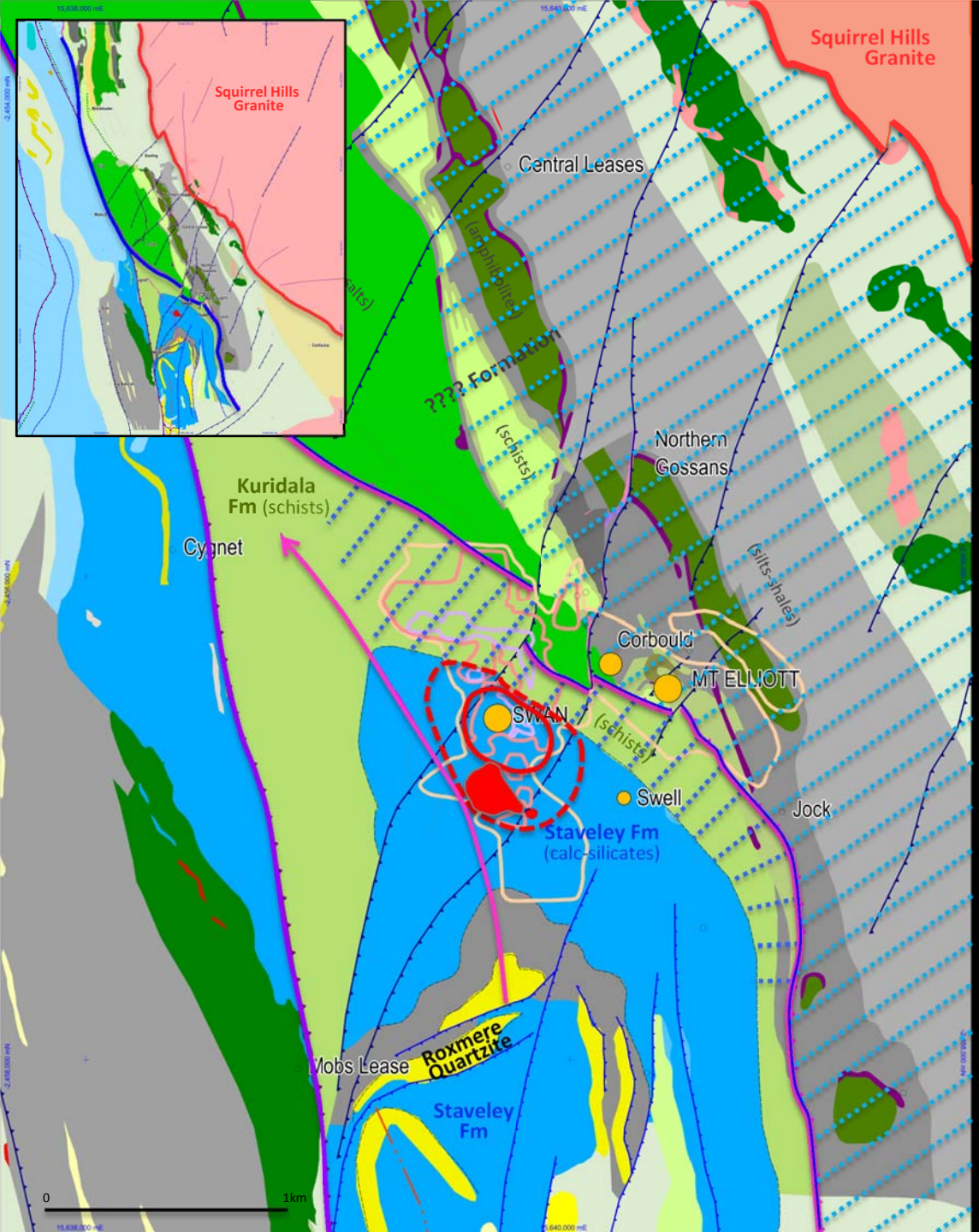
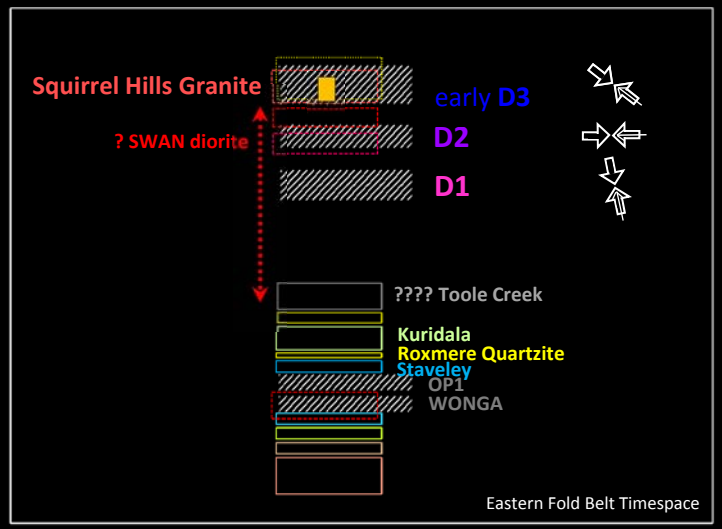
> 2.0eq%Cu





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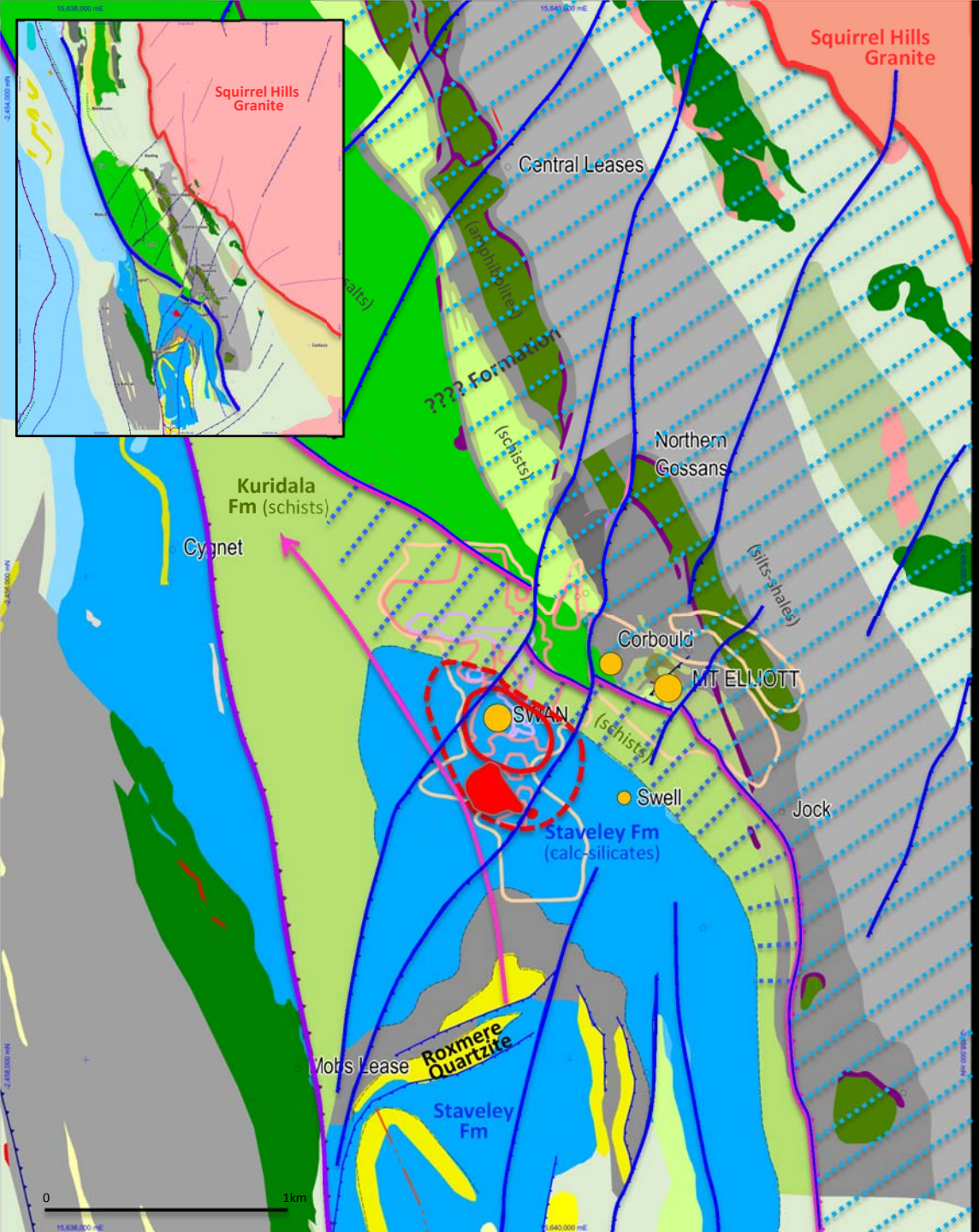
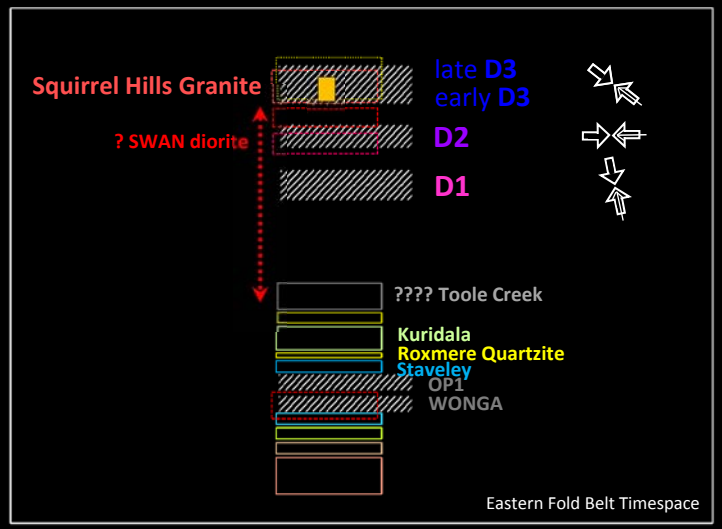
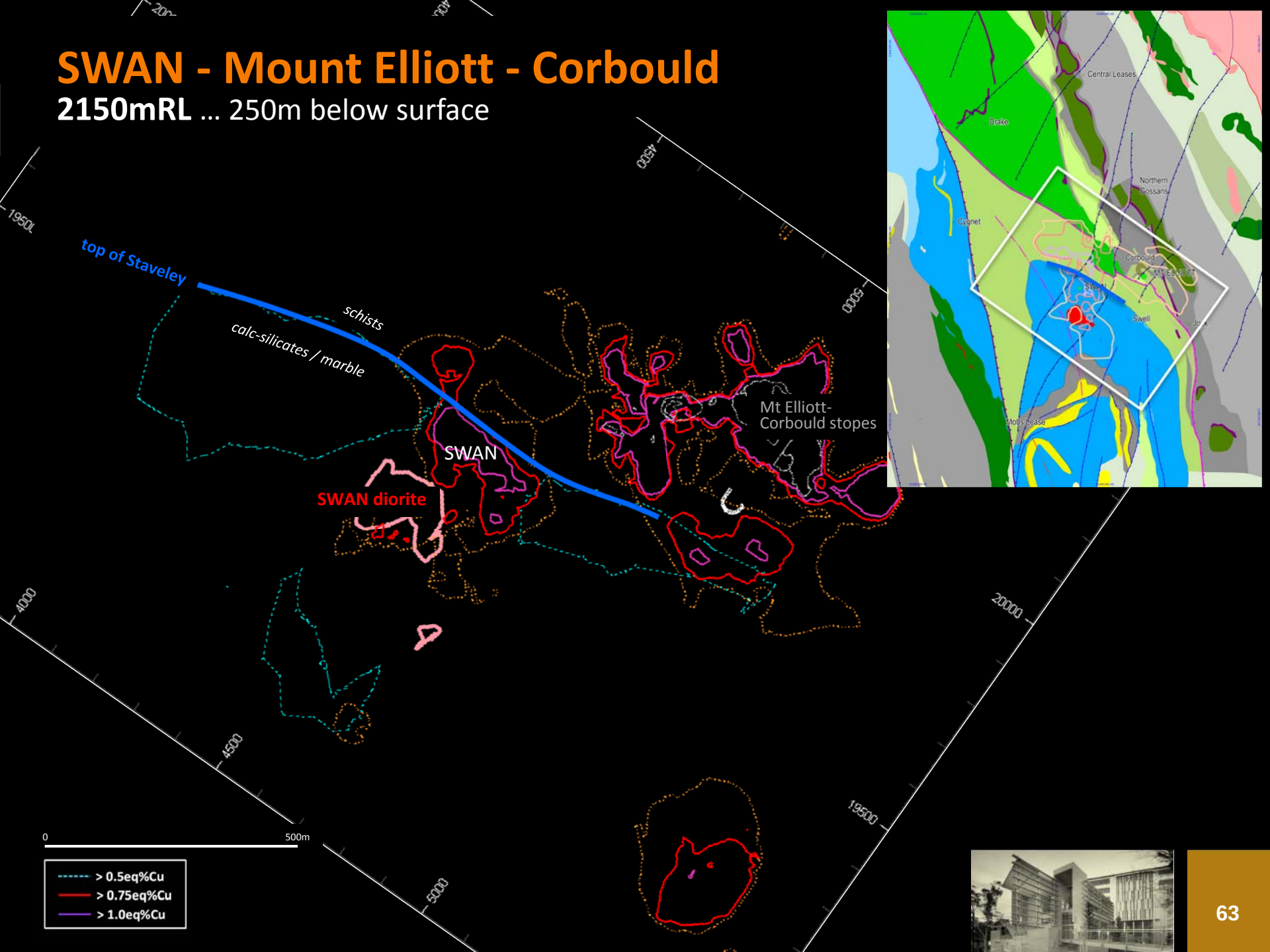




