SMI BRC
WH Bryan Mining & Geology Research Centre

DMQ Project Completion Forum 2017

'Insights into the Architectural Development of the southern Cloncurry IOCG/ISCG Terrain - Time-Space, Solid Geology & EFB Assembly'

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Department of Natural Resources and Mines
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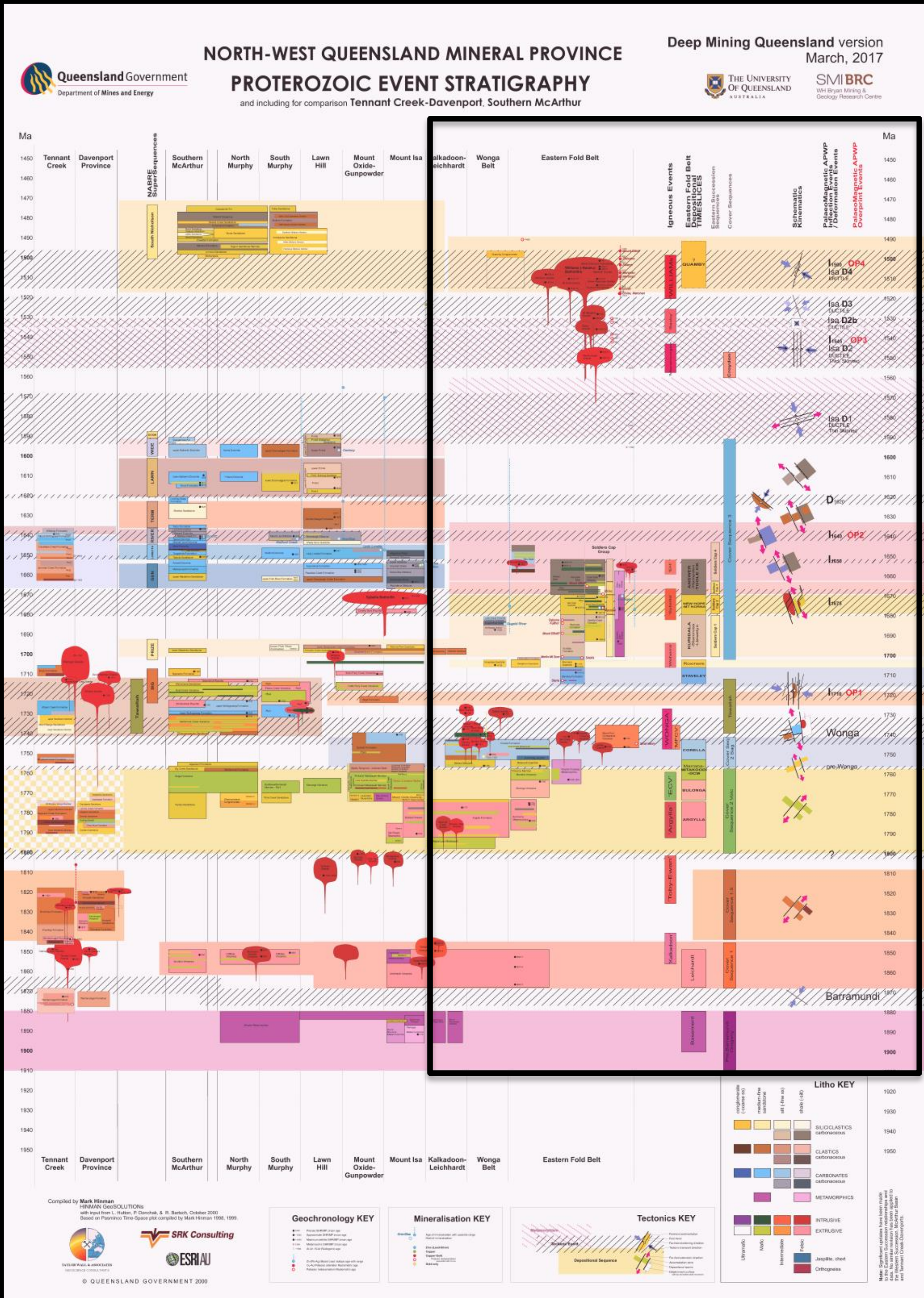
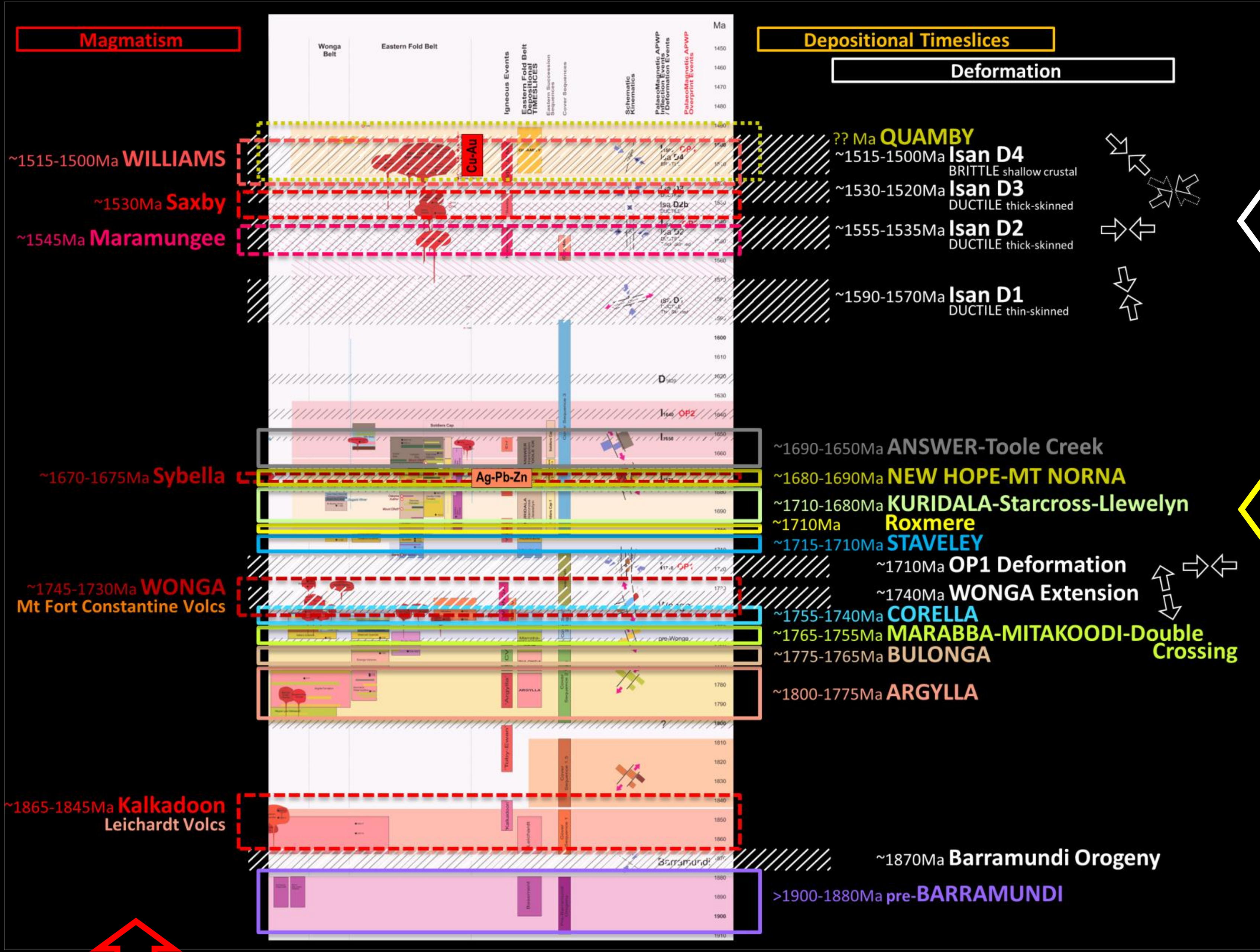
HiSeis
Fullagar Geophysics Pty Ltd
chinova resources