> 0.25eq%Cu
> 1.0eq%Cu
> 2.0eq%Cu

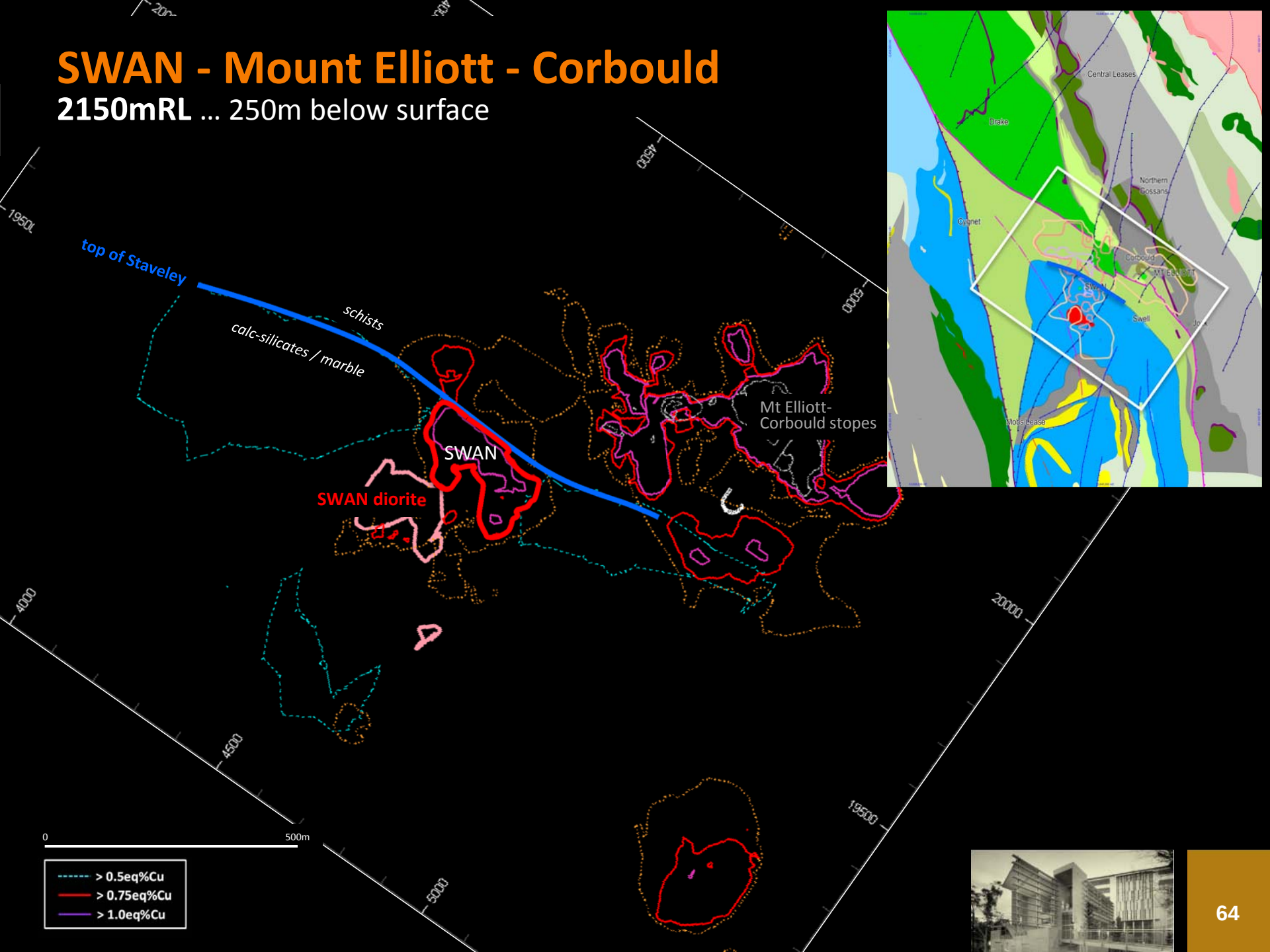
SWAN - Mount Elliott - Corbould

2150mRL … 250m below surface



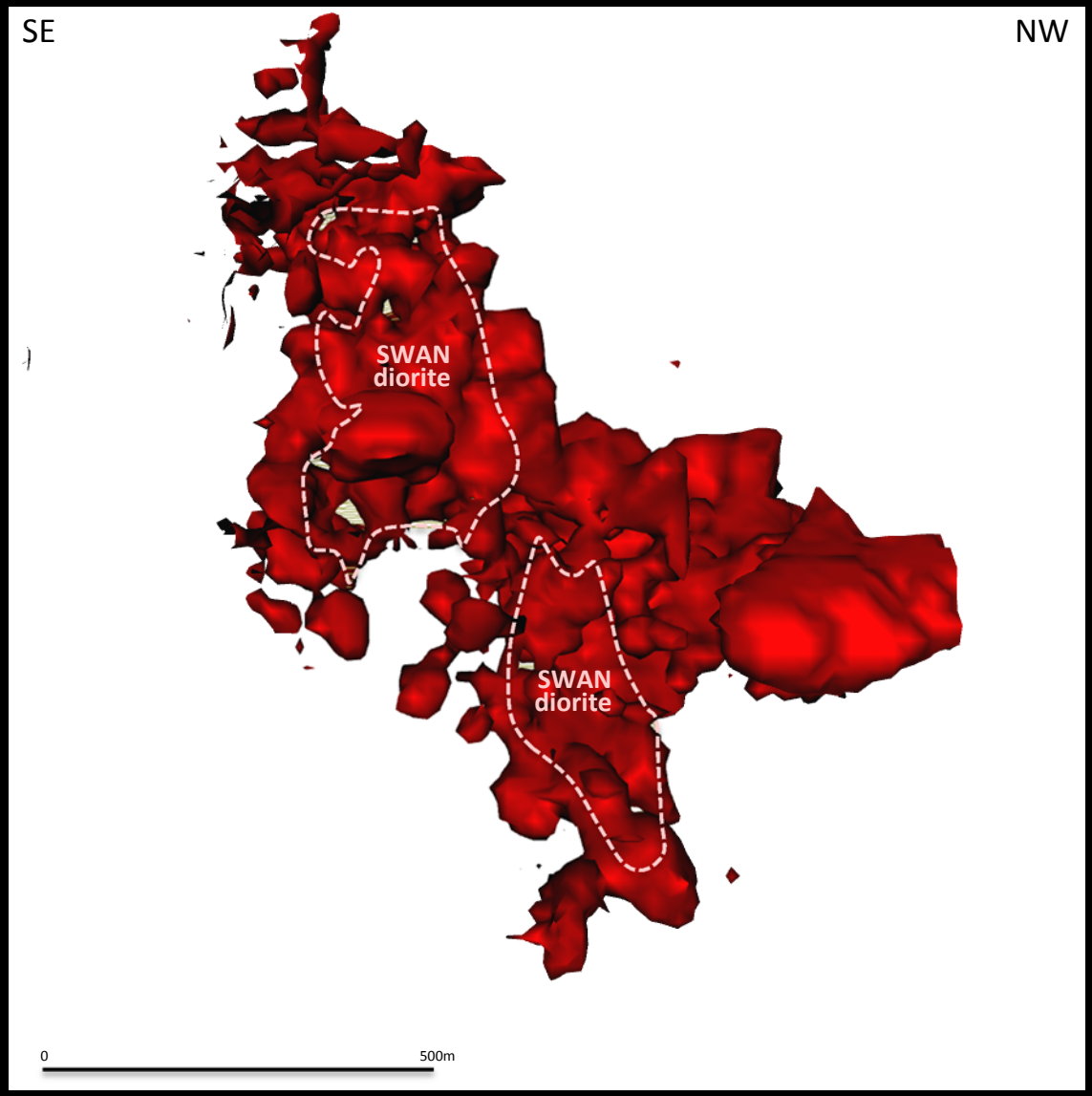
SWAN - Mount Elliott - Corbould

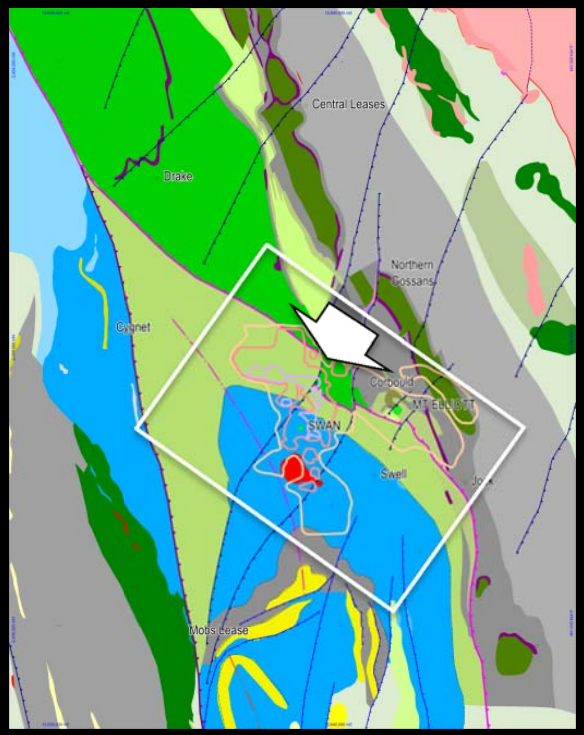
2150mRL … 250m below surface



SWAN 0.75eq%Cu

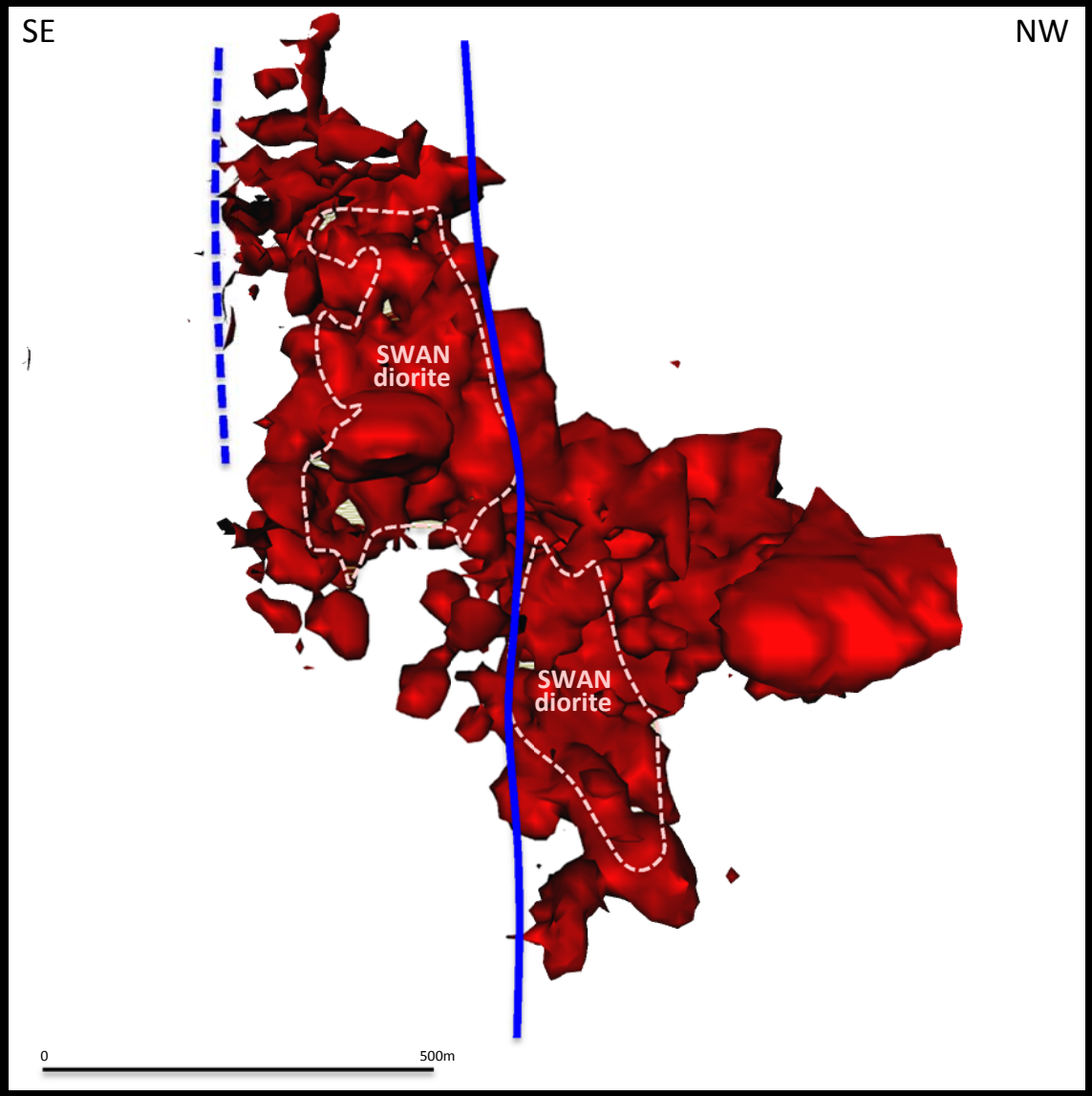
Long Section ... looking SW **through** SWAN

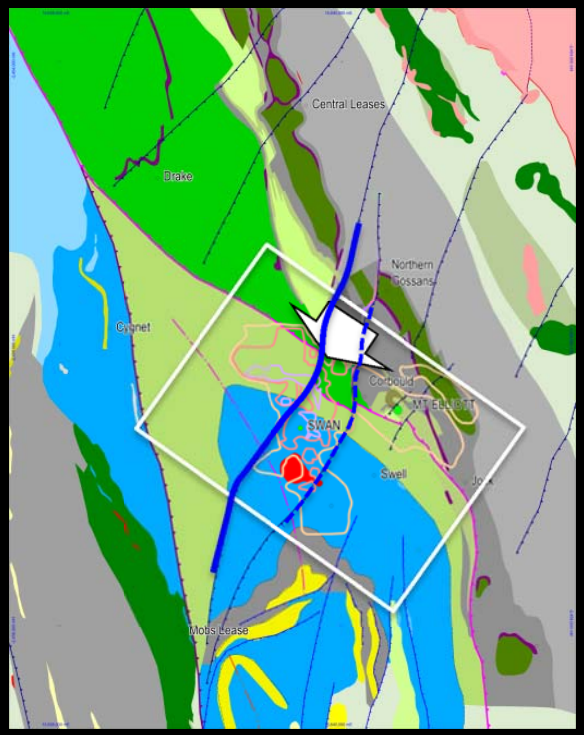




SWAN 0.75eq%Cu

Long Section … looking SW **through** SWAN

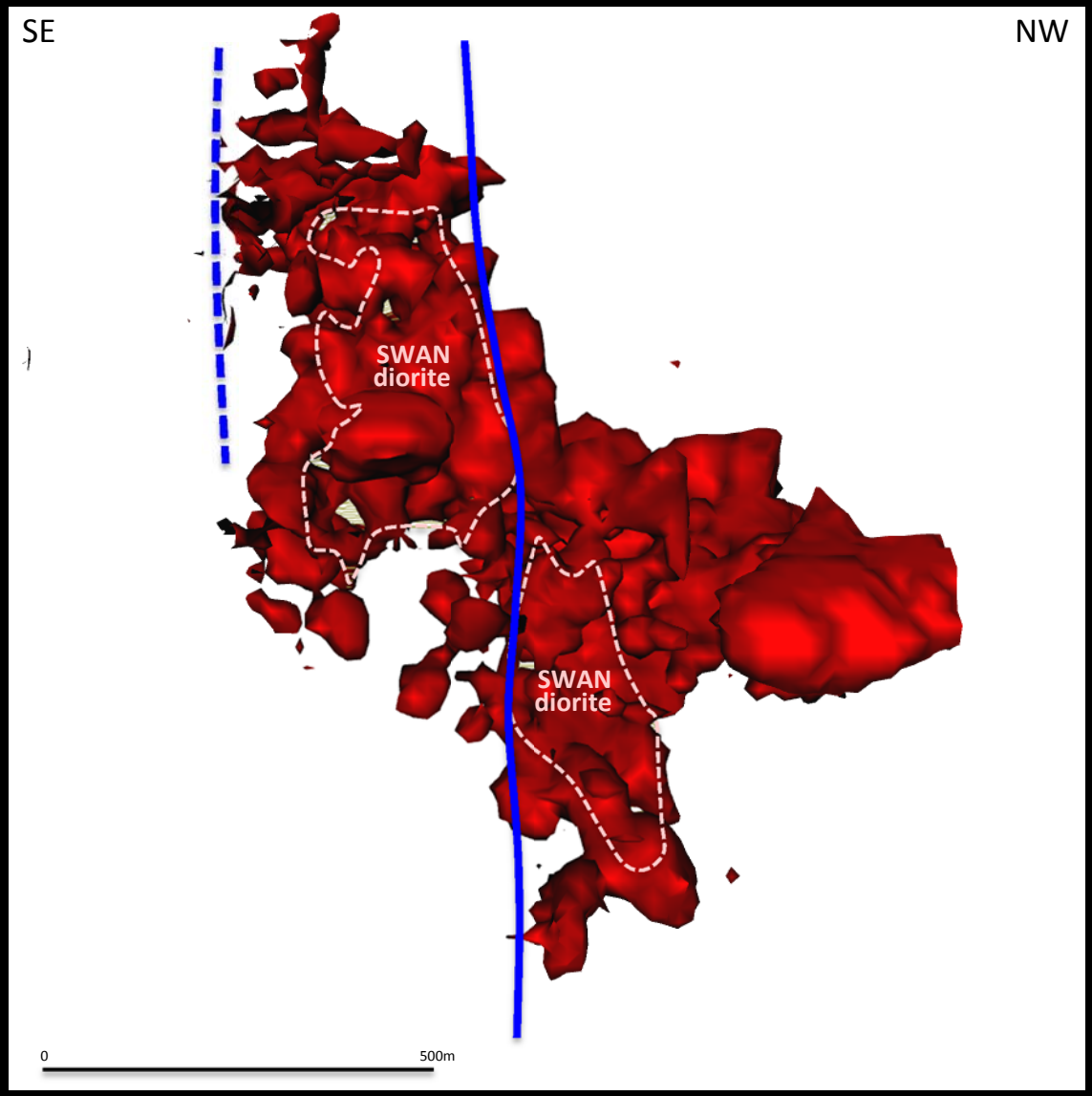




- **post-mineral D3 Faults**

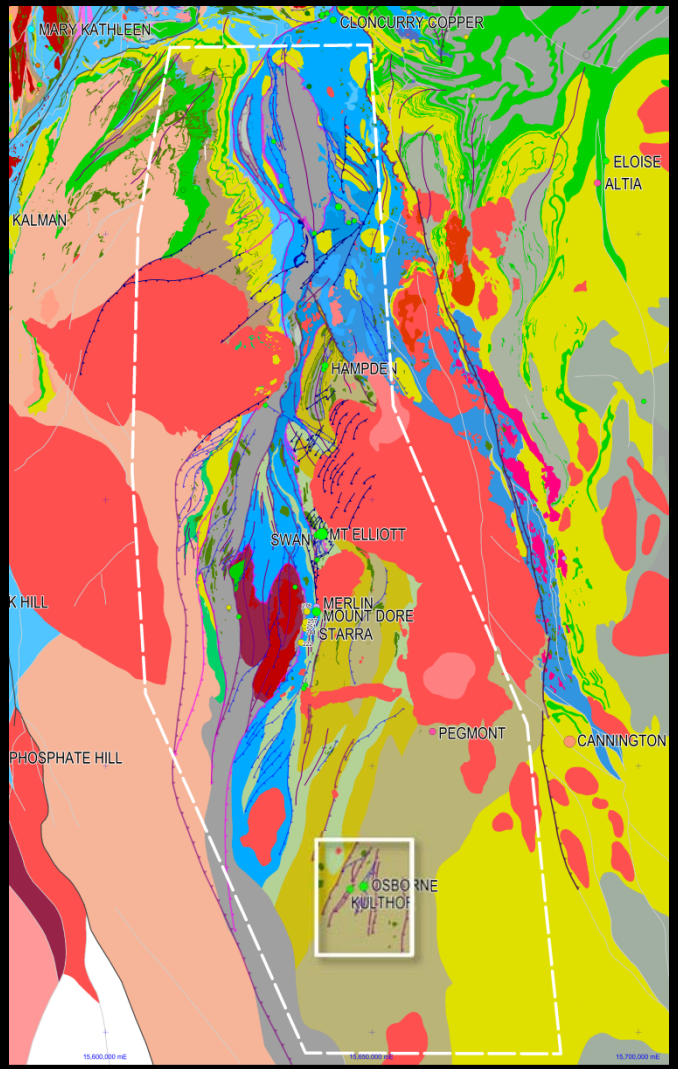
SWAN 0.75eq%Cu

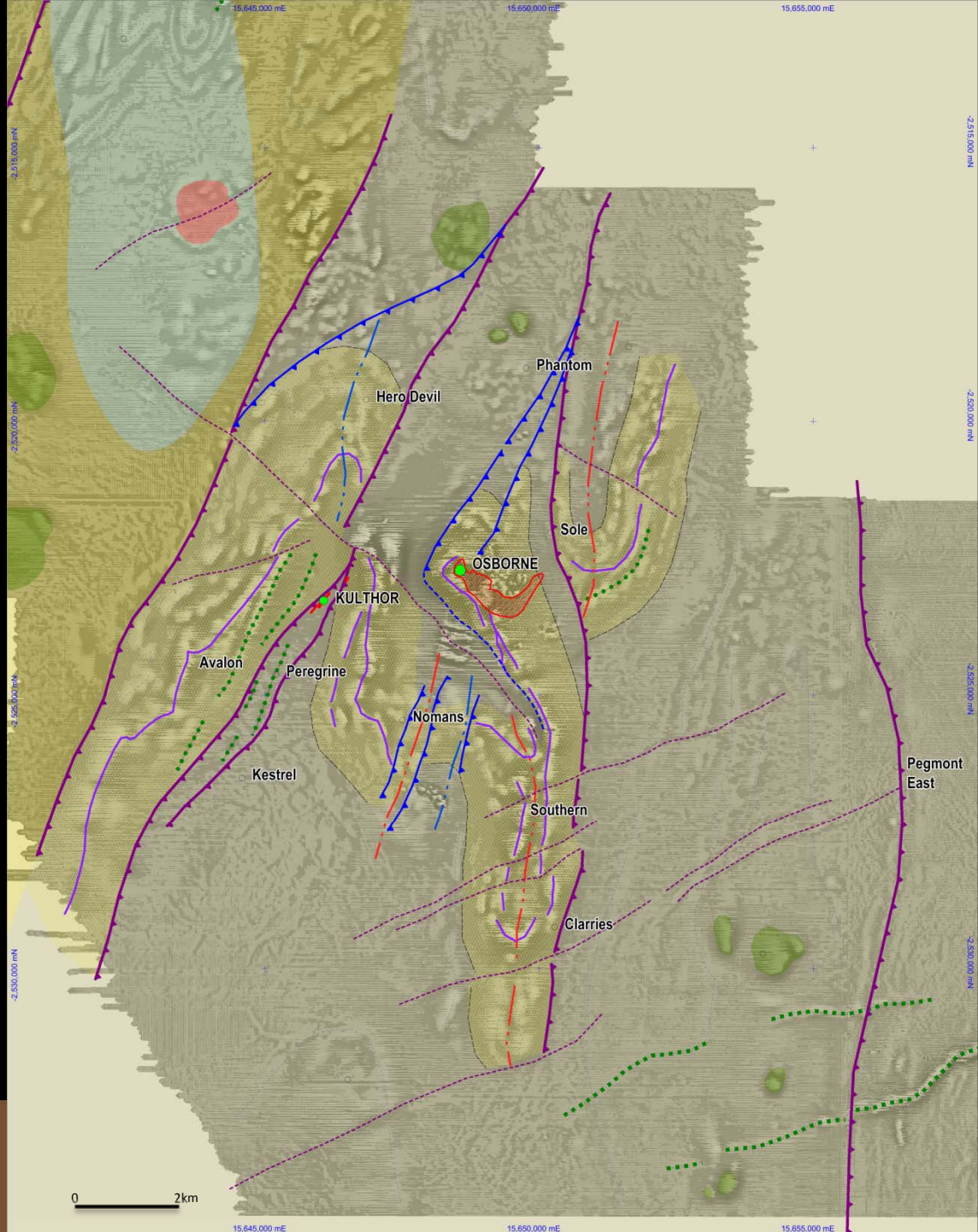
Long Section … looking SW **through** SWAN



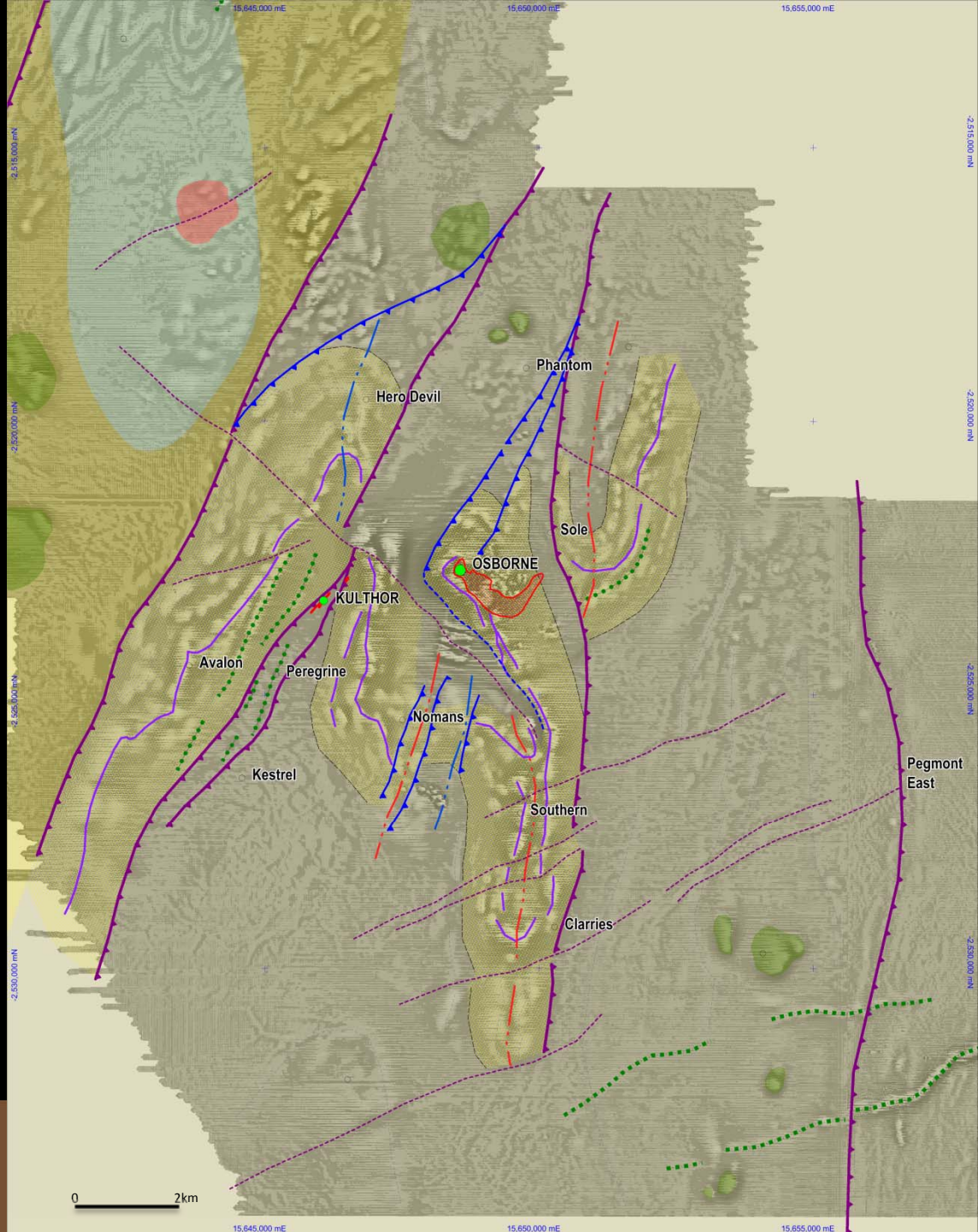
- **post-mineral D3 Faults**
- **family cuts Squirrel Hills Granites**

Kulthor-Osborne

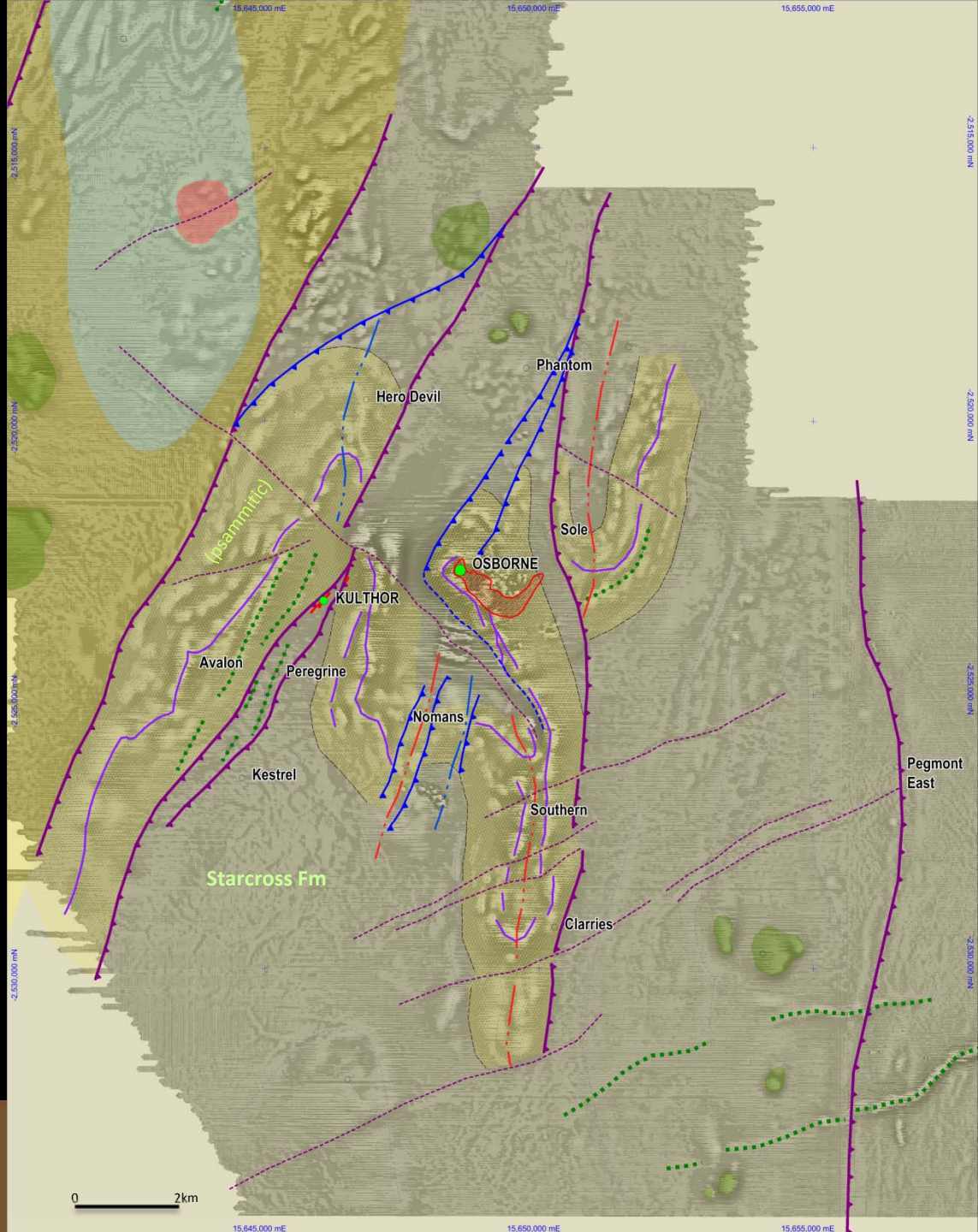




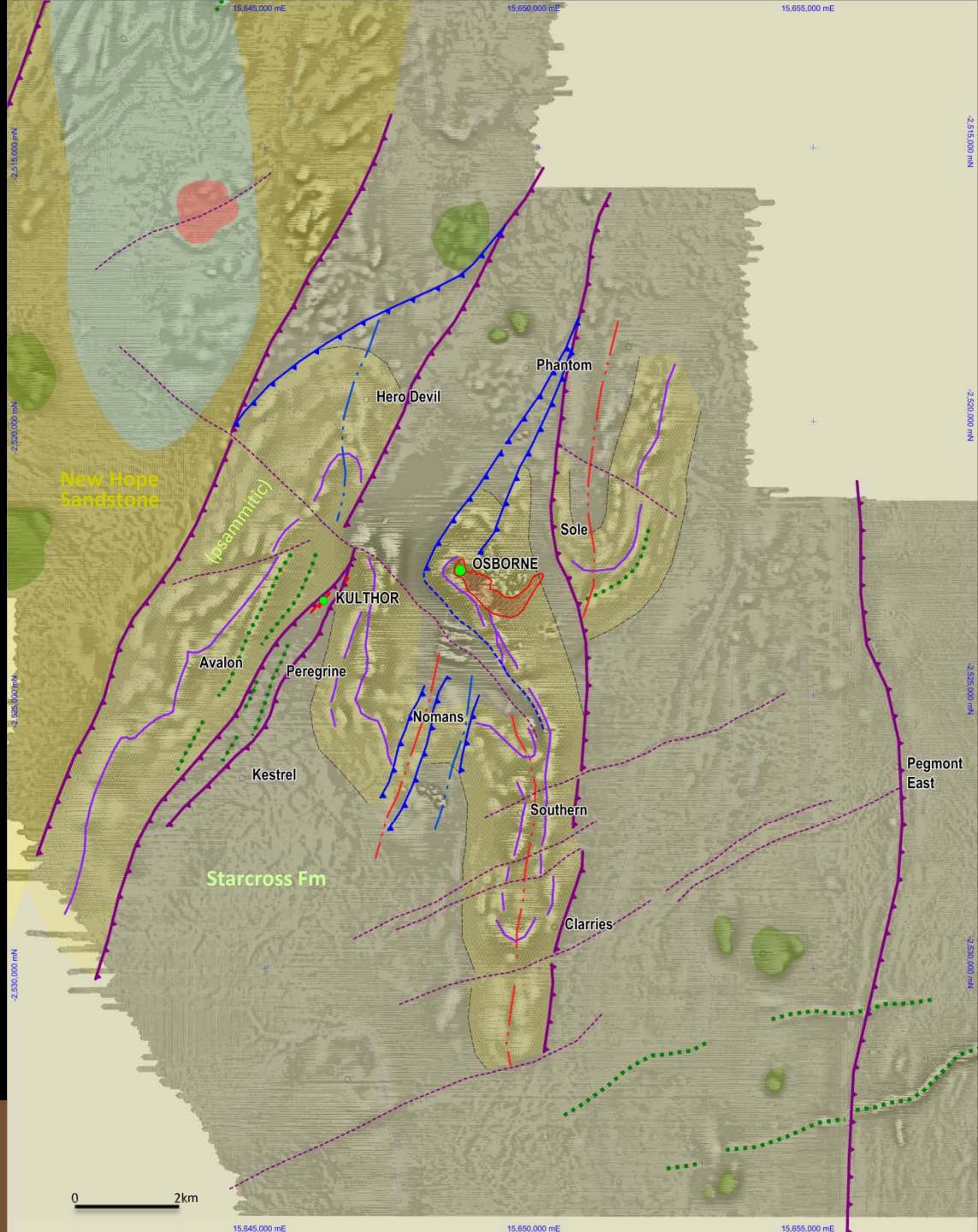
Kulthor-Osborne



Kulthor-Osborne

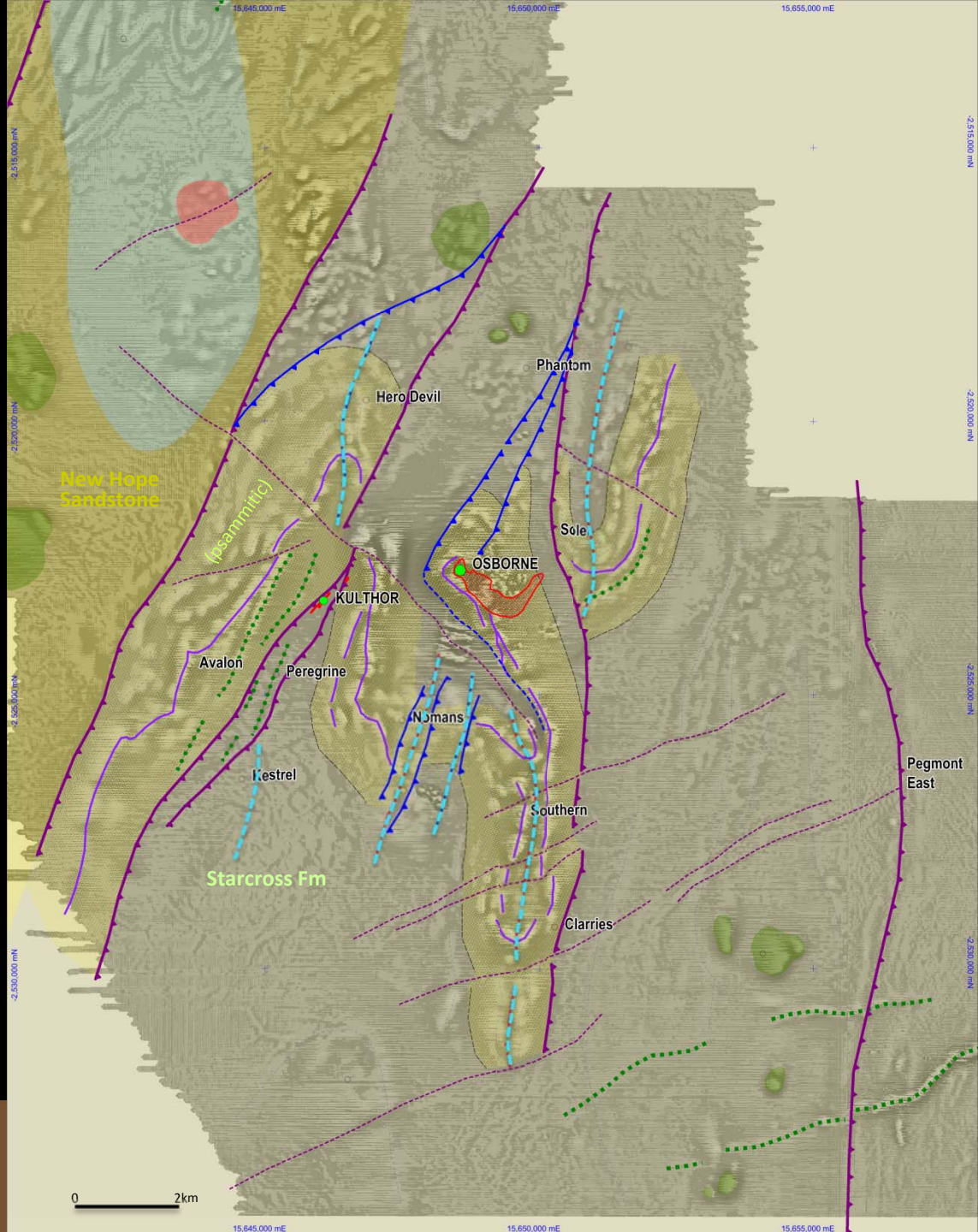


Kulthor-Osborne



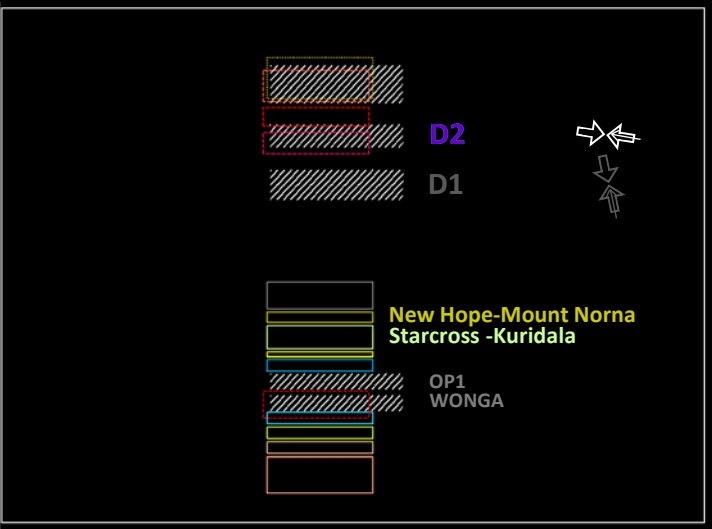
Kulthor-Osborne

- **disharmonic D2 folding during high grade metamorphism**
  > meta pelites-psammites, amphibolites, MIF



Kulthor-Osborne

- **disharmonic D2 folding during high grade metamorphism**
  > meta pelites-psammites, amphibolites, MIF
- **D2 Faulting … short limb, transpressive failure .. DUCTILE**



Kulthor-Osborne

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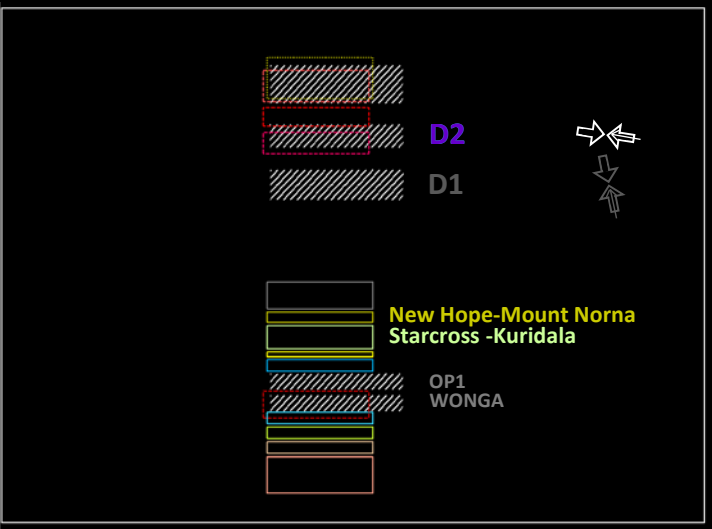
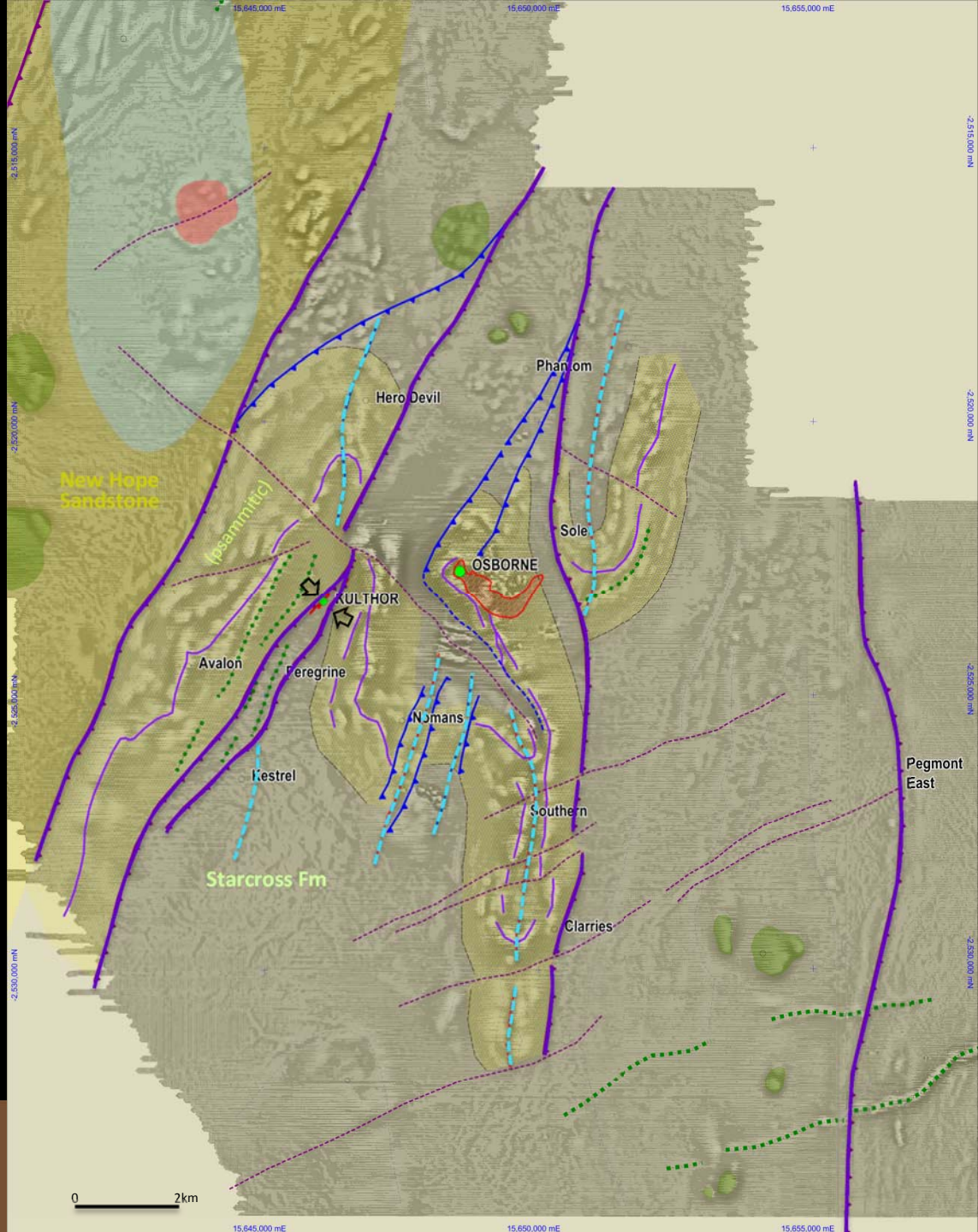
- **D2 Faulting … short limb, transpressive failure .. DUCTILE**
- **at Kulthor, D2 fault-juxtapositioning of opposite facing limbs**





Kulthor-Osborne

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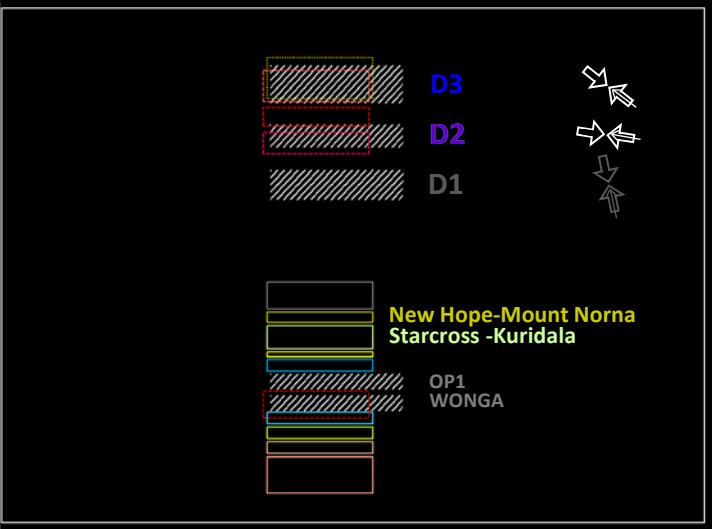
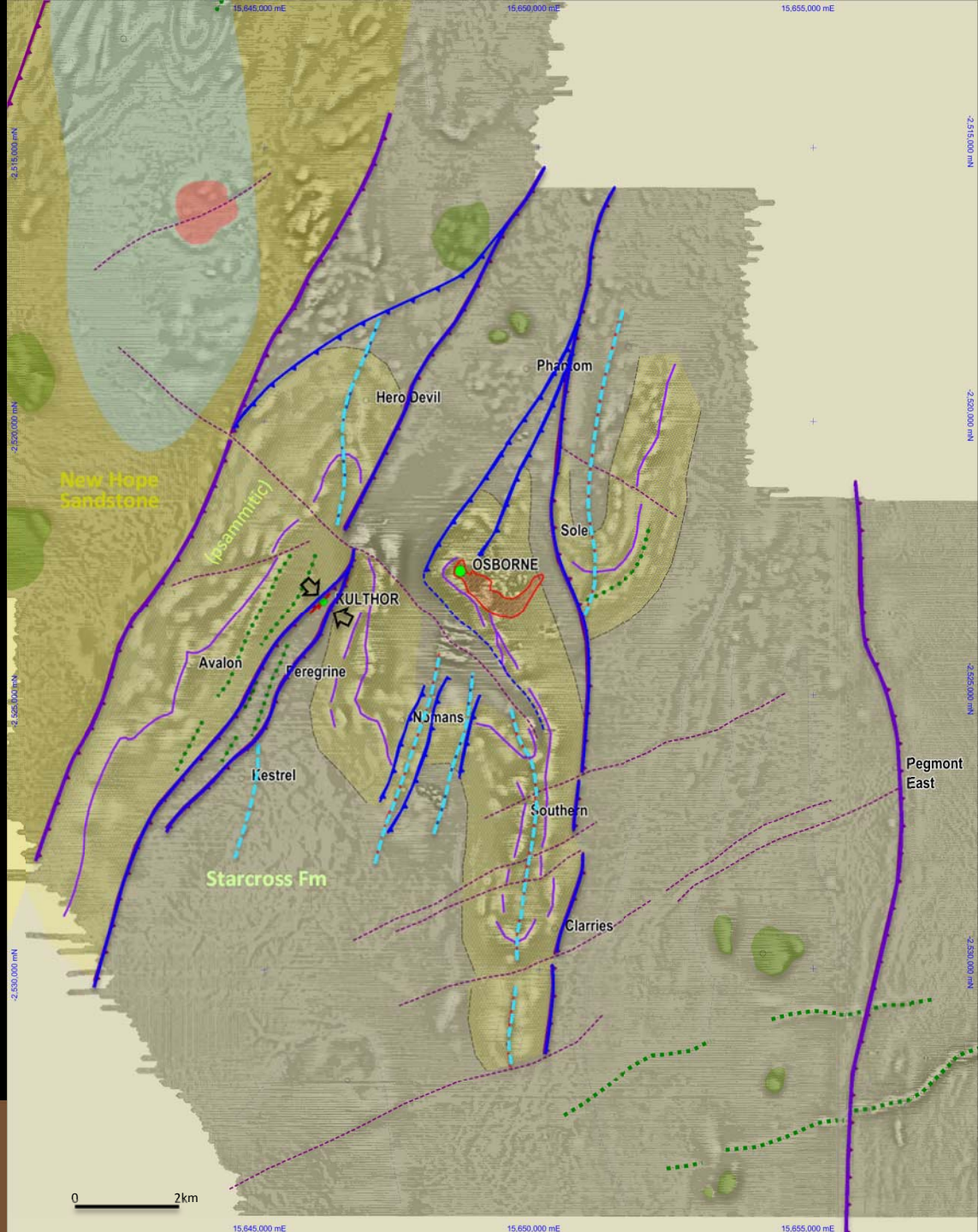
- **at Kulthor, D2 fault-juxtapositioning of opposite facing limbs**
- **D3 fault reactivation .. BRITTLE** (where lithology allows!)