Updated DMQ 2017 version

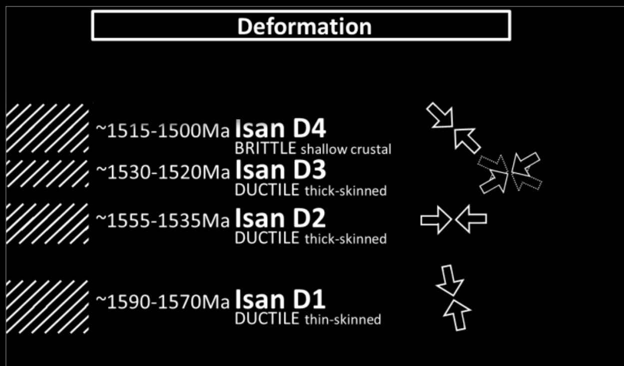
of 2000 NWQMP T-x Chart

- Reflects current understanding of EFB package relationships & latest geochronology (Withnall-Parsons, 2007-2009; NWQMEP, 2011; GSQ geochron database, Withnall, 2016)
- Updated Isan Deformation Events to reflect D1, D2, D2b, D3 & D4 in common usage.
- TIMESLICES reflecting DMQ re-packaging of mapped Formations, Members & units.
- No modification of WFB geochronology & package relationships.
- Minimal modifications of alteration & mineralisation dating, however, broad timings of Cu-Au and Ag-Pb-Zn accurate. Excellent compilations exist (Duncan et al., 2011)



Highlights 29 phases of **Accumulation** in TIMESLICES, **Deformation** EVENTS and Episodes of **Magmatism** in relation to Mineralisation

Review of Isan Orogeny Events

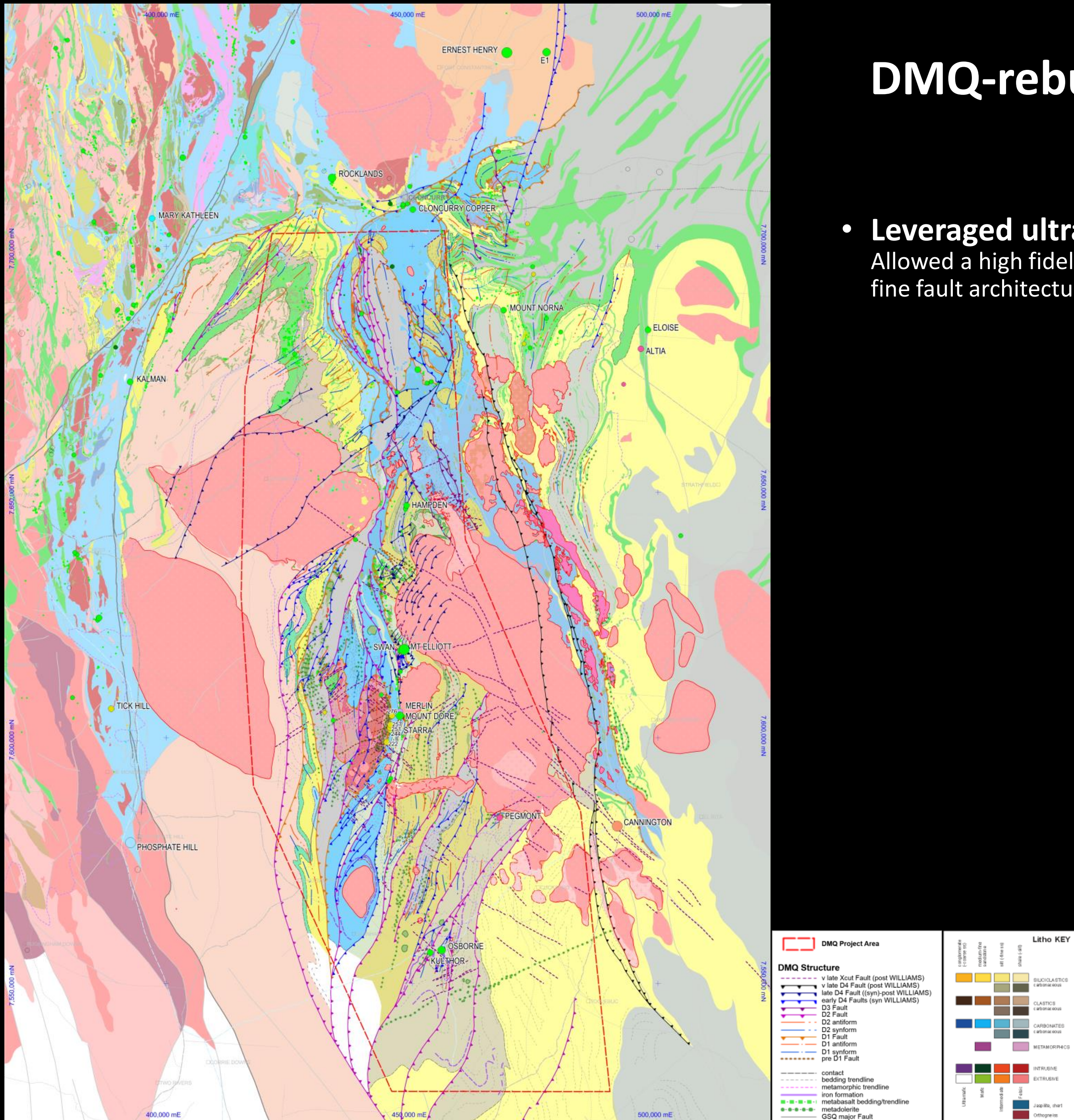


Understanding & nomenclature around the Isan Orogeny has matured since the 1980s

- Thin-skinned, **Ductile D1** with highT-modP meta
- Thick-skinned, **Ductile D2** with highT-highP meta
- Orogenic-collapse D2b
- Resumed thick-skinned, **Ductile D3** with local inhomogeneity
- Mid-shallow crustal, **Brittle D4**

DMQ has adopted this D1-D2-D2b-D3-D4 scheme.