Kulthor-Osborne

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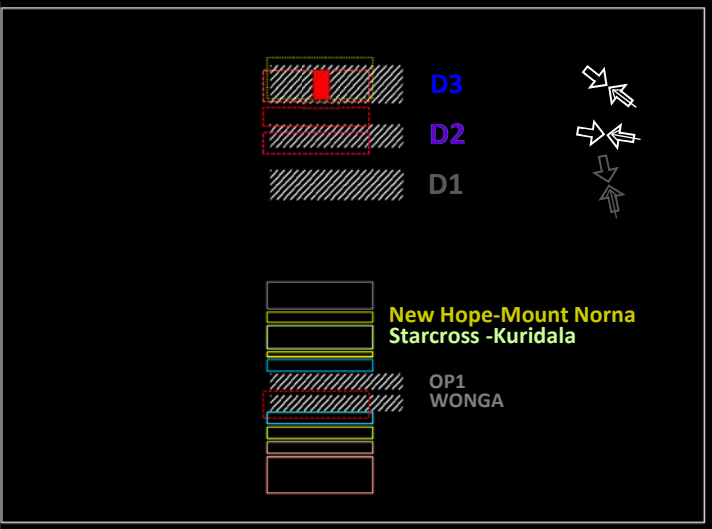
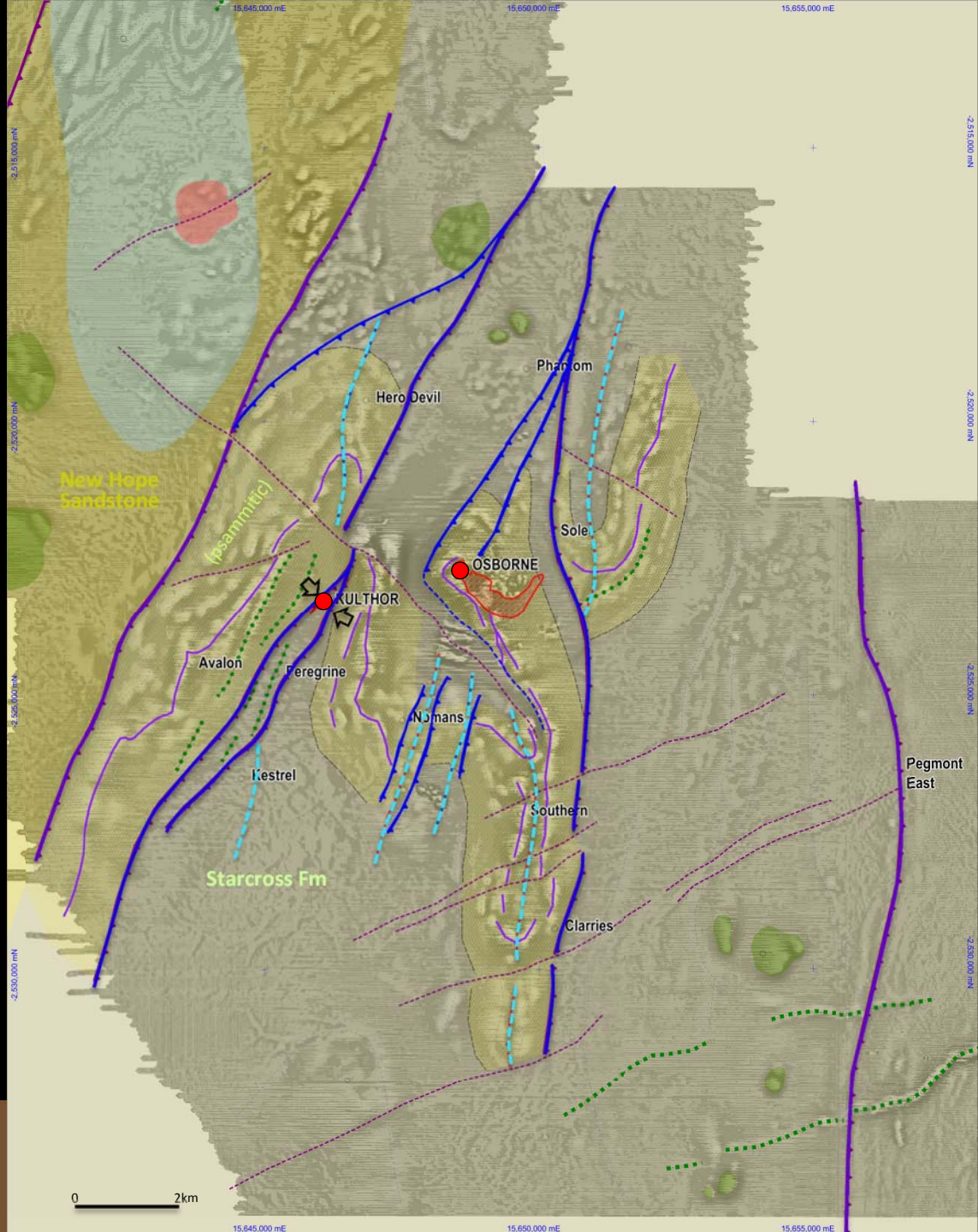
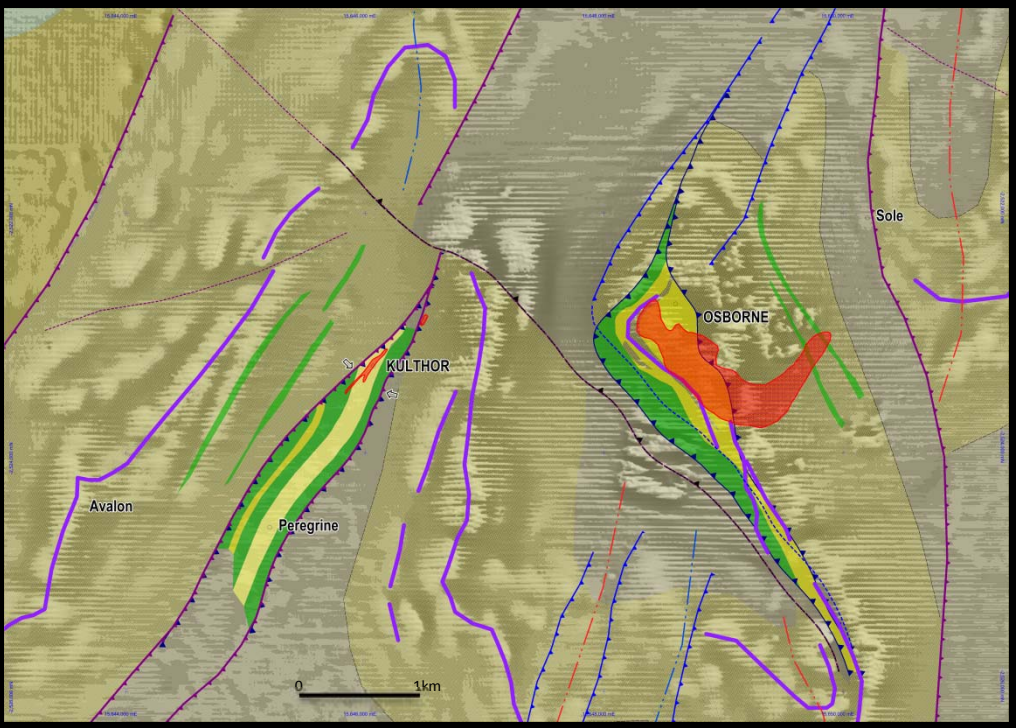
Kulthor & Osborne Cu-Au





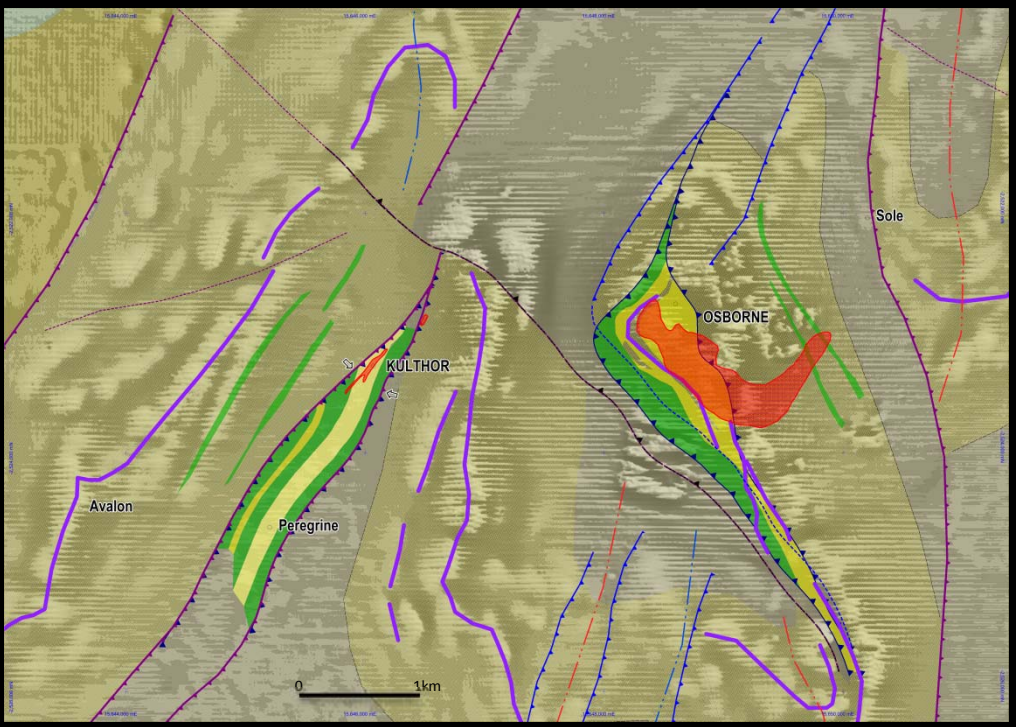
Kulthor-Osborne

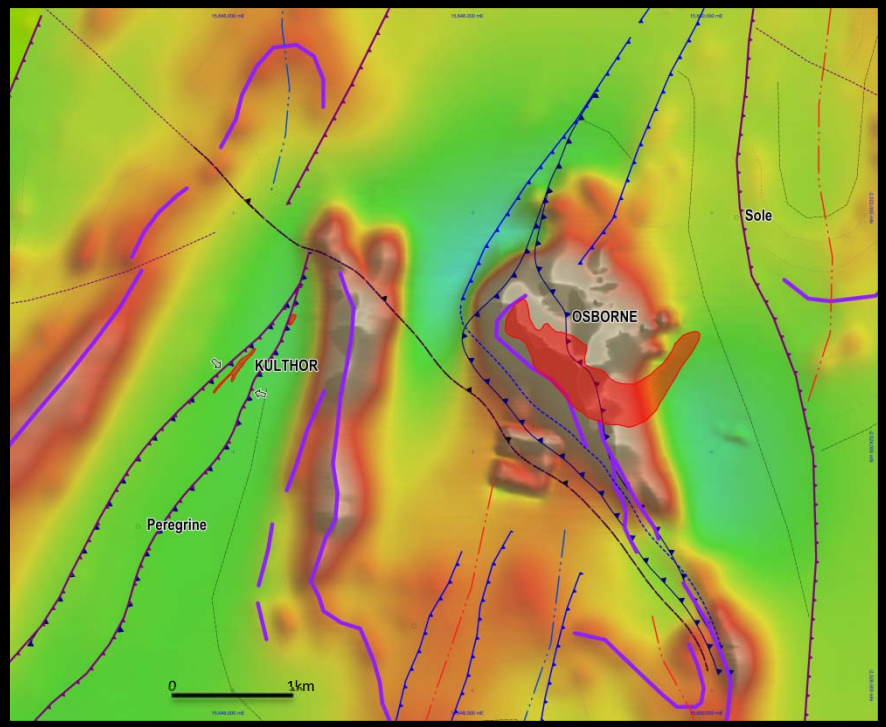


Both Kulthor & Osborne associated with similar, siliceous, meta psammitic-siltstone, amphibolite ± MIF packages (BRITTLE)

… in a sea of DUCTILE migmatitic, granoblastic & pegmatitic, interbedded meta-pelites & psammites.

Kulthor-Osborne





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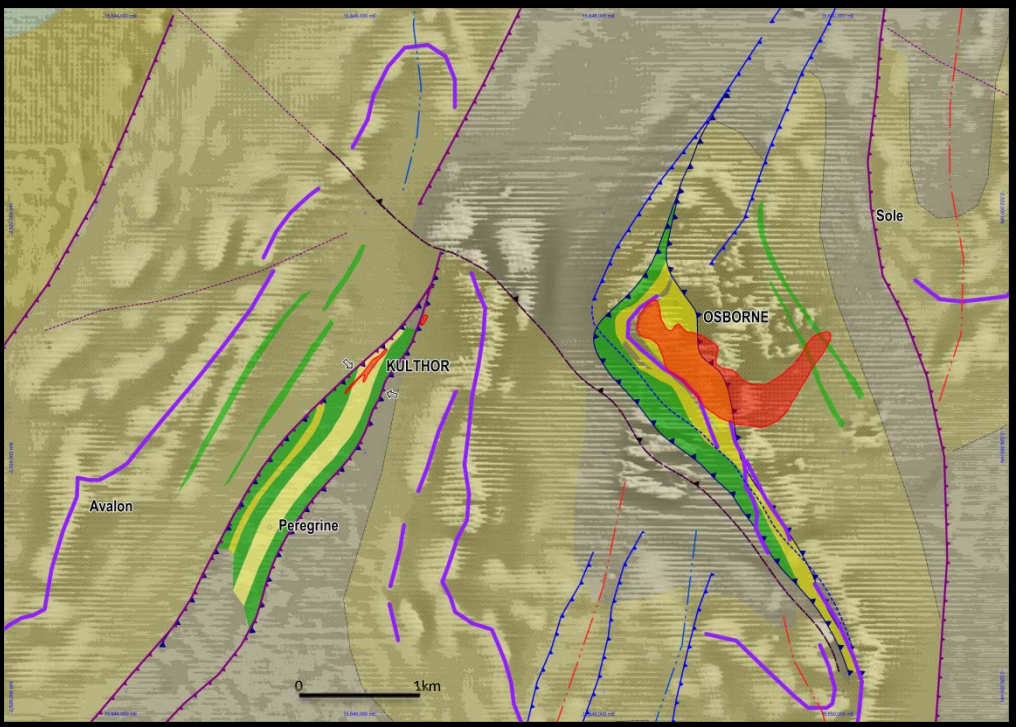
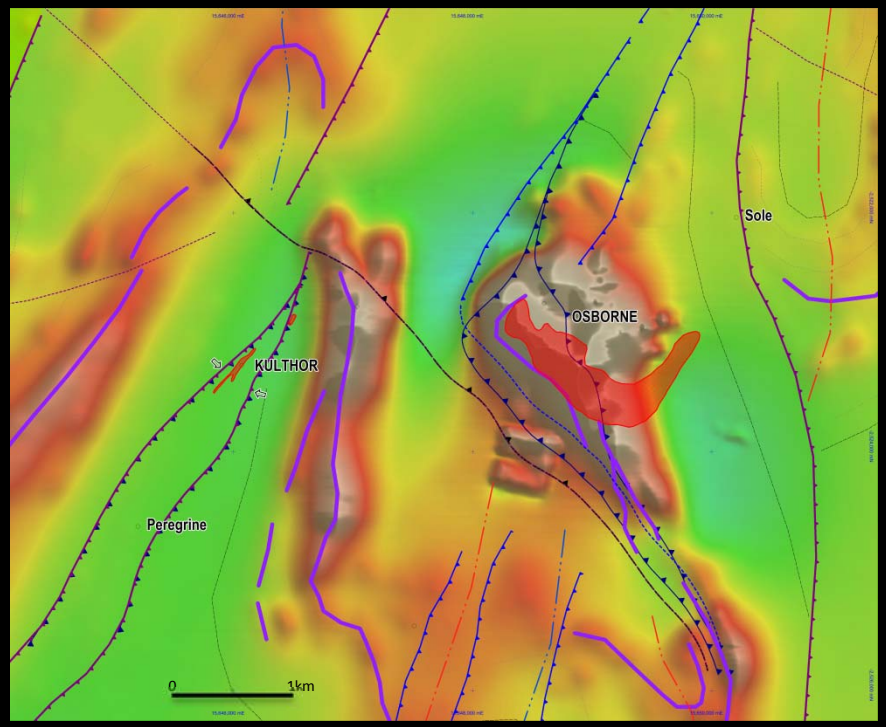
Kulthor
sulphide-dominated
ISCG

Osborne
oxide-dominated
IOCG

Kulthor-Osborne





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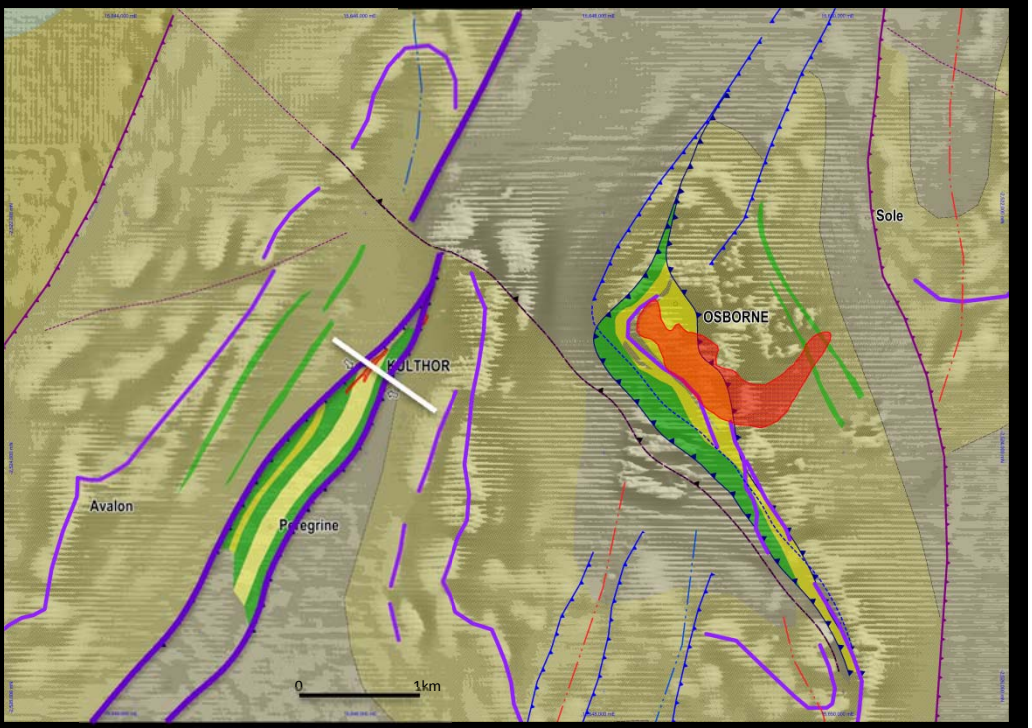
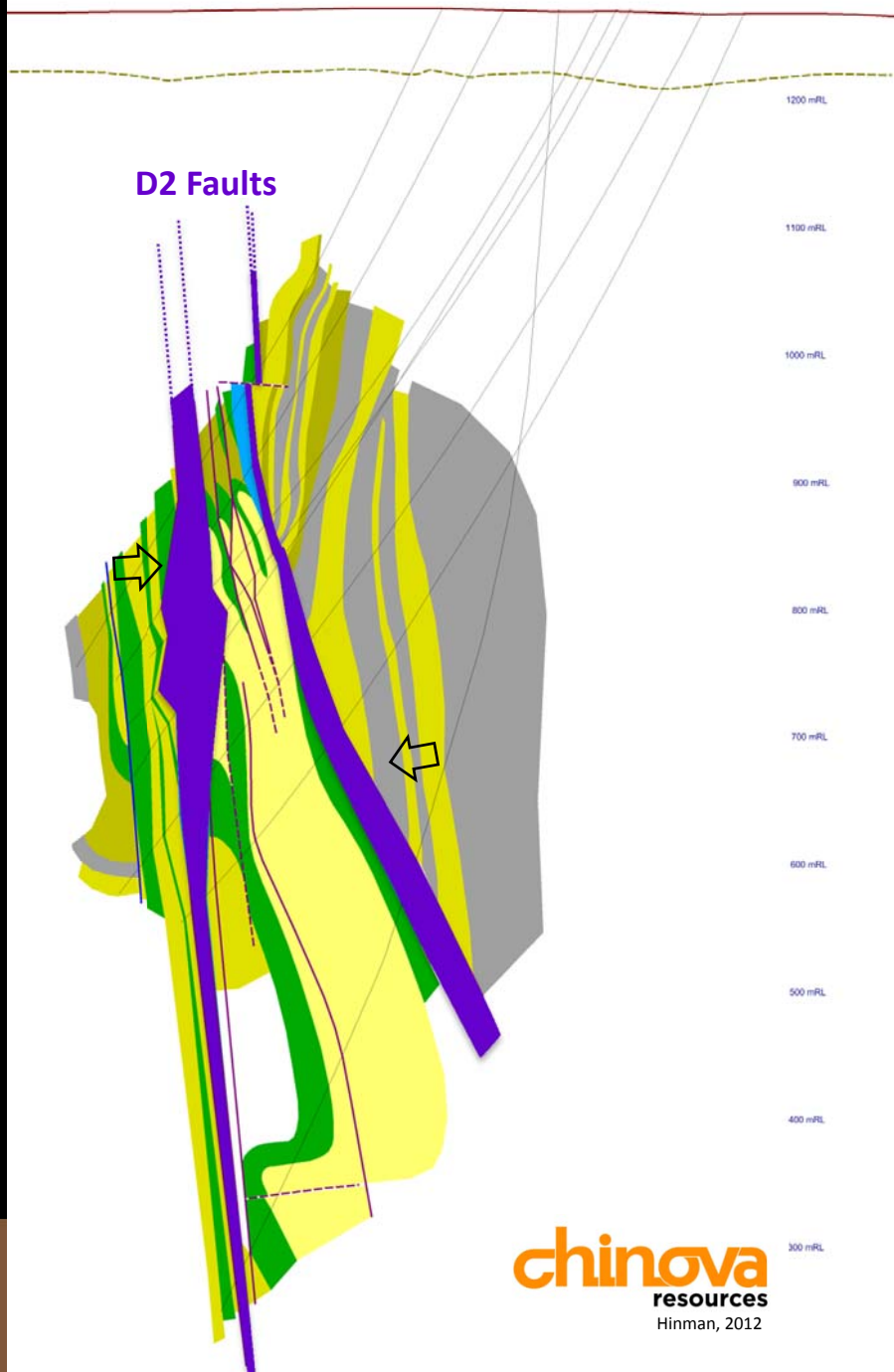
Kulthor
sulphide-dominated
ISCG

Osborne
oxide-dominated
IOCG

Both post-peak metamorphism & brittle, fracture & breccia controlled
Adshead (1995), King (2001) ***despite*** Re-Os date of Gauthier et al (2001)

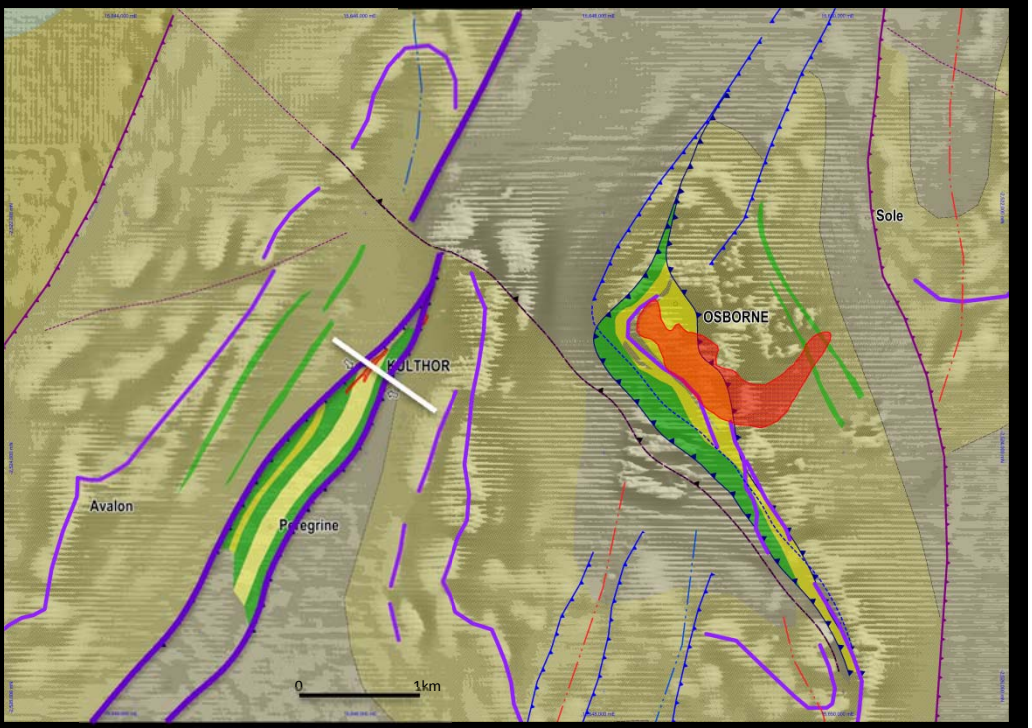
Kulthor Section 8





Hinman, 2012

Kulthor Section 8



Central Block comprising ….