Shortening	BRC-DMQ, 2017	BRC-DMQ, 2015	Rubenach et al., 2008	Austin et al., 2008	Giles et al., 2006 *a, b*	O'Dea et al., 2006	Rubenach & Lewthwaite, 2003	Laing, 1998	Adshead-Bell, 1998	Bell & Hickey, 1998	Bell, 1983; 1991	Rubenach et al., 2008 Metamorphism
			D_{bp}		d_1 *(1600Ma)*		D_1		D_1			M_1
~N-S	D_1	D_1	D_1		d_2 *(1600-1580Ma)*	D_1 SSE-NNW	D_2	D_1		D_1	D_1	M_2 highT-modP
~E-W	D_2	D_2	D_{2a}	D_2	d_3	D_2 ESE-WNW	D_3	D_2	D_2	D_2	D_2	M_3 highT-highP
sub-vertical	D_{2b}	D_{2b}	D_{2b} topW				D_4		D_3 topW	$D_{2.5}$ topE&W		M_4
various (local)	D_3	$D_{3\text{-}4}$	D_3 ENE-WSW	D_3 ENE-WSW	d_4	D_3 E-W	D_5 ENE-WSW		D_4	D_3 variable	D_3 ENE-WSW	M_5
~SE-NW	D_4	$D_{3\text{-}4}$	D_4 SE-NW	D_4 SE-NW			D_6 SE-NW	D_3	D_5			M_6 vhighT-lowP
	southern EFB	*southern EFB*	*Snake Creek*	*Cloncurry Fault*	*SE EFB-Pegmont, Snake Creek*	*Mitakoodi Culmination*	*Snake Creek*	*southern EFB*	*Starra-Selwyn*	*Mt Isa, WFB*	*Mt Isa, WFB*	*Snake Creek*



DMQ-rebuilt Solid Geology

- **Leveraged ultra-detailed Chinova geophysics**
  Allowed a high fidelity interpretation of package continuity & fine fault architecture

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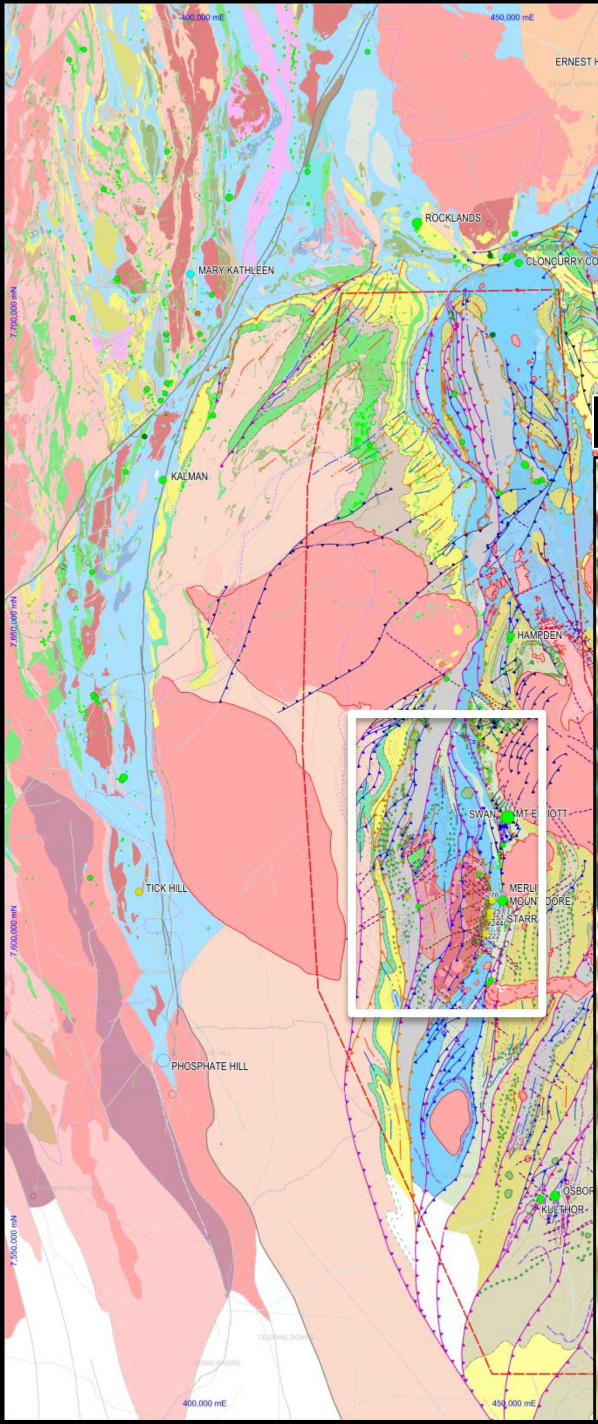
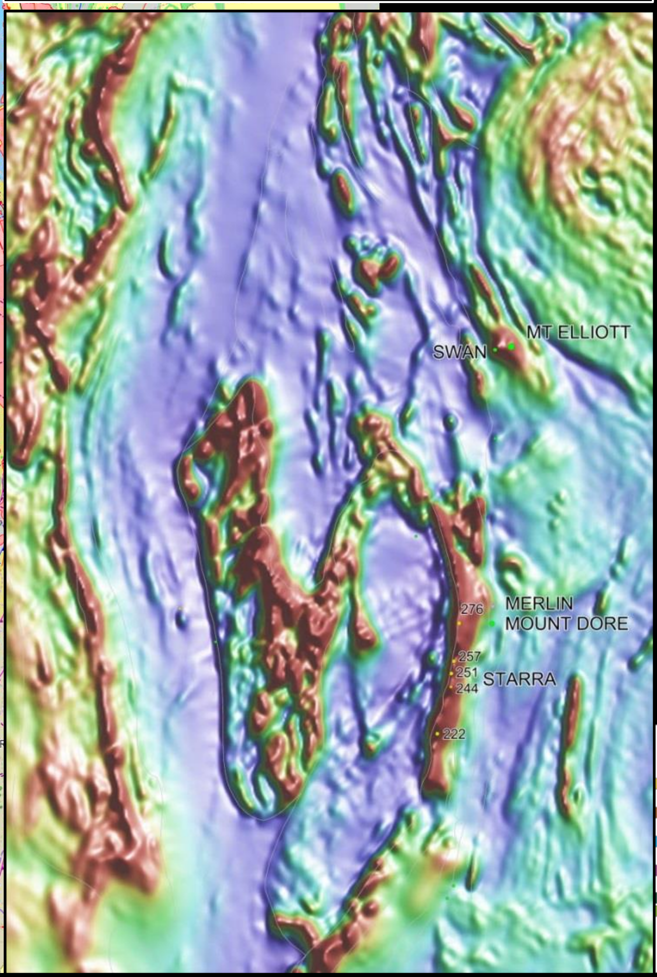
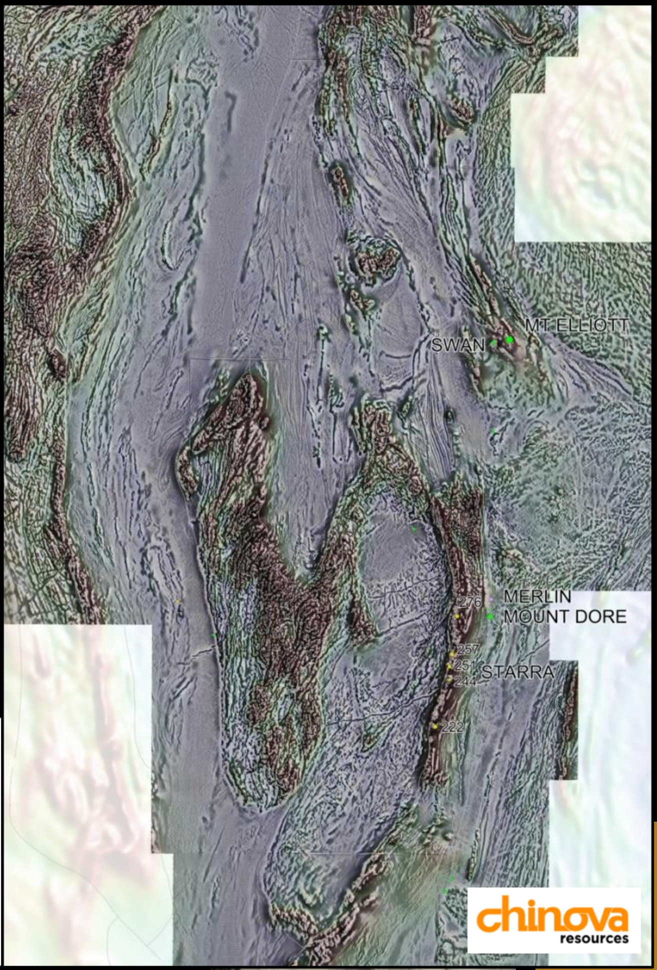