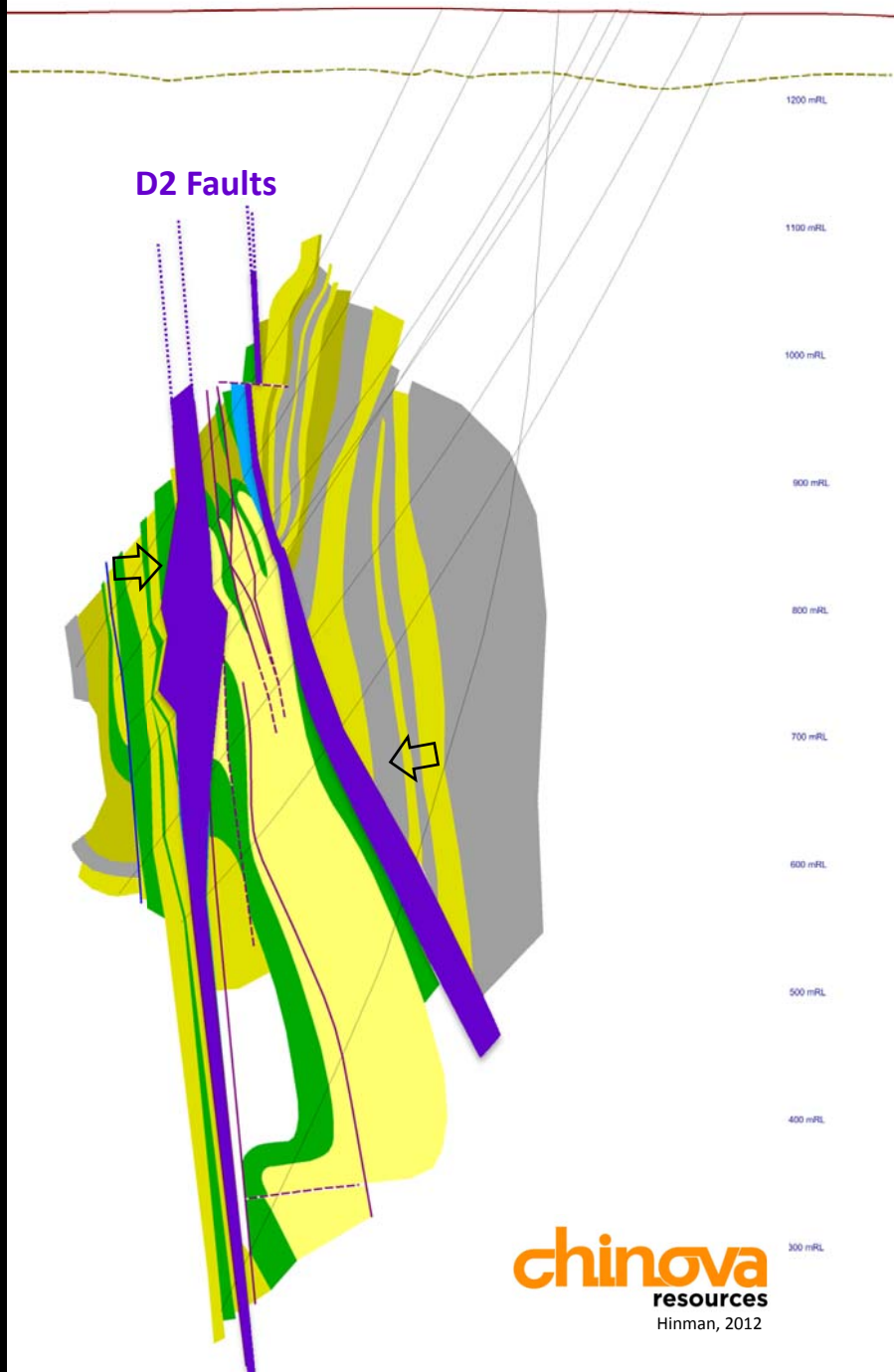
BRITTLE, siliceous, SULPHIDIC, finely-laminated sediment

amphibolite

psammite-dominant

mixed psammite-pelite

…. in a FW and HW sea of DUCTILE migmatitic, granoblastic & pegmatitic, interbedded meta-pelites & psammites.



chinova resources

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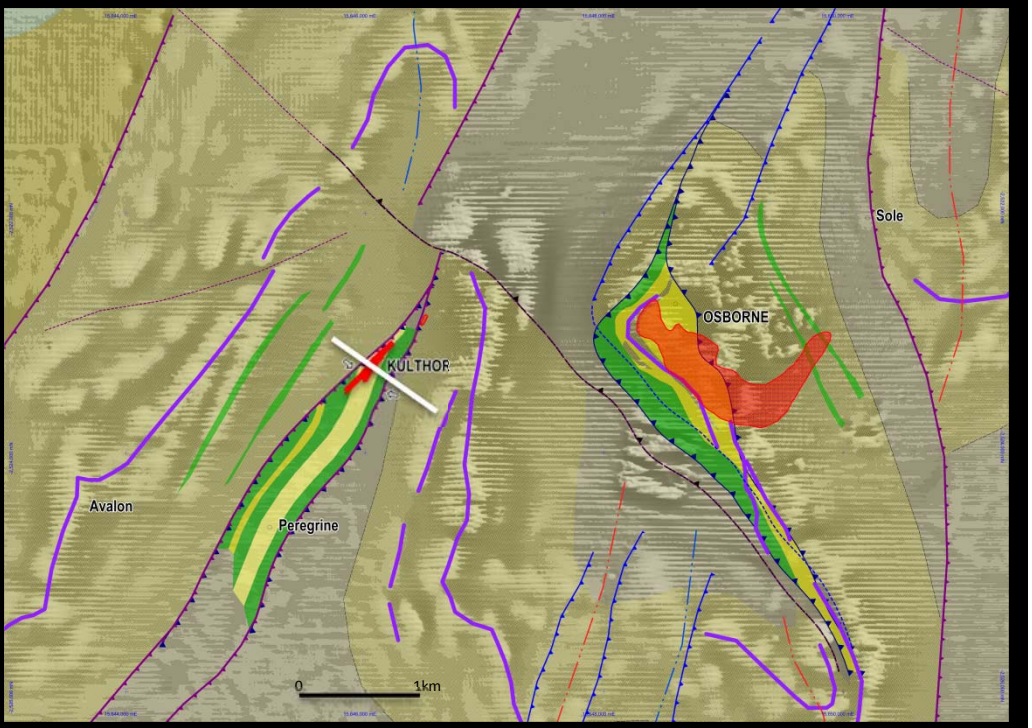
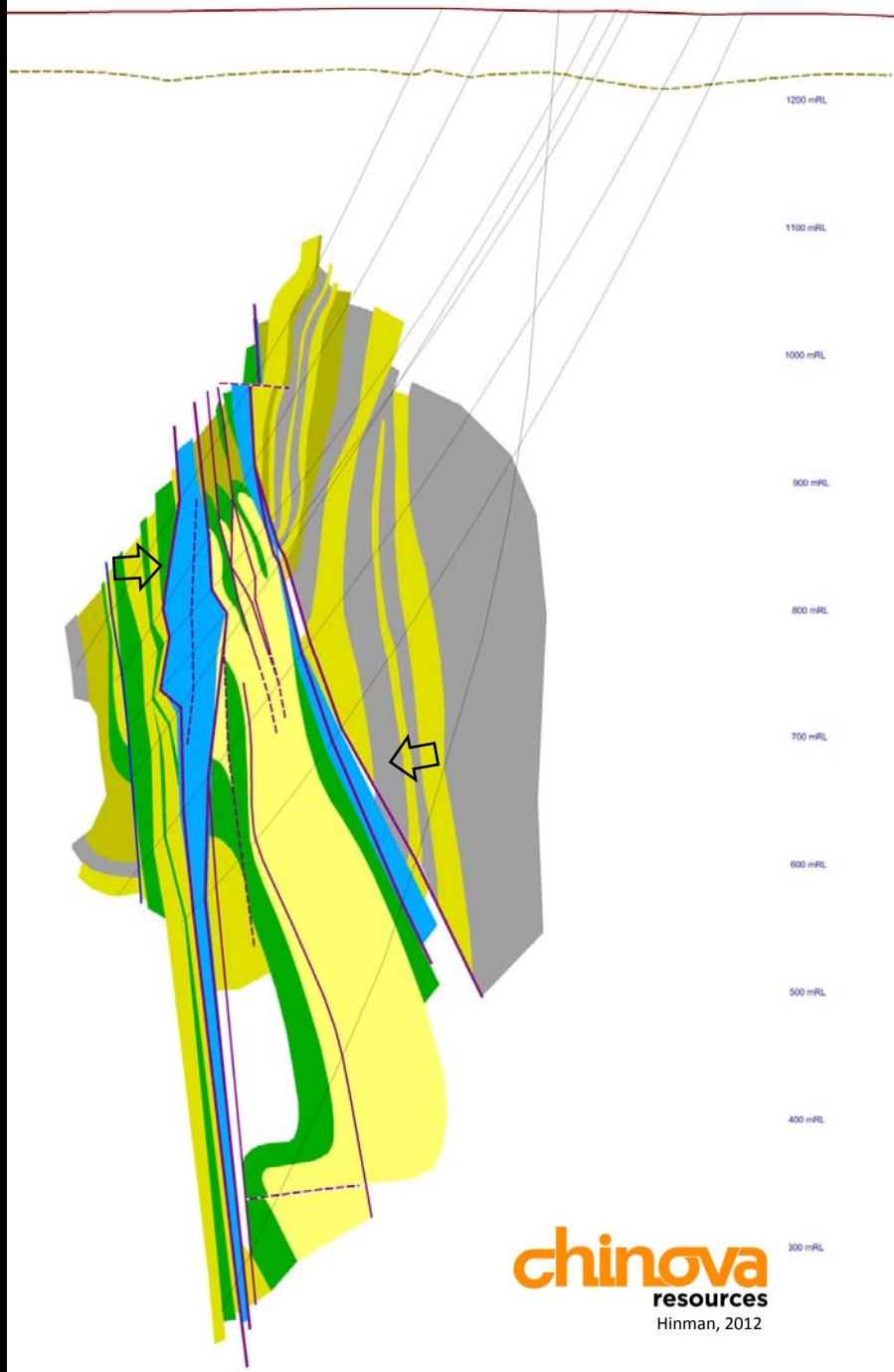


Post-D2 relaxation phase, probably still at high grade …

mega-coarsely crystalline DOLOMITE



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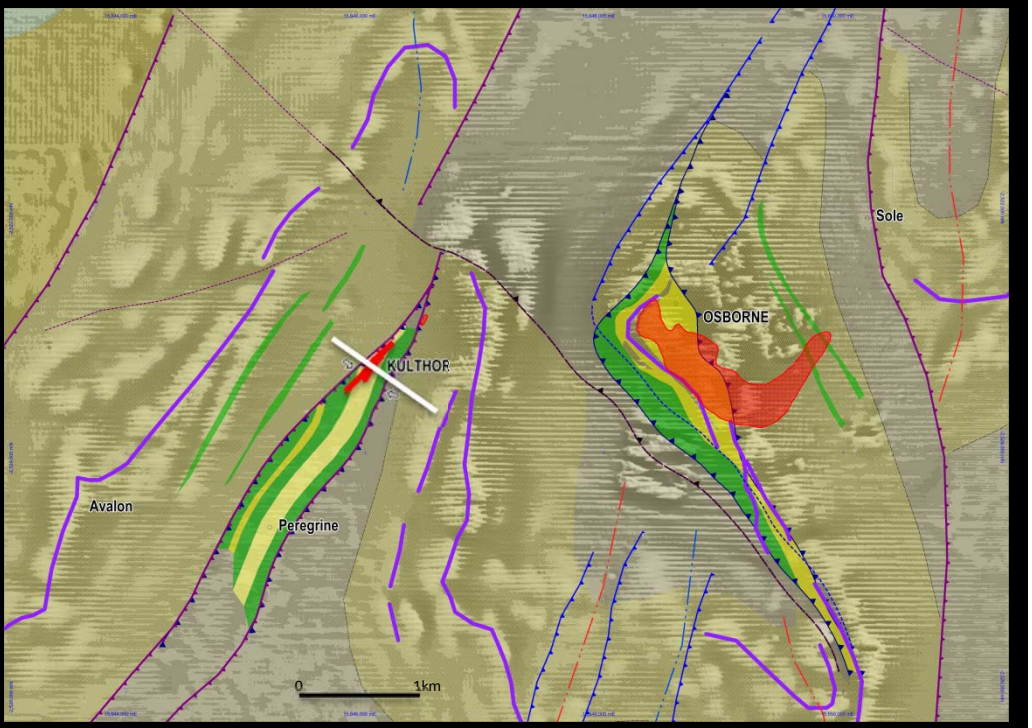

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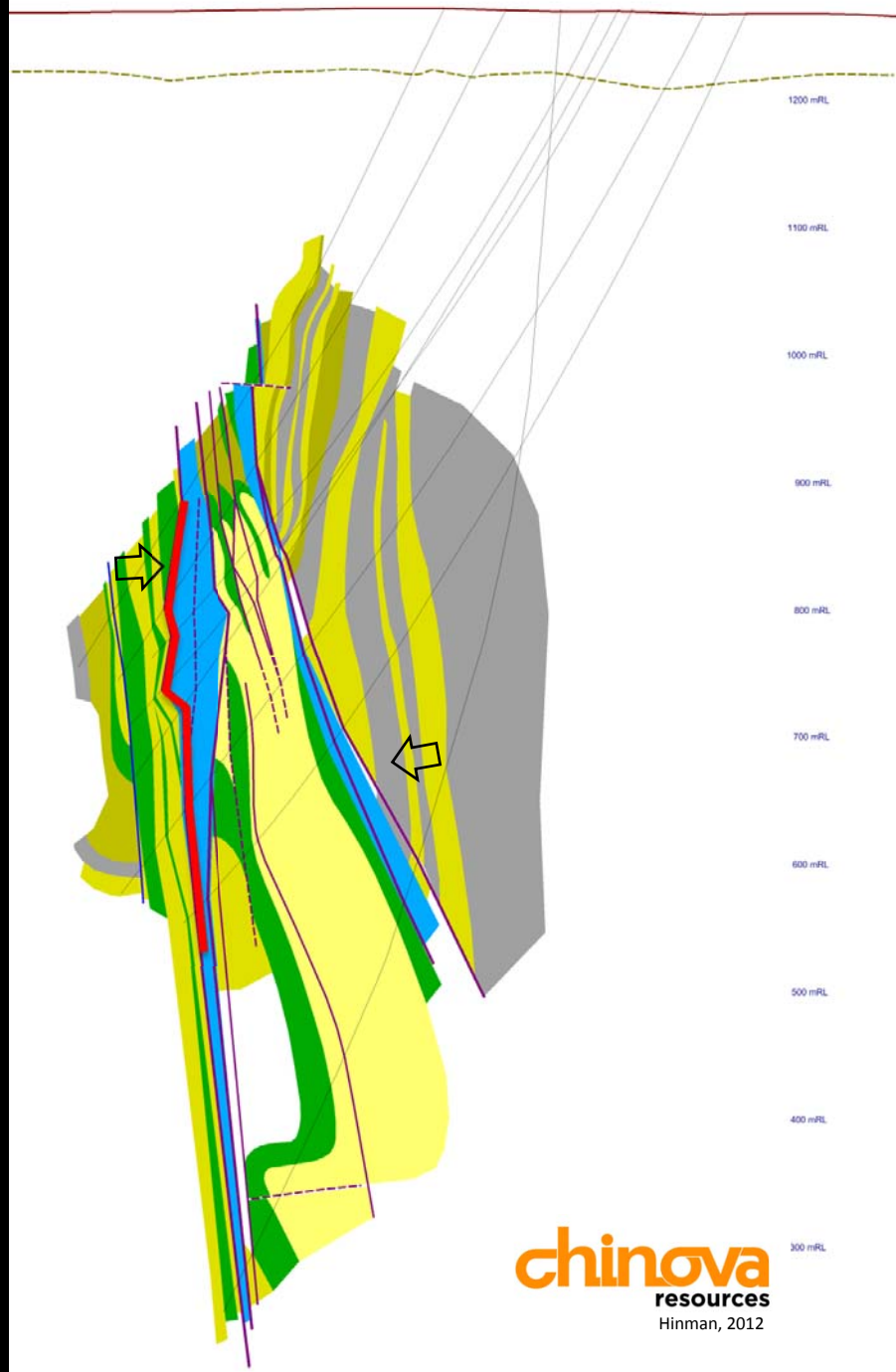

chinova resources

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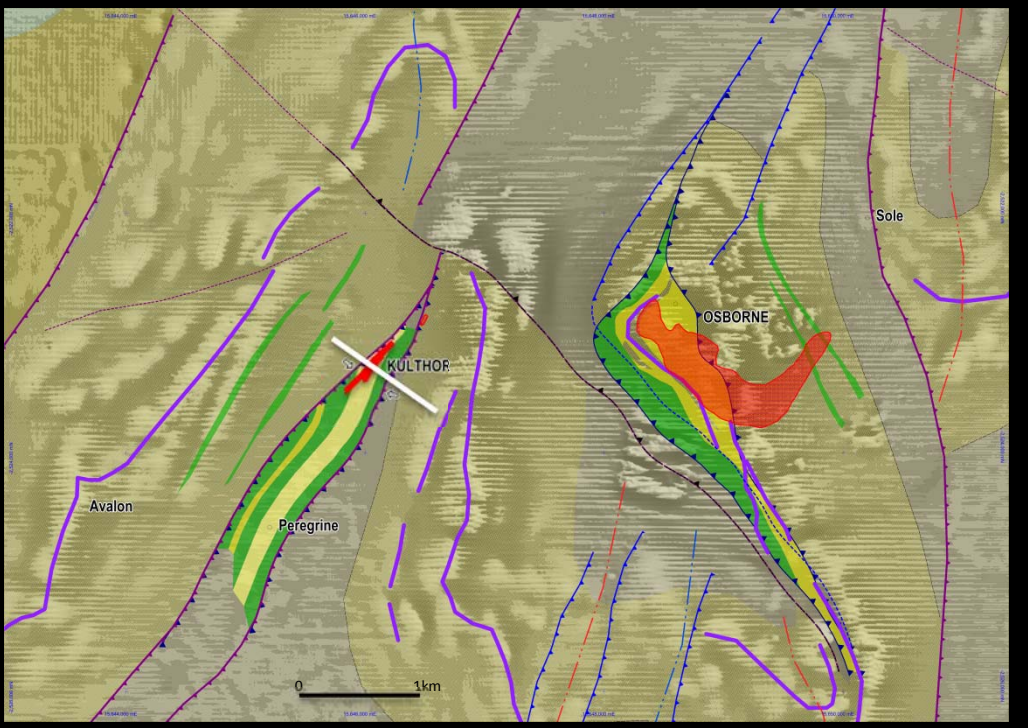

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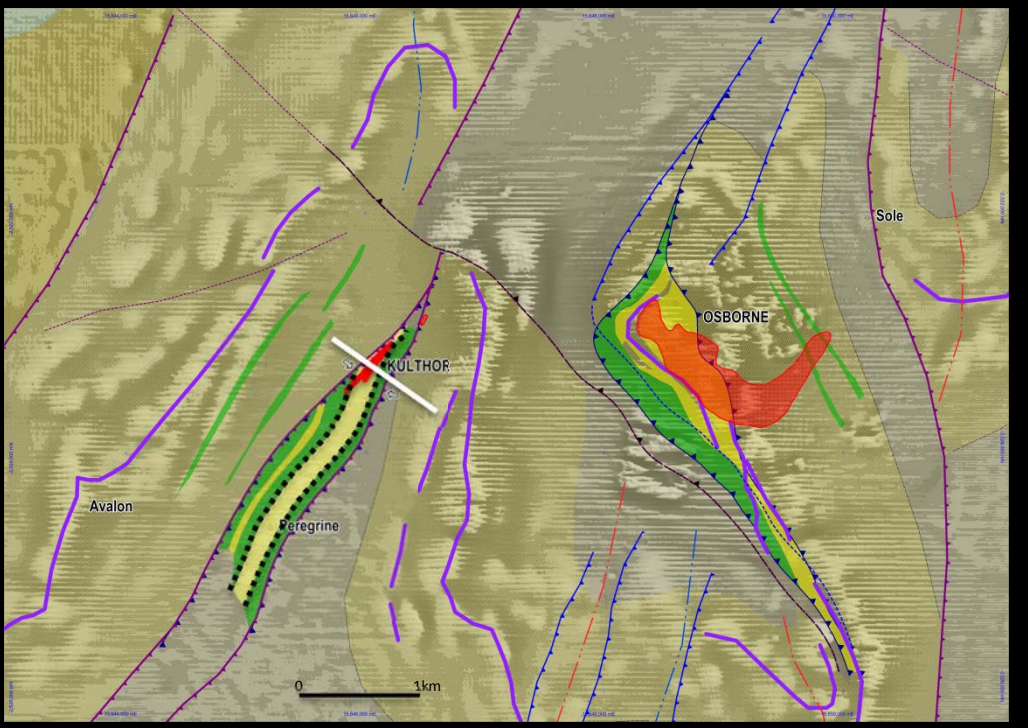
D3 complex, breccia & fracture zones in thickest DOL .. **Central** or **KC Lodes**

chinova resources

Hinman, 2012

Kulthor Section 8



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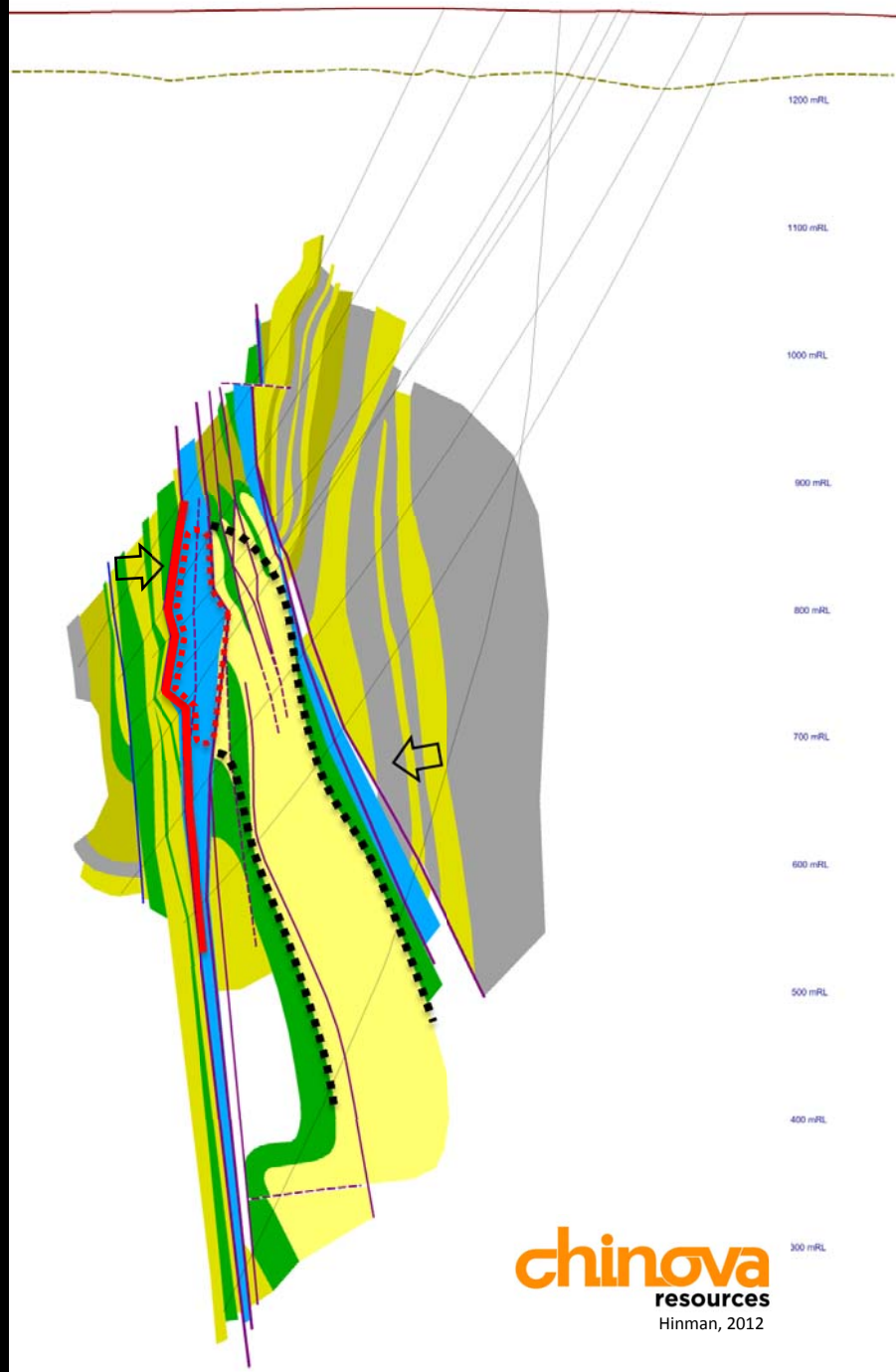