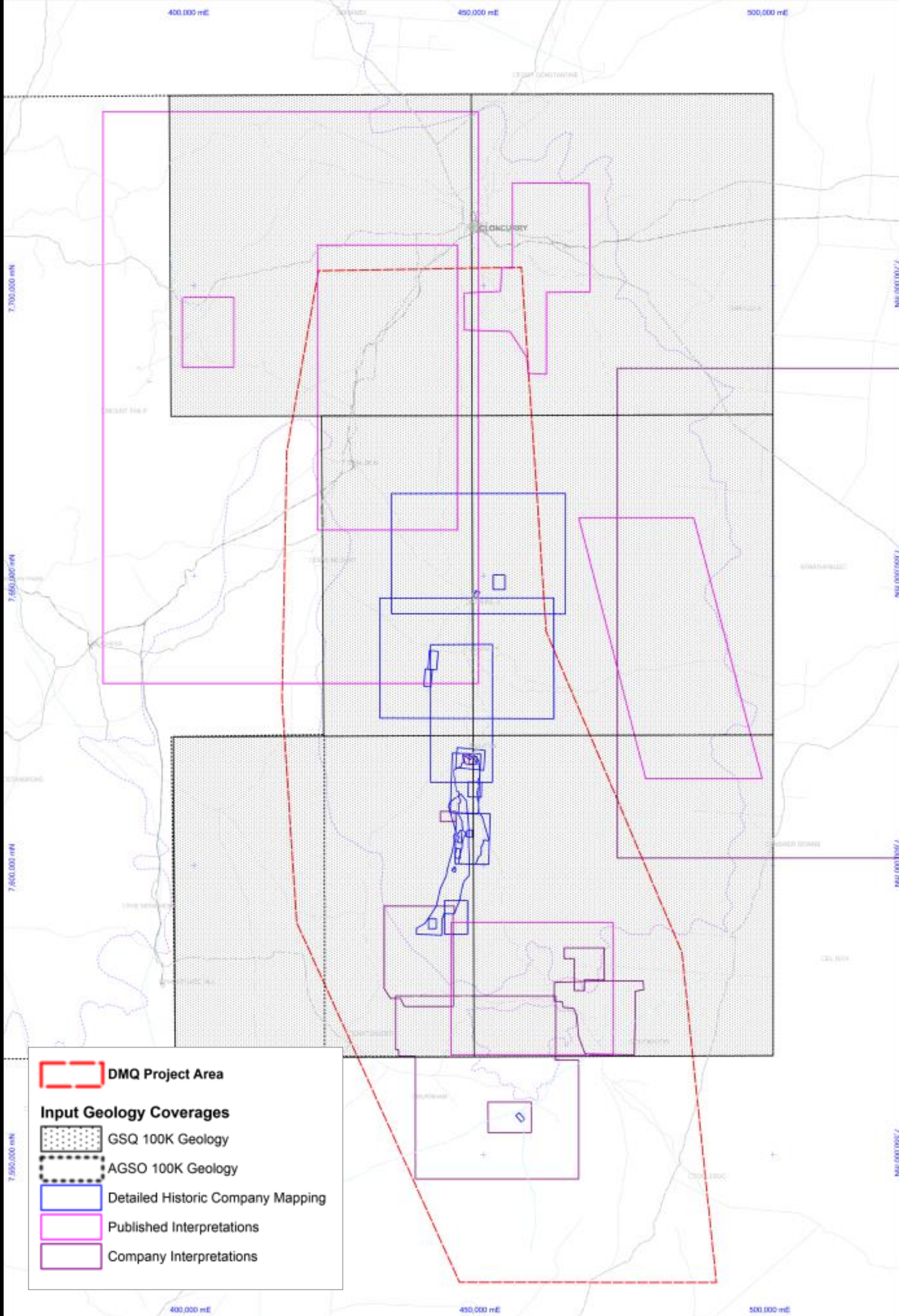
GA Mag tmi-rtp v6 (**2015**) 80m grid



Chinova detailed Mag vrmi-2vd (**2010**) 10m grid



chinova resources



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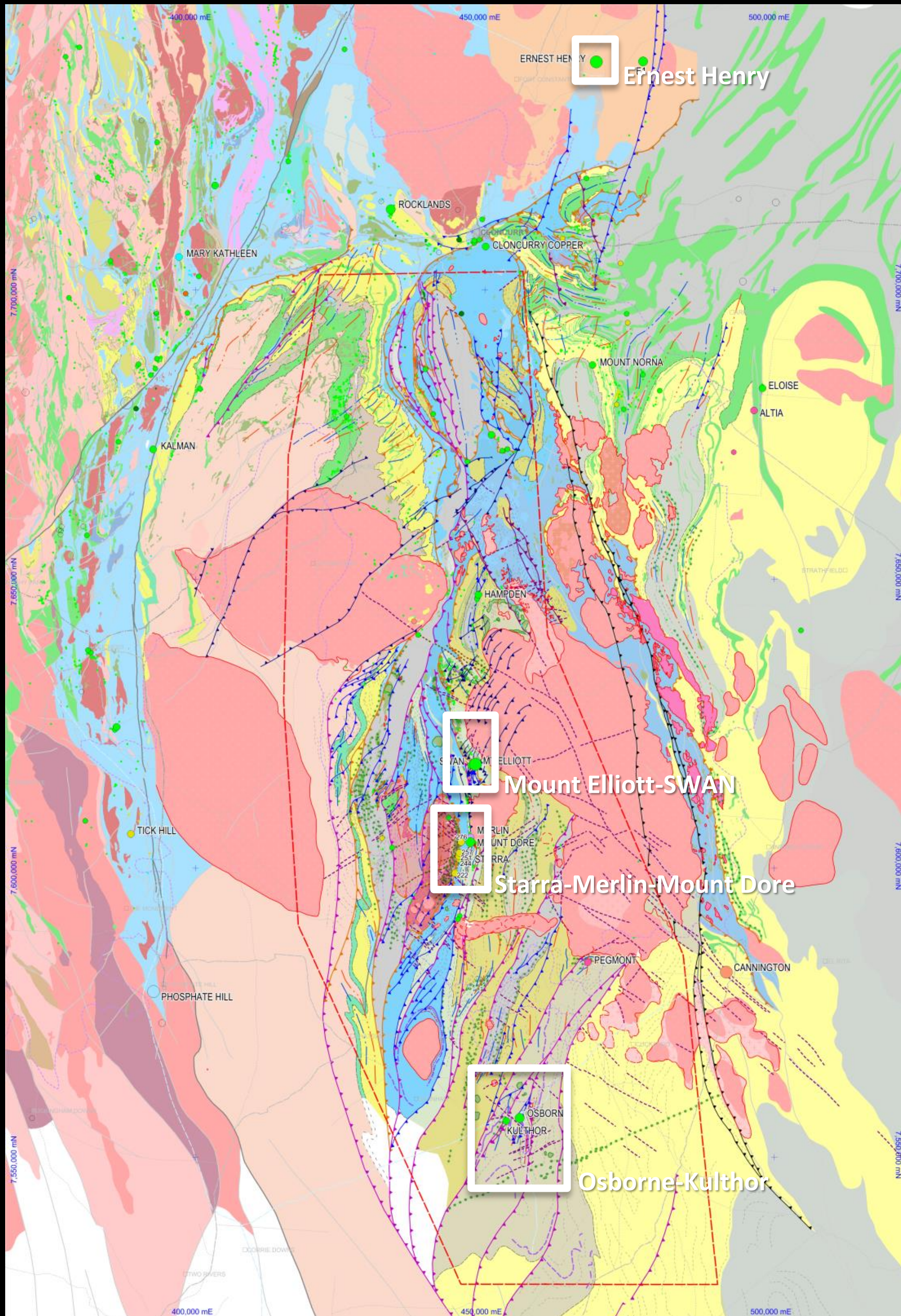
  Allowed a high fidelity interpretation of package continuity & fine fault architecture
- **Incorporated prospect-scale geology …**

  Historic mapping, including in particular that of John Leishman (1970s-1980s); previous company interpretations & journal-published maps …