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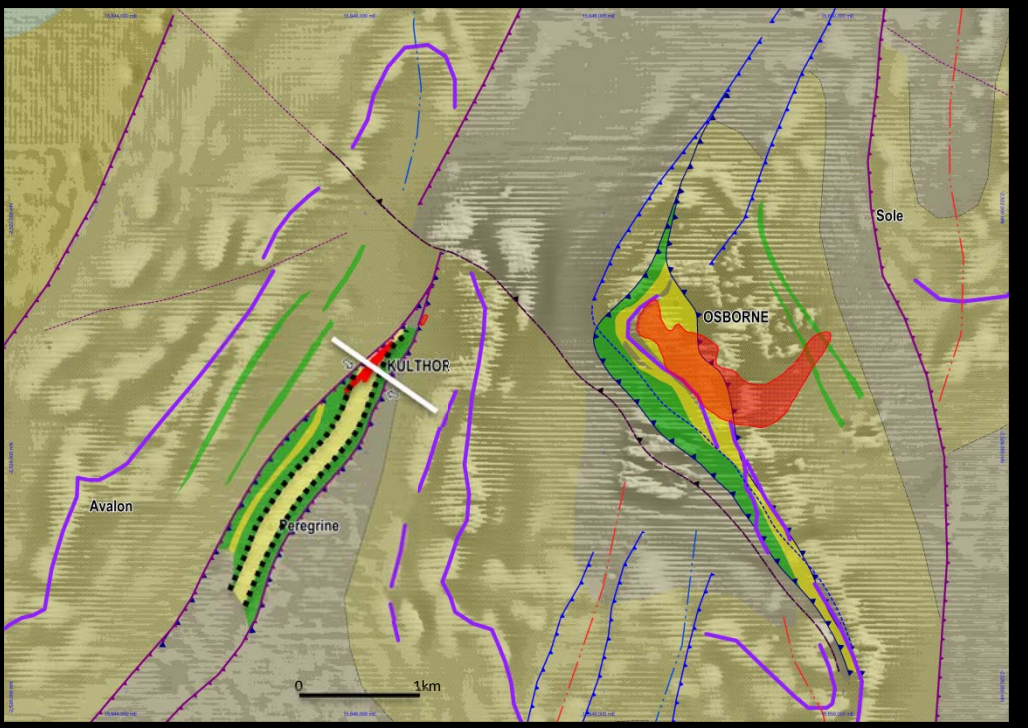

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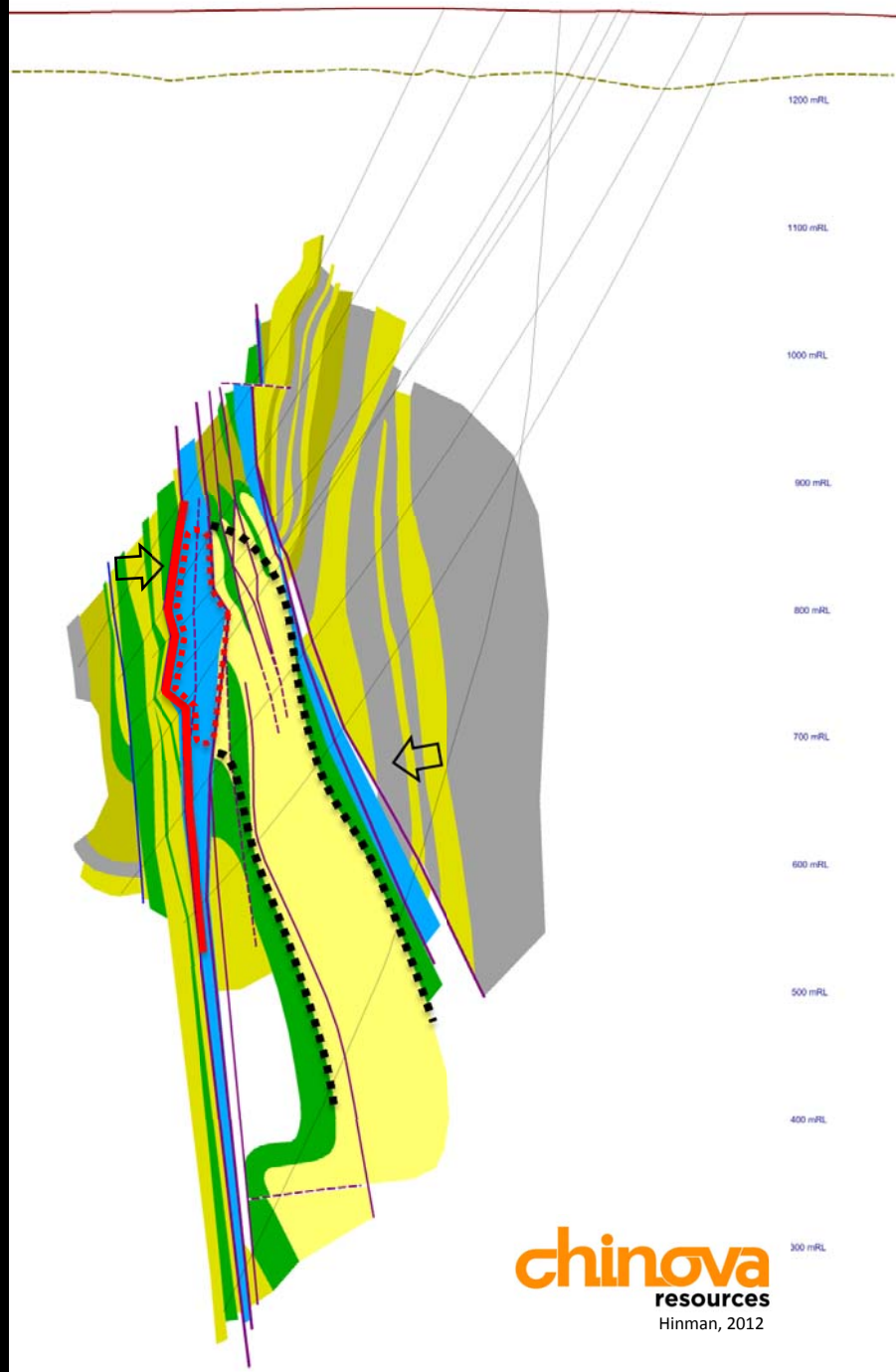

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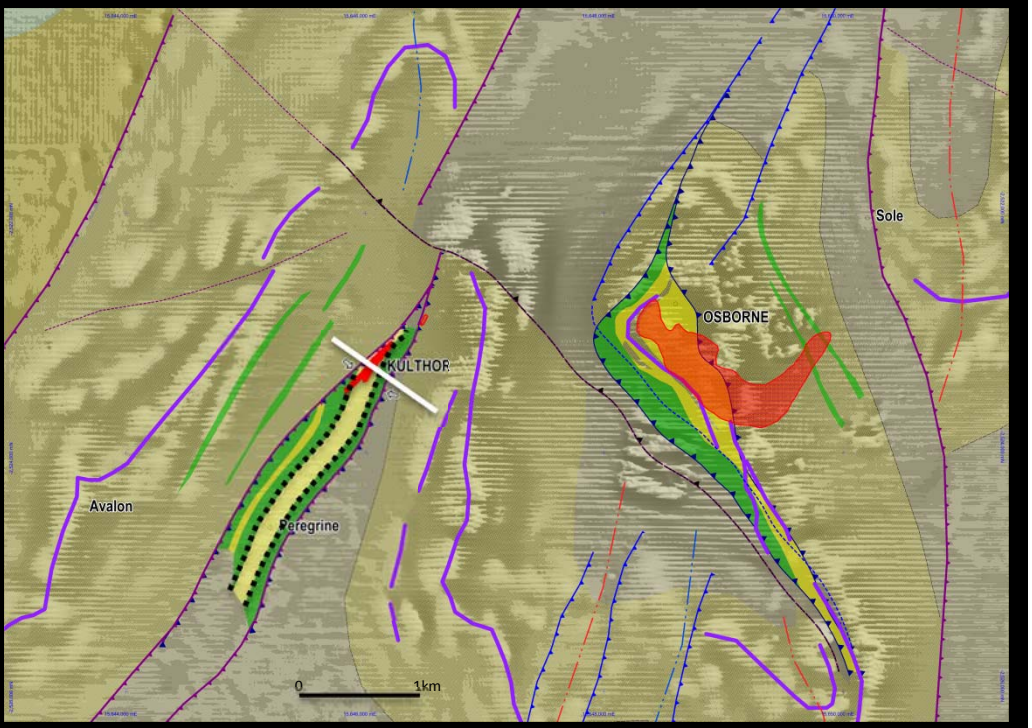

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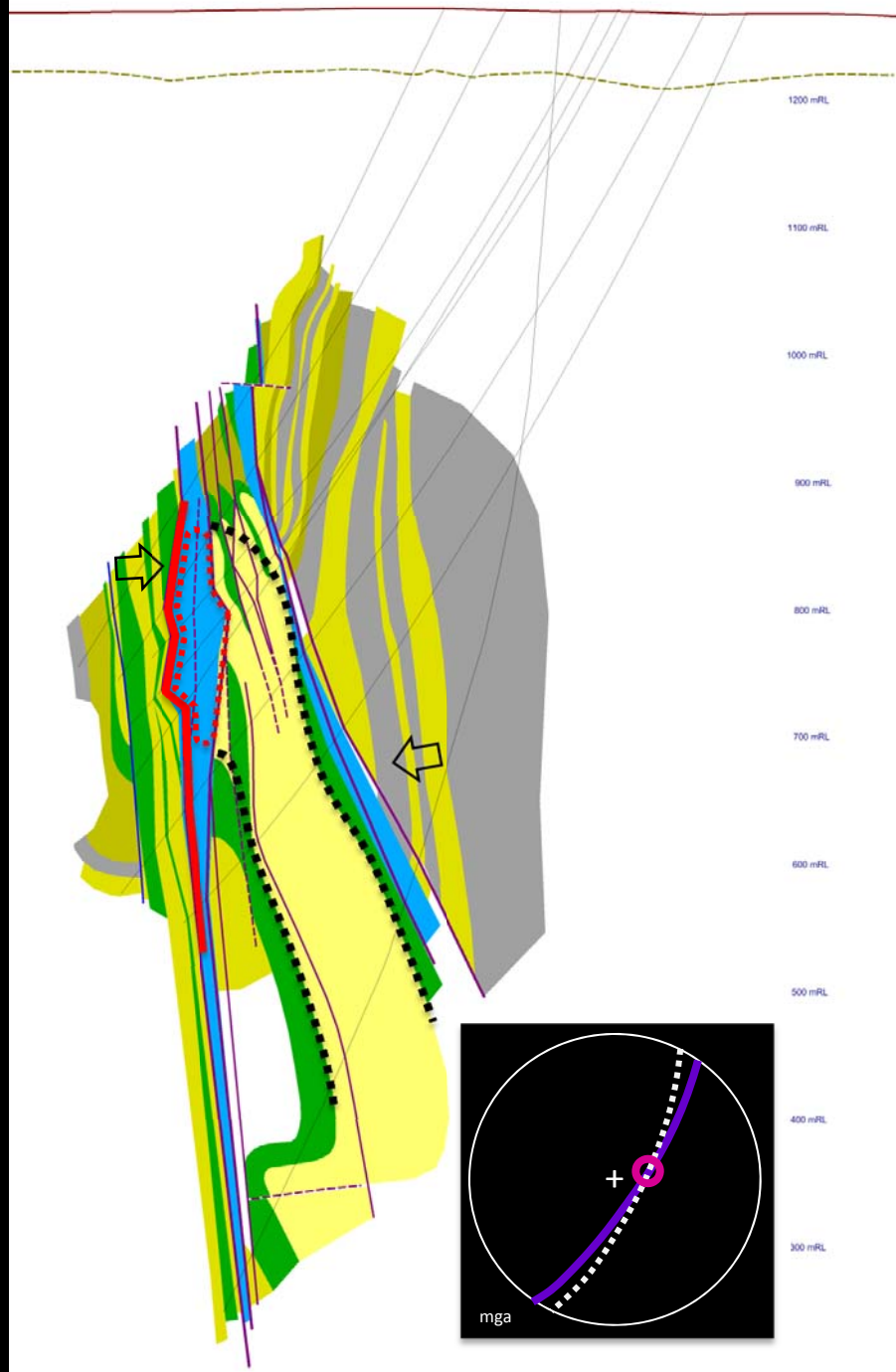
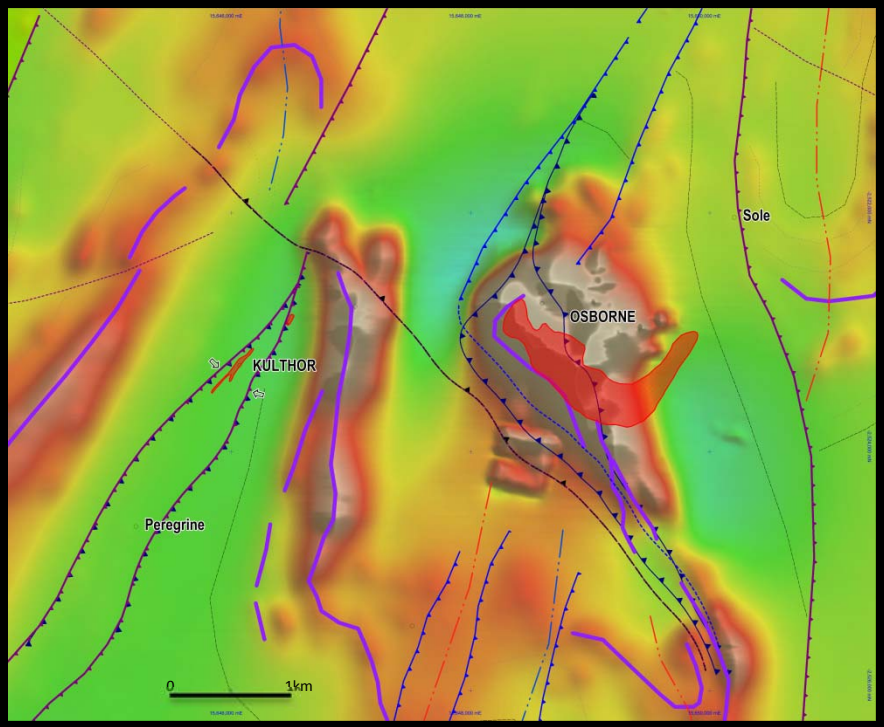


Kulthor-Osborne



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sulphide-dominated
ISCG

Osborne
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IOCG

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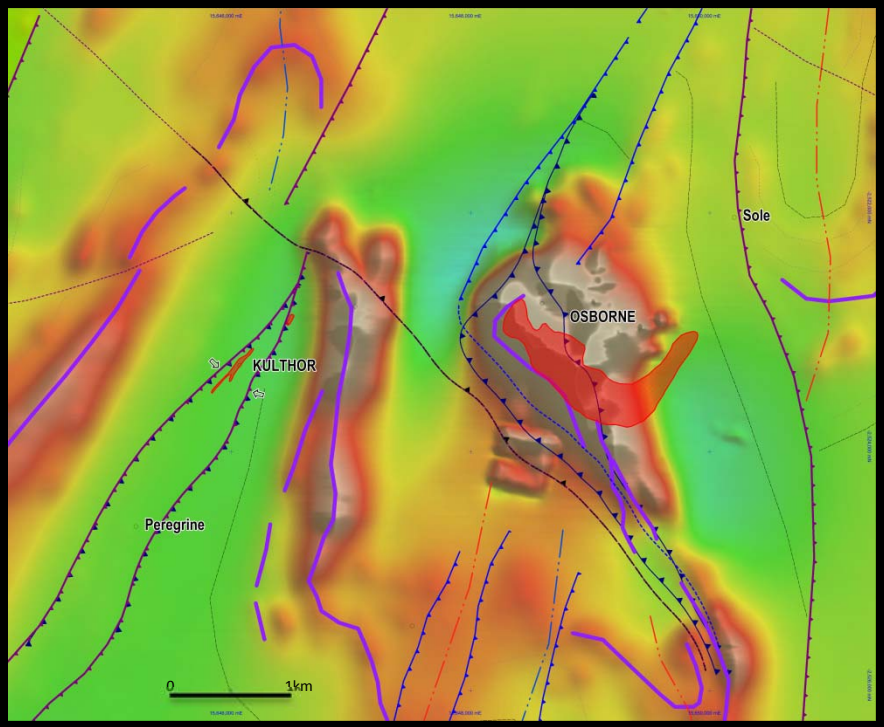
Adshead (1995), King (2001), Hinman (2012)

Kulthor-Osborne



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1595Ma Re-Os molybdenite
Gauthier et al (2001)

vs

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

Merlin
Deformed Molybdenite

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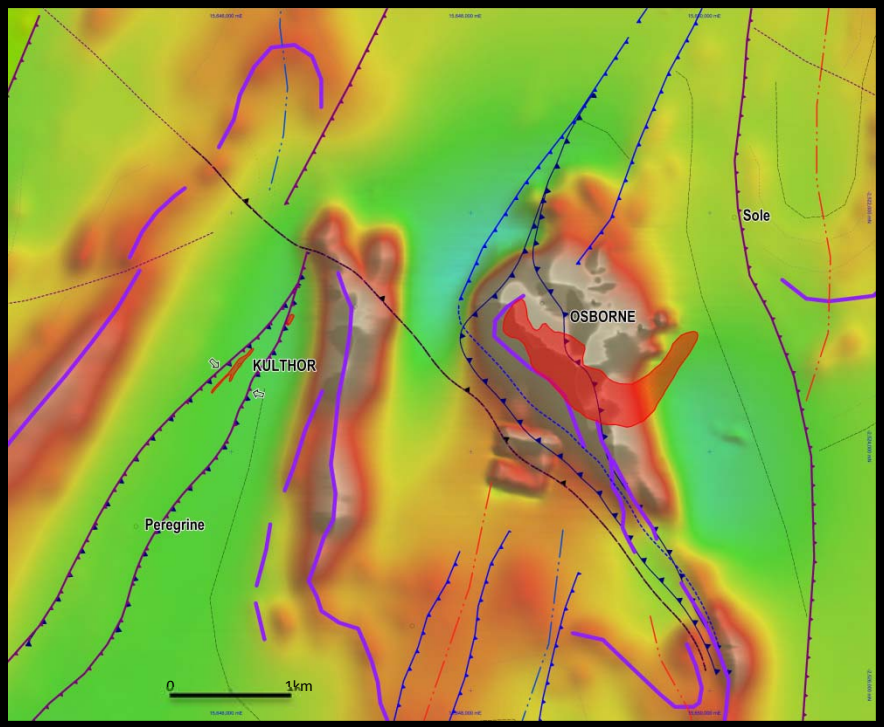

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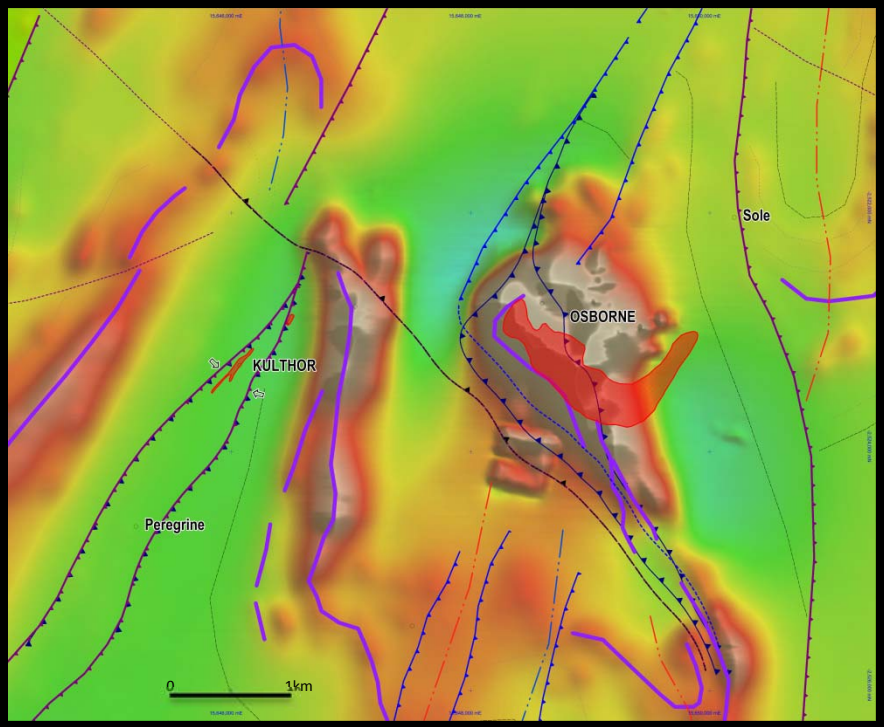
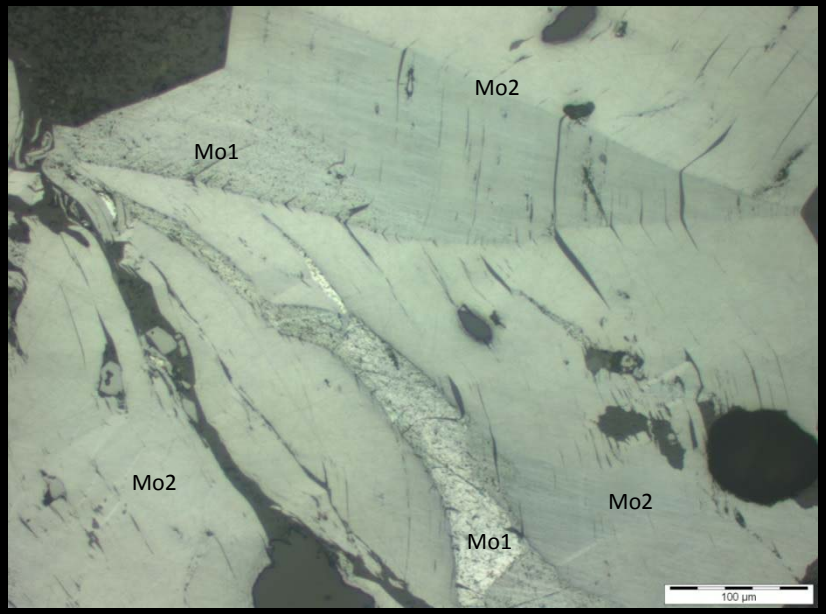