  … building on the GSQ 100K series Maps



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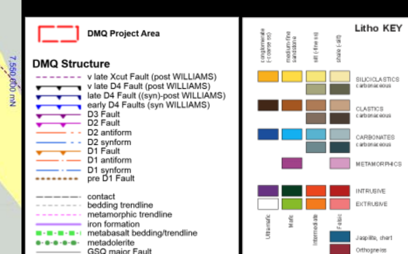
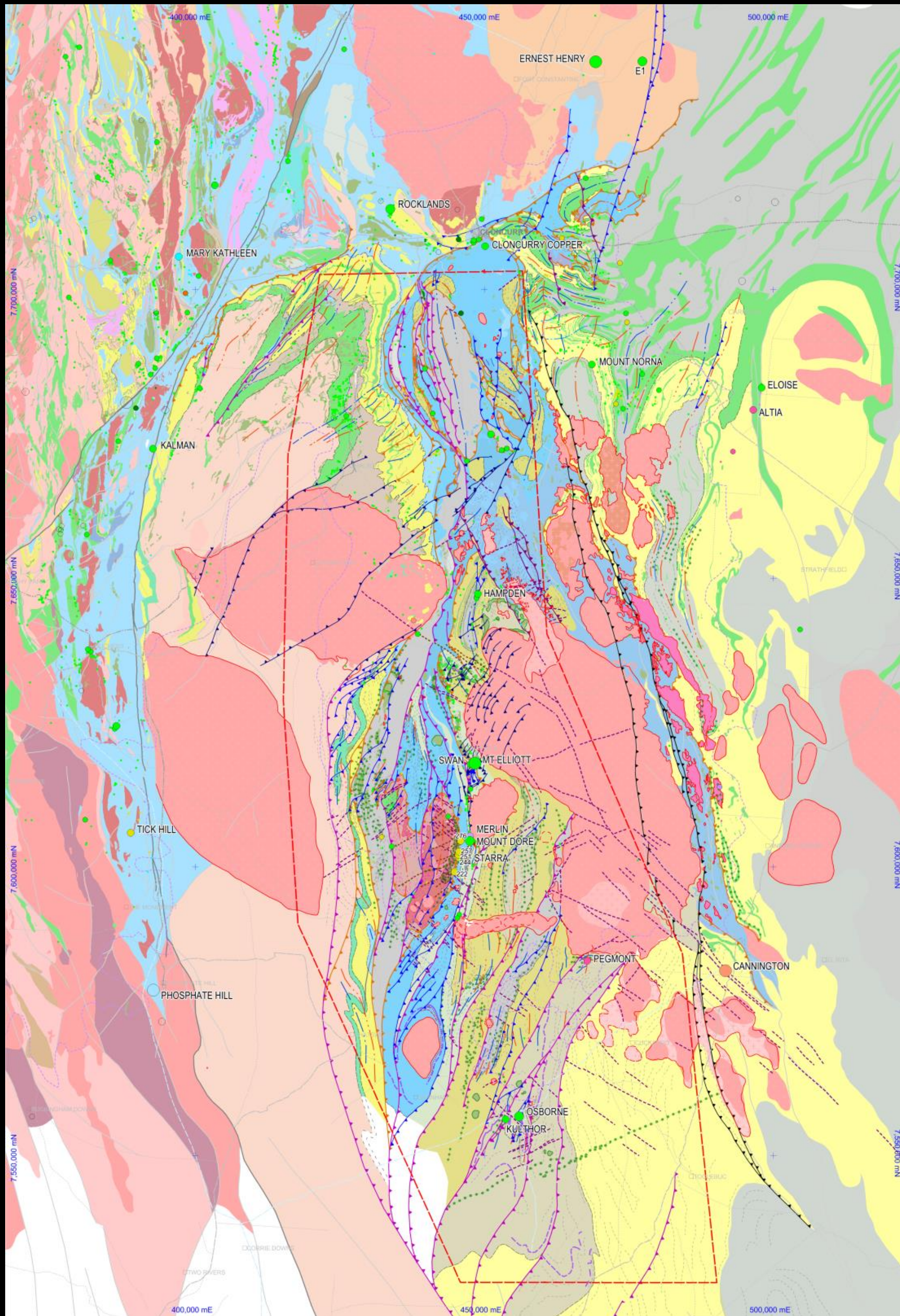
DMQ PRODUCTS

- **~1:50K Solid Geology Interpretation**
- **GIS Package of TIMESLICED Geology**
- **GIS Event-attributed Structures**
- **Detailed ~1:5-10K Local Compilations**
- **29-step EFB Assembly Model**





Assembly of the southern Cloncurry Eastern Fold Belt

Tectono-Stratigraphic-Magmatic Assembly

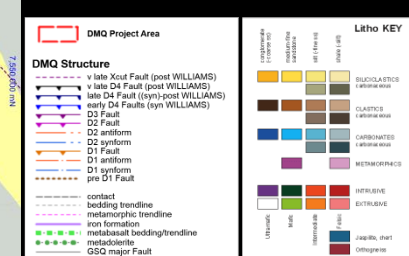
FLICK through **depositional TIMESLICES**, **Magmatic EPISODES** and **Deformation EVENTS** that speak to the **geodynamic and mineral development of the belt** …

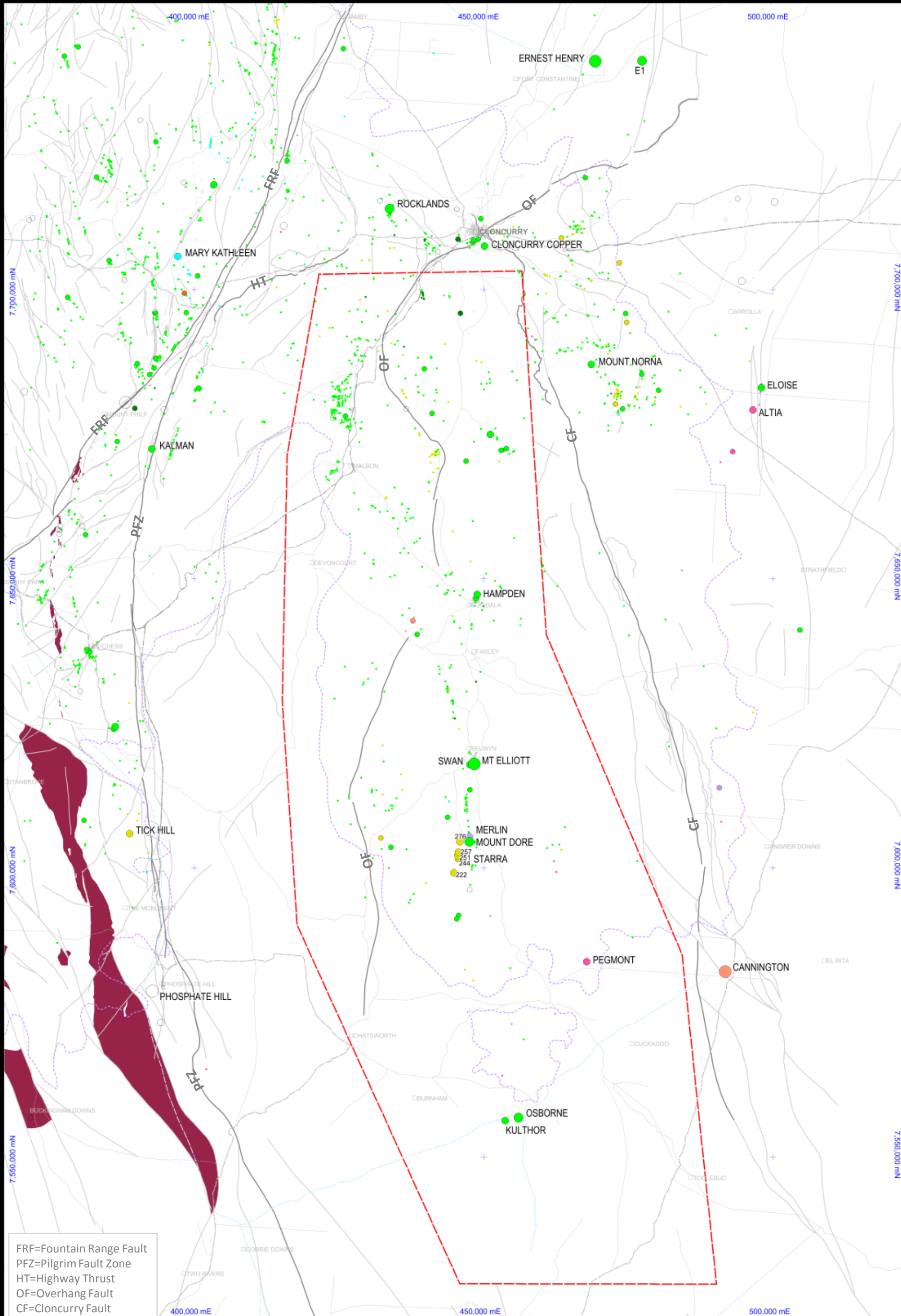
… from **~1900Ma to ~1400Ma**, and which