Merlin Mo1-Mo2, Subira Sharma CODES (2015)



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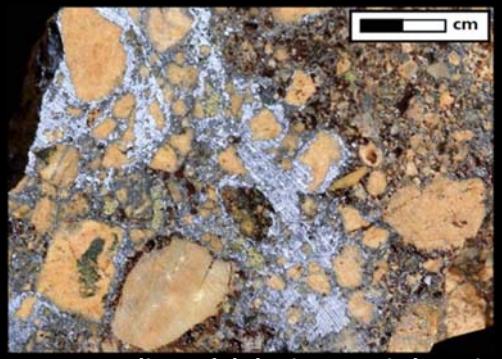

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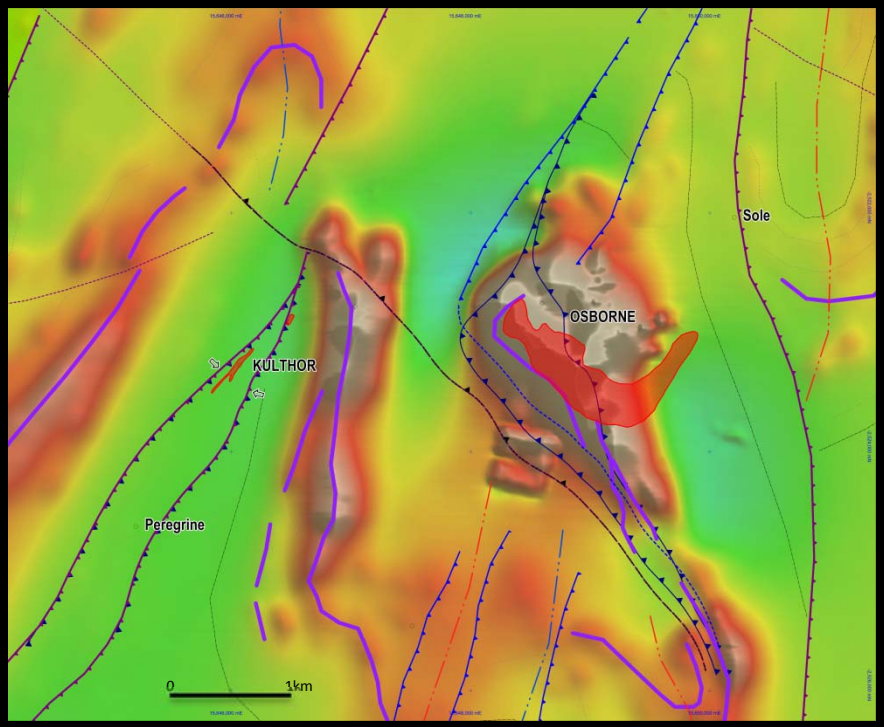

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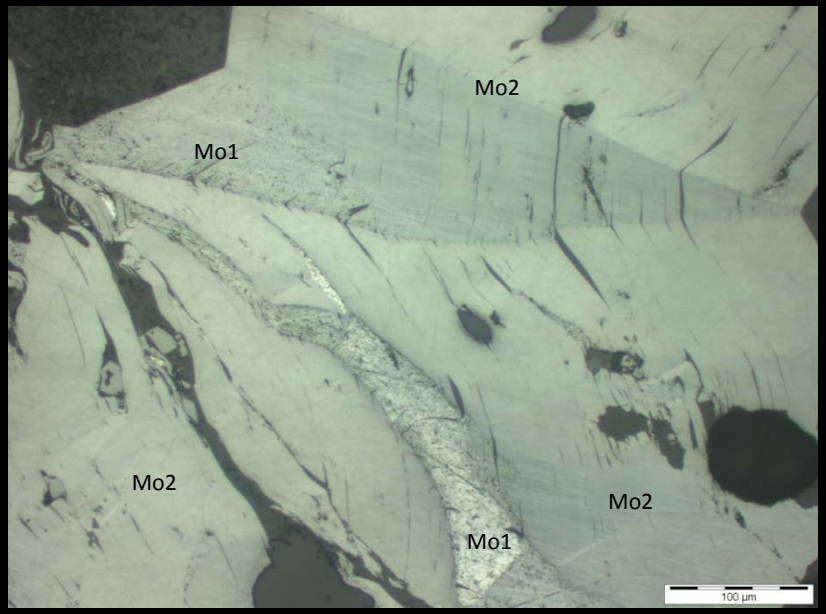

Mo1 primarily precipitated, inclusion-rich, **Re-rich**
Mo2 deformed-kinked, inclusion-cleared, **Re-depleted**

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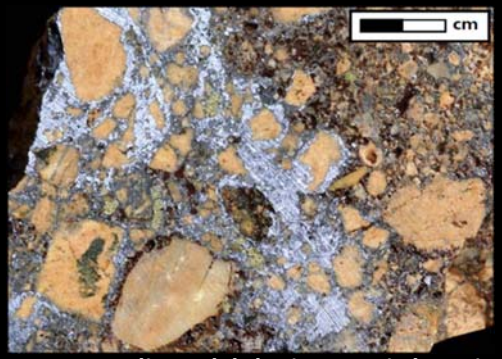

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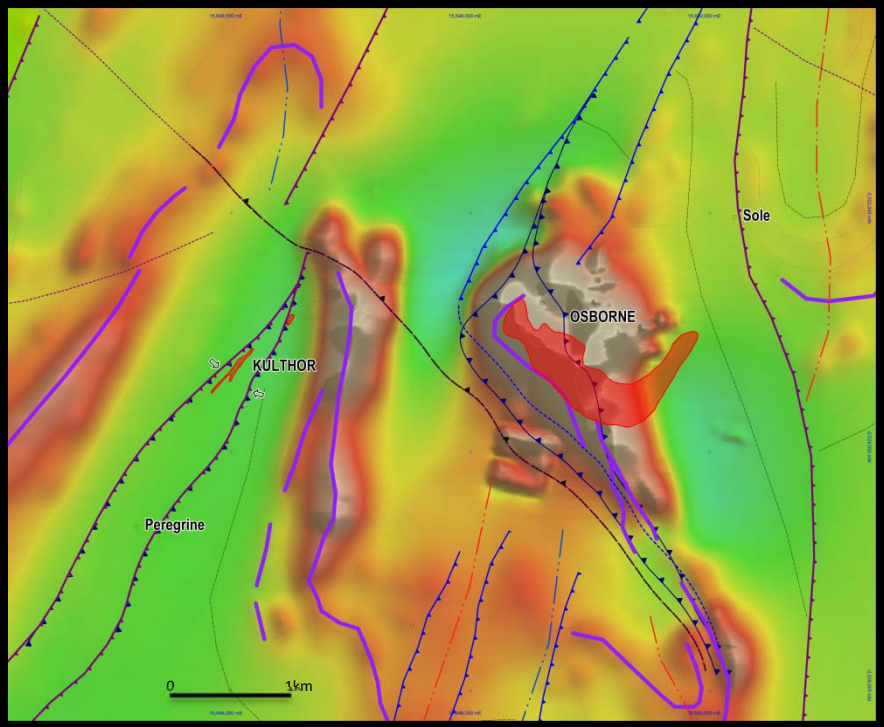

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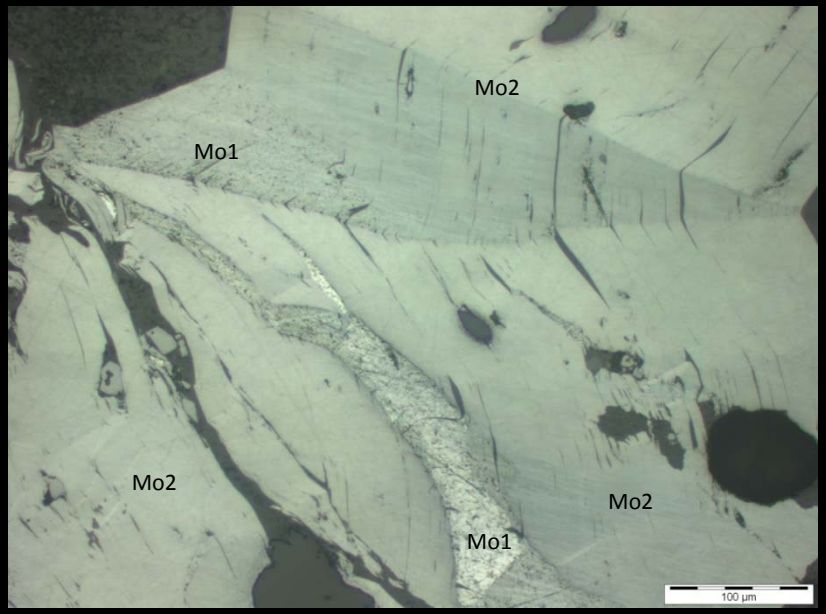

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disturbed Re-Os system
Re-depletion > older ages

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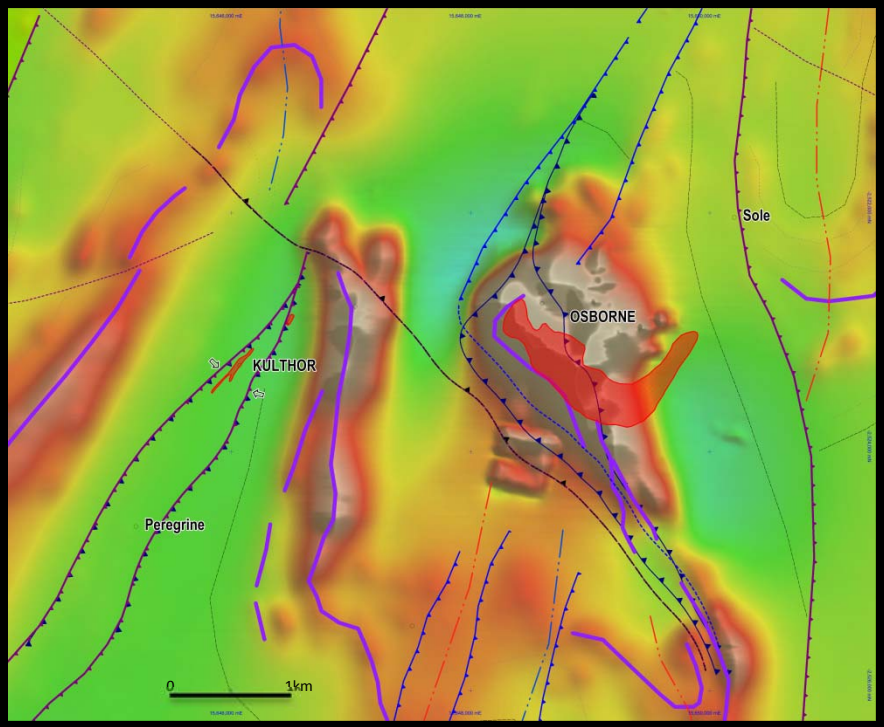

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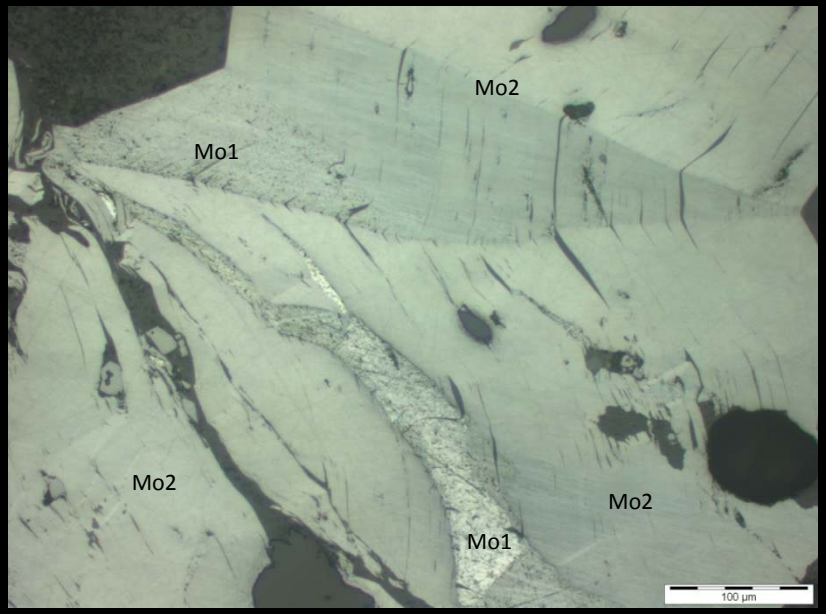

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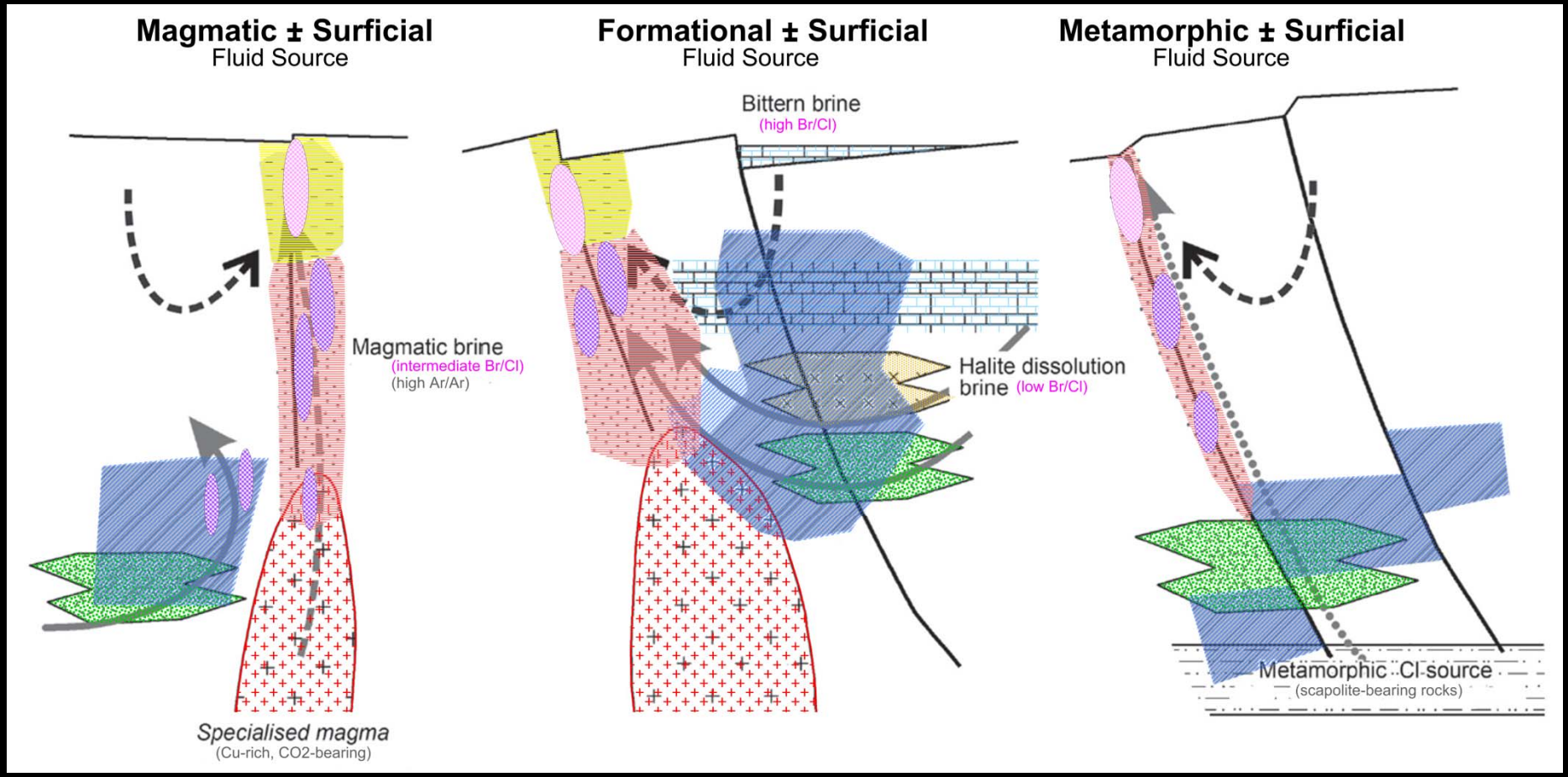

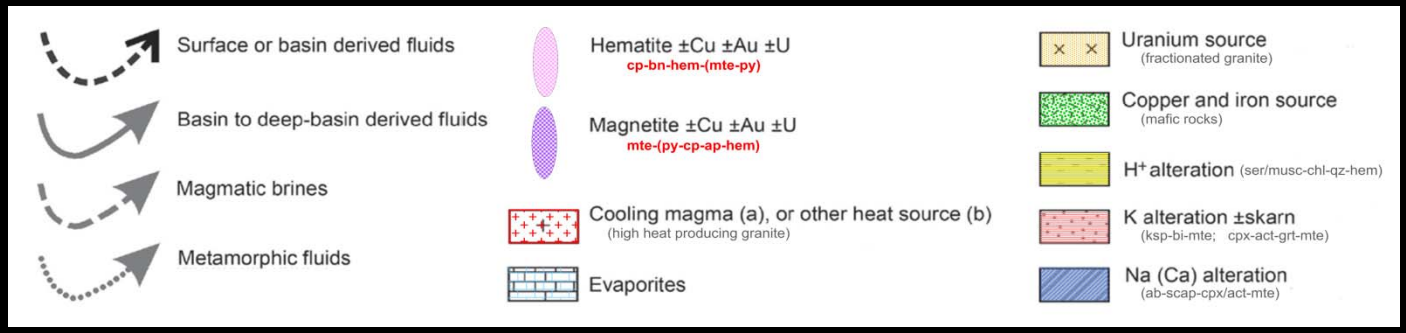

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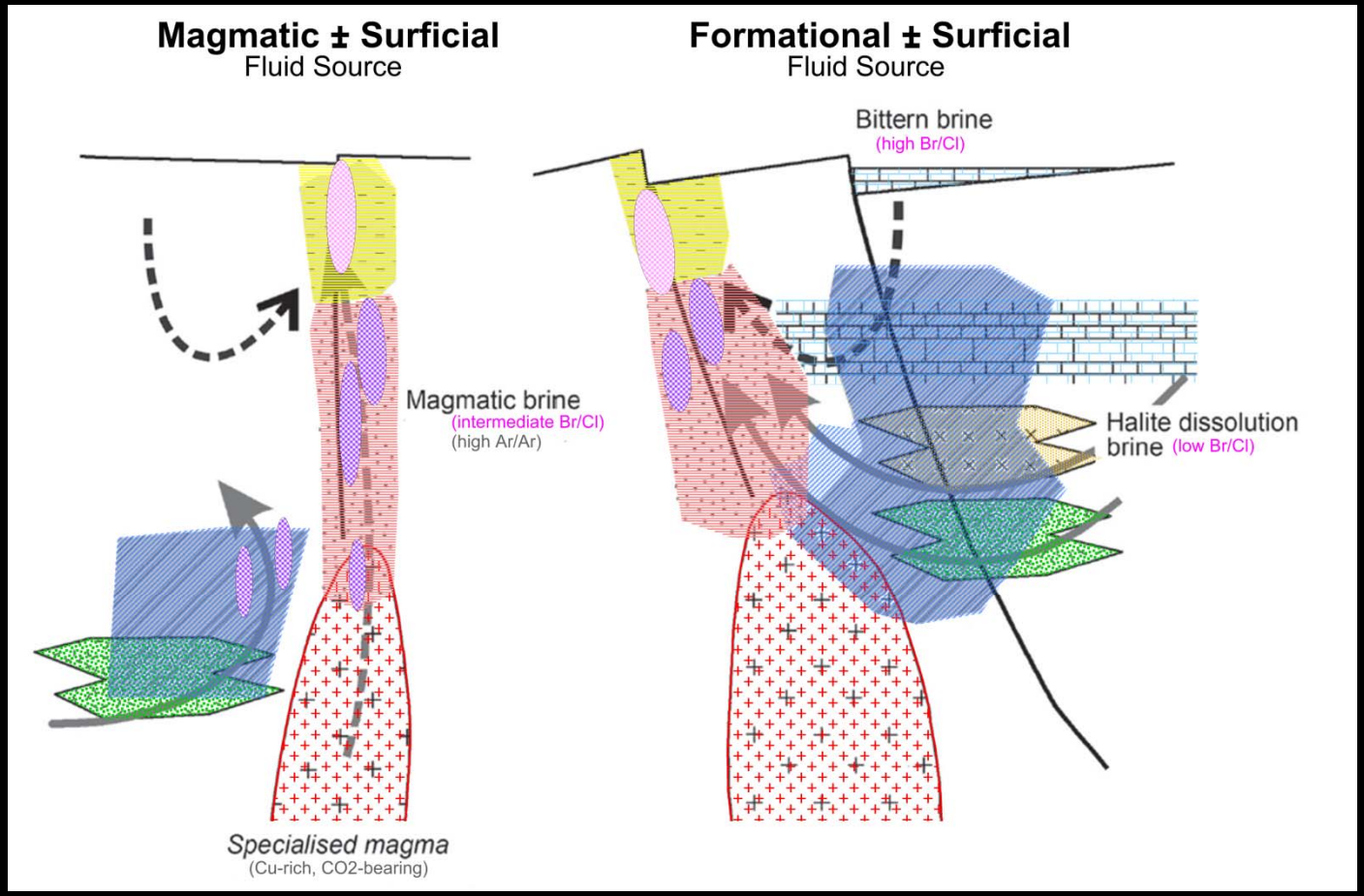