… culminate in Cu-Au-Mo mineralisation

Insights into package relationships, their origins, compositions & natures of their structural juxtapositioning …

… all which is integral to DMQ Propsectivity Analysis





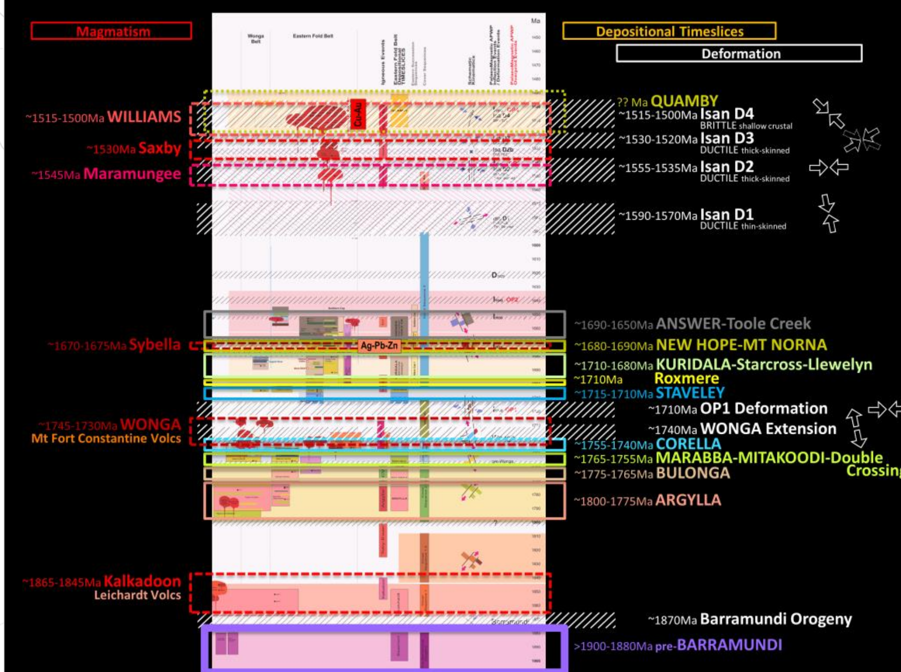
>1870Ma
Pre-Barramundi

Plumb Mountain Gneiss, Kurbayia Metamorphic Complex, Bushy Park Gneiss

Felsic gneisses, augen gneisses, minor mafic gneisses, porphyritic granite, schistose metasediments

- **NAC deposition** hypothesised to be controlled by **NE-SW Extension** with **NE-SE Accommodation Zones**
-

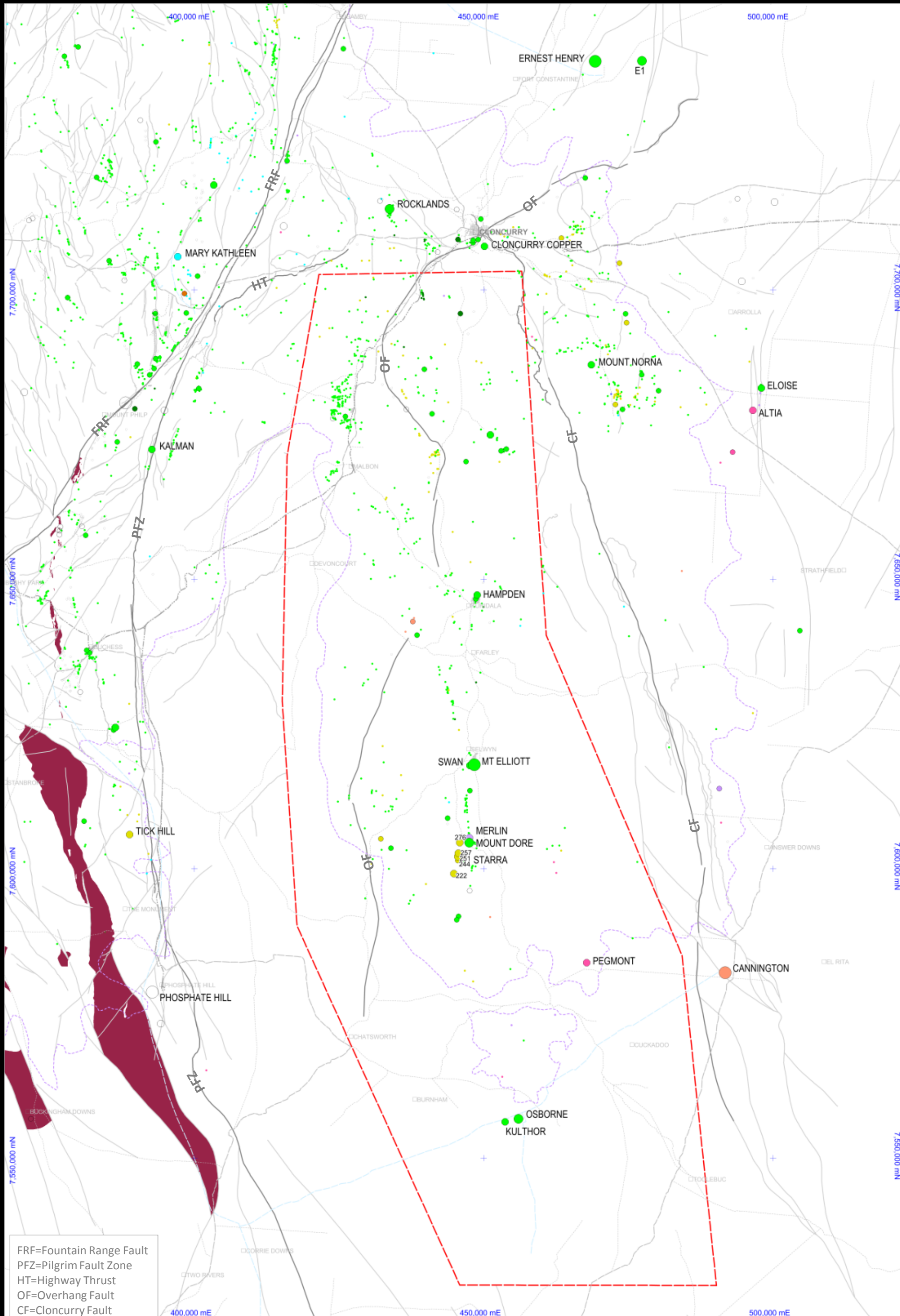
…. one possibly NE-extension of Overhang Fault Zone