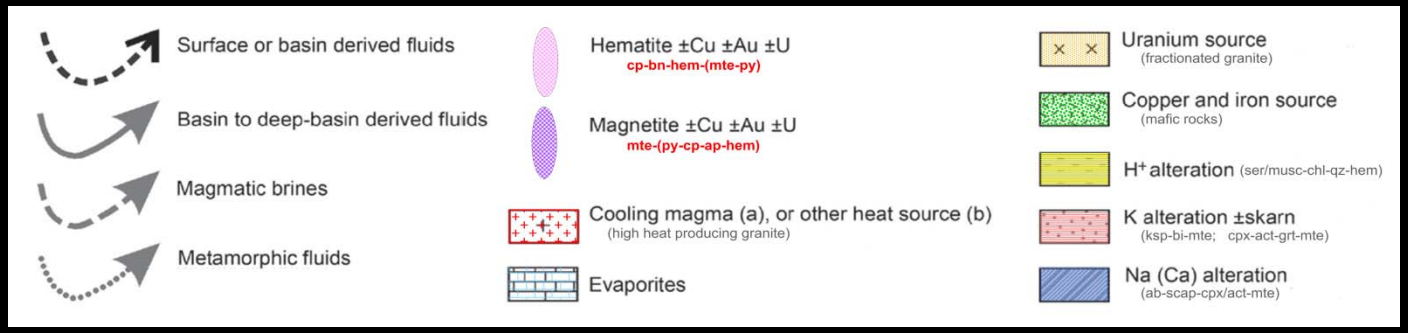

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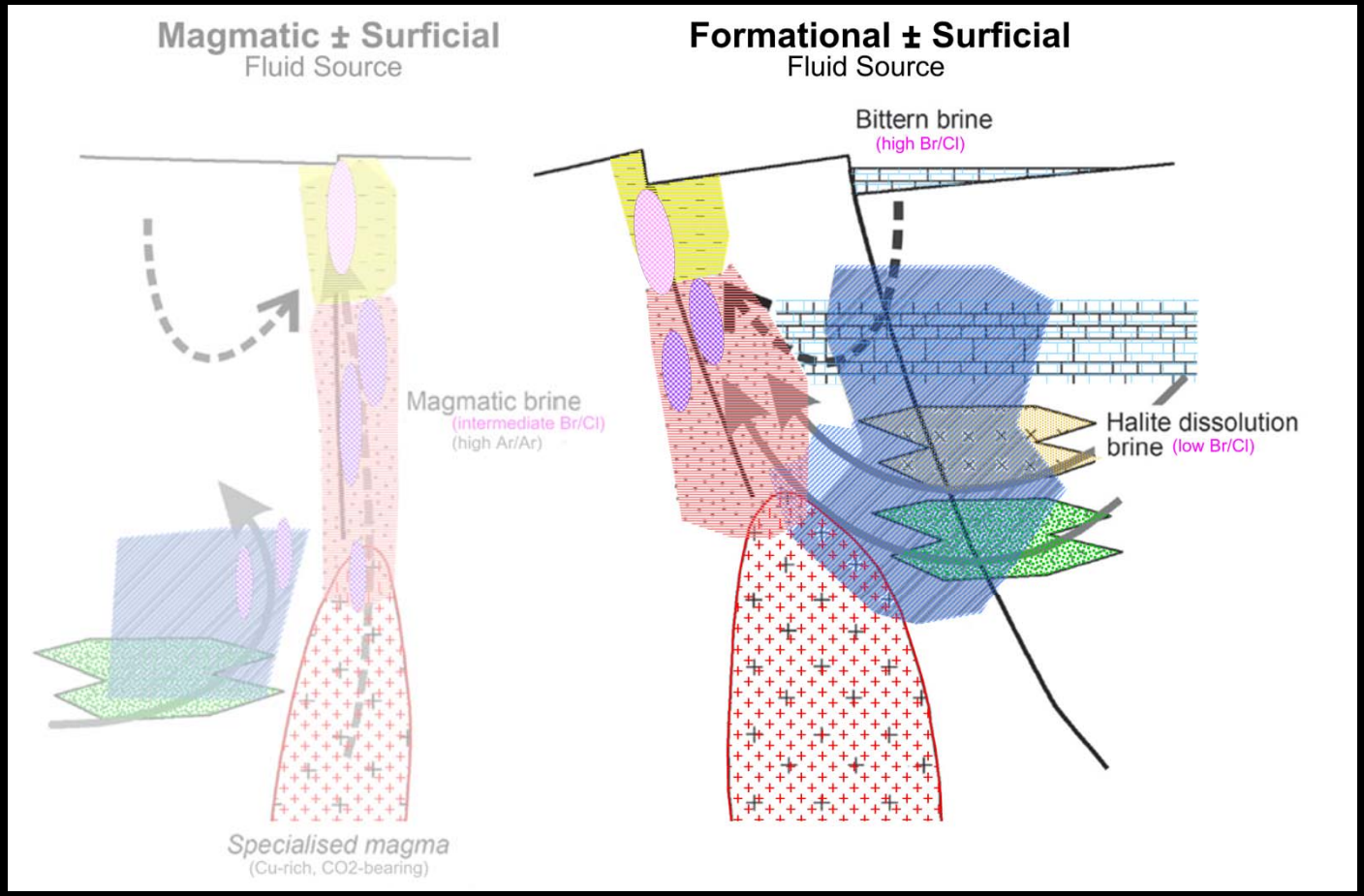

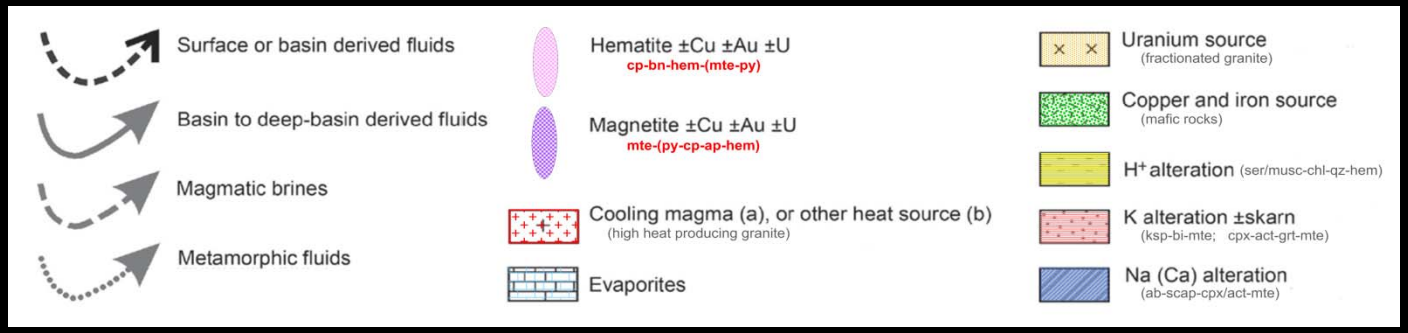

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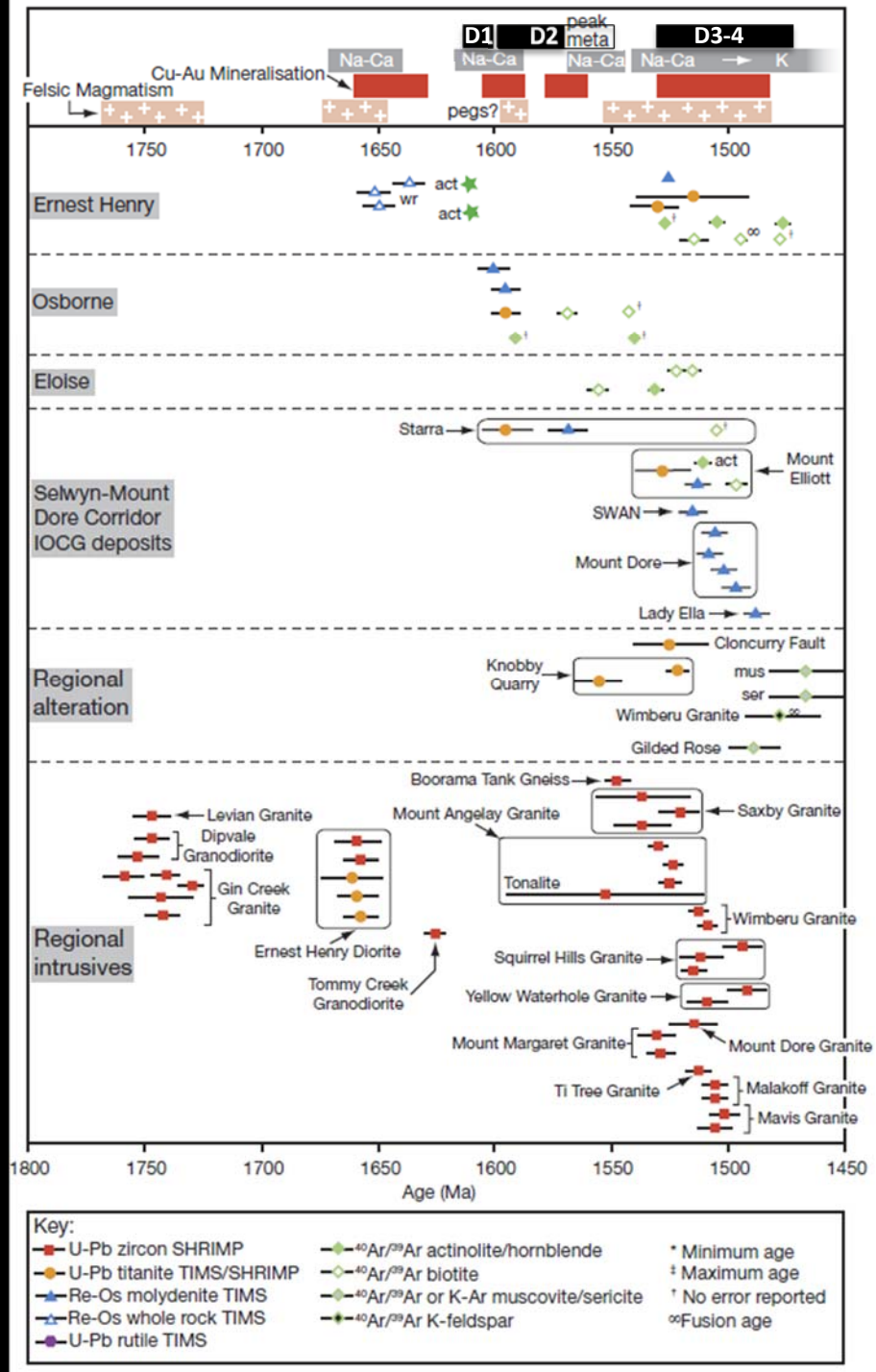

Duncan et al. (2010)

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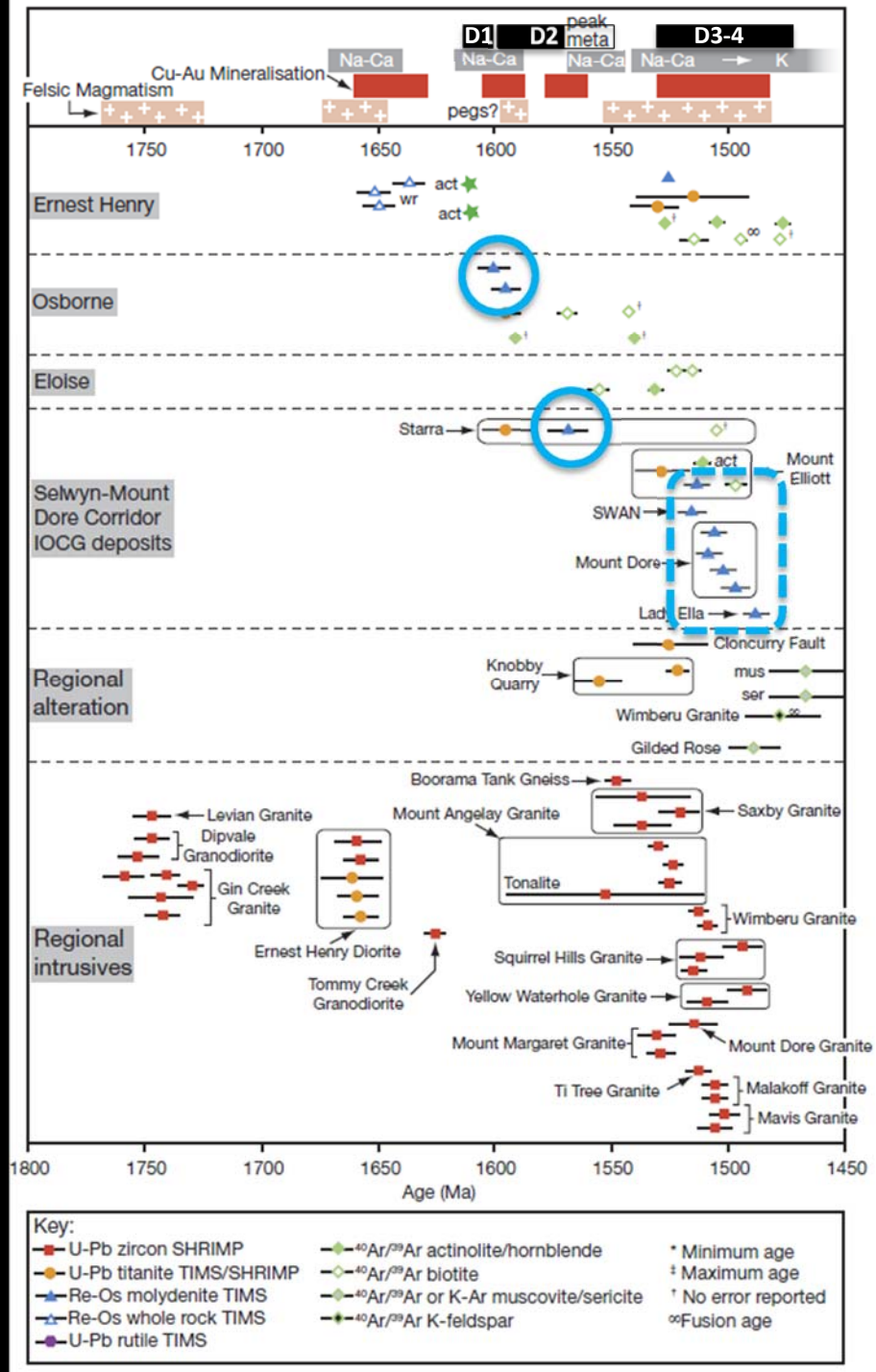
Re-Os moly ages … HANDLE WITH CARE!



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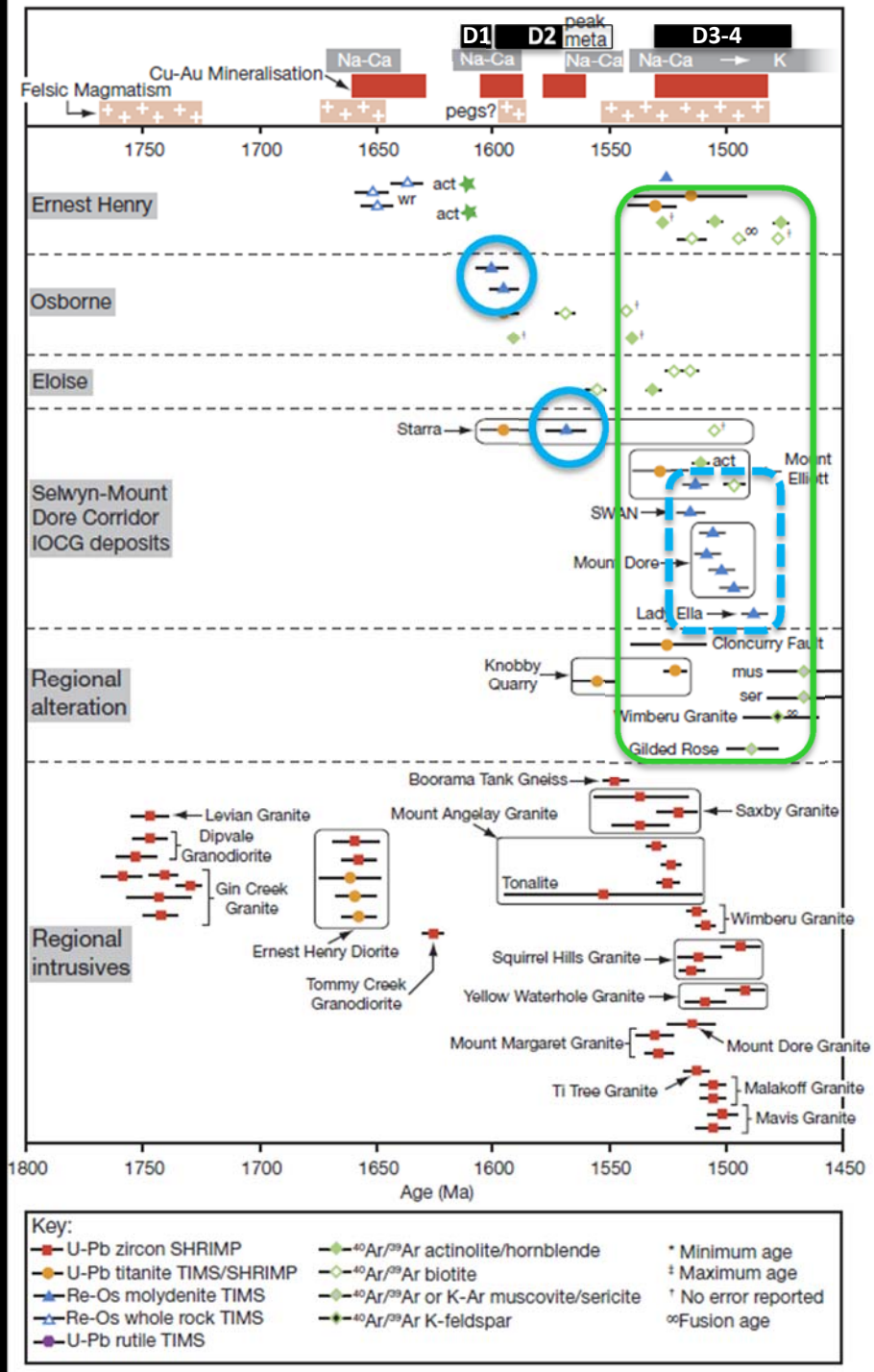

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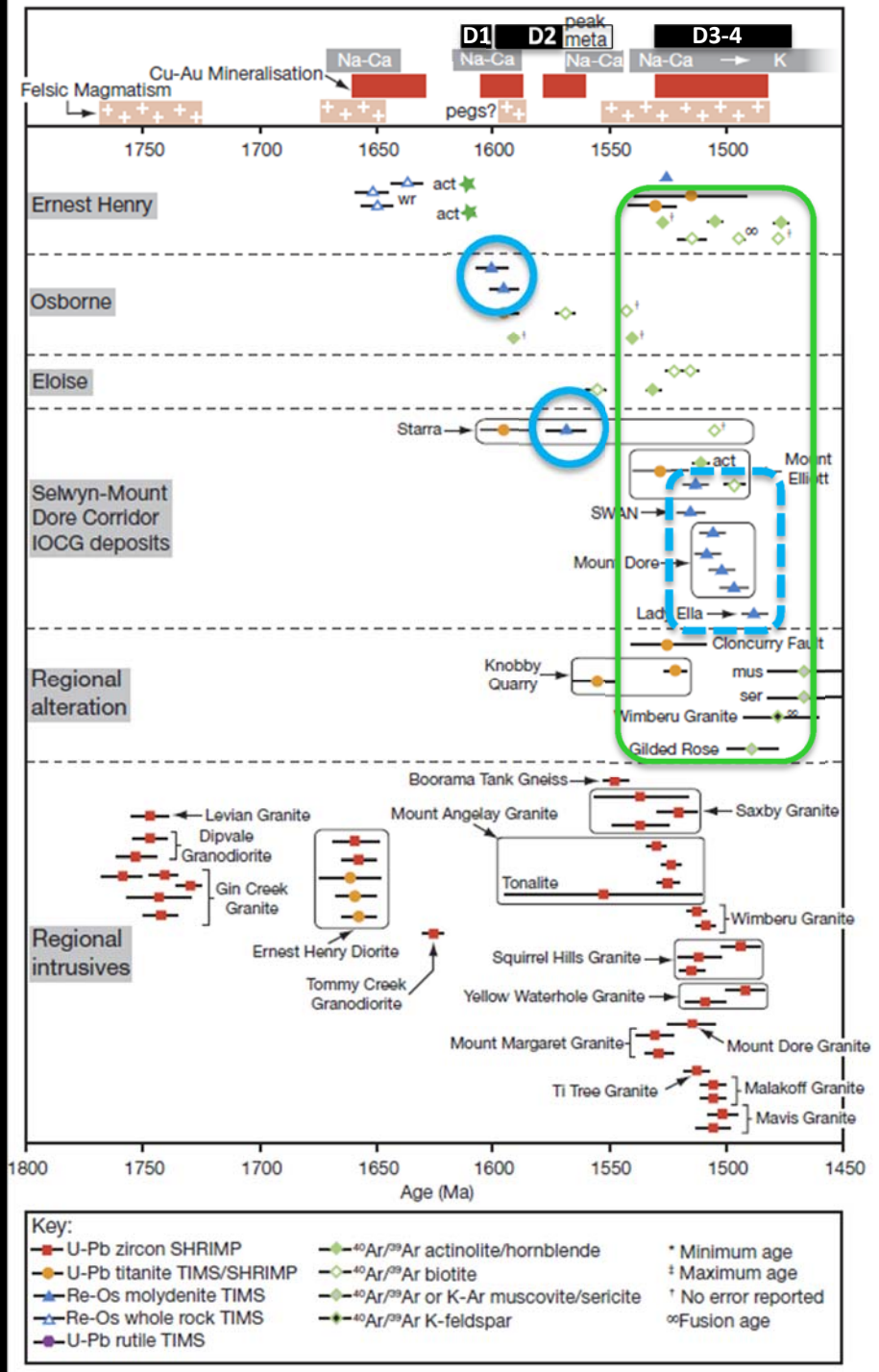

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… more in line with the geological observations of:

- **Post-peak metamorphism,**
- **K-alteration** overprinting **Na-Ca alteration**
- **D3-4 brittle control,** and
- **Temporal** & **spatial** association with **Williams magmatism**

Duncan et al. (2010)

CONCLUSIONS

DMQ southern Cloncurry IOCG Belt

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

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

CONCLUSIONS

DMQ southern Cloncurry IOCG Belt

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