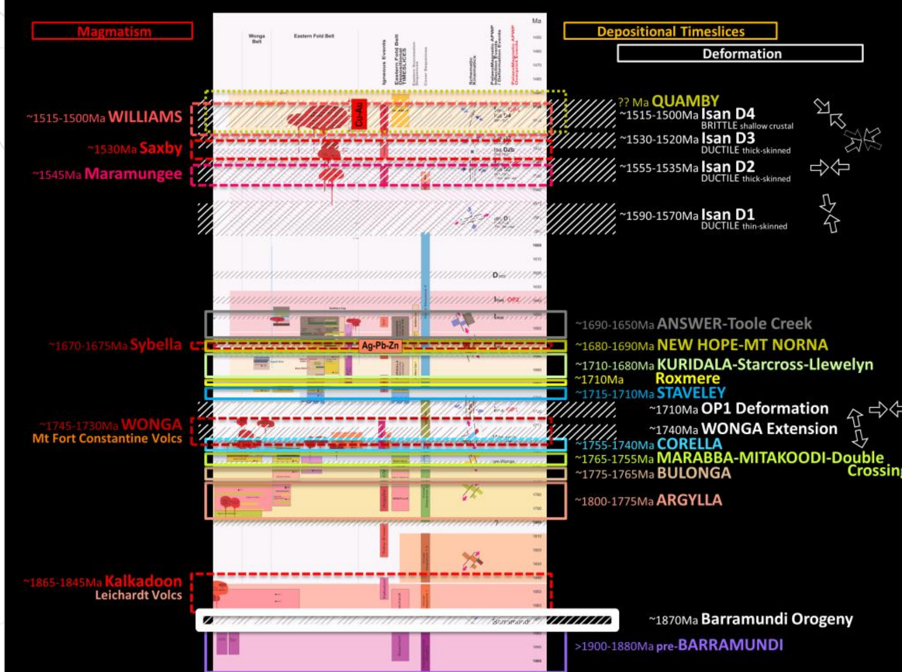


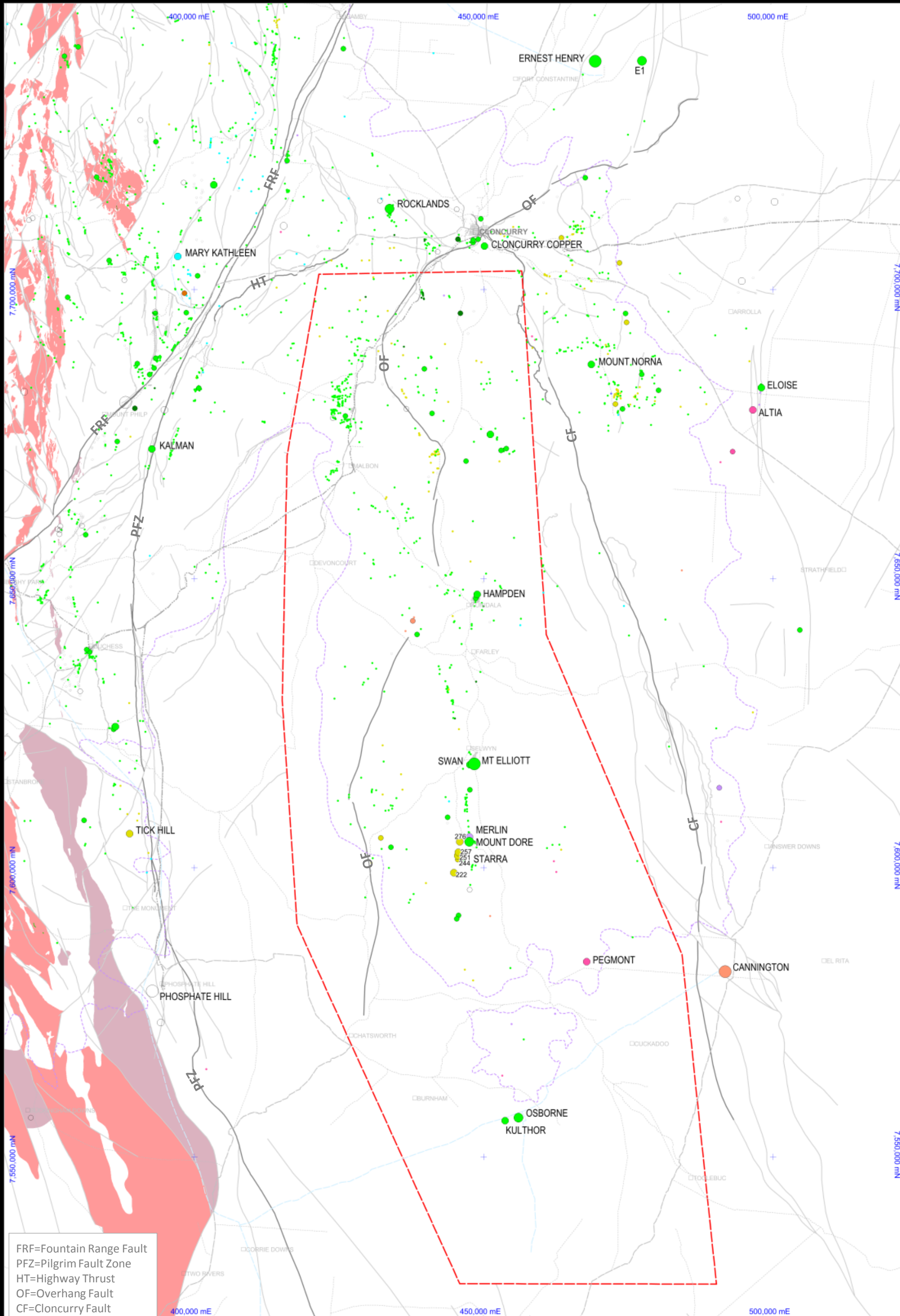
~1870Ma
Barramundi Orogeny

North Australia-wide Orogeny:
NE-SW shortening ….
…. upper amphibolite-granulite metamorphic grades

- Intense gneissic foliation
- NAC shortening generally NE-SW, locally E-W potentially over older architectures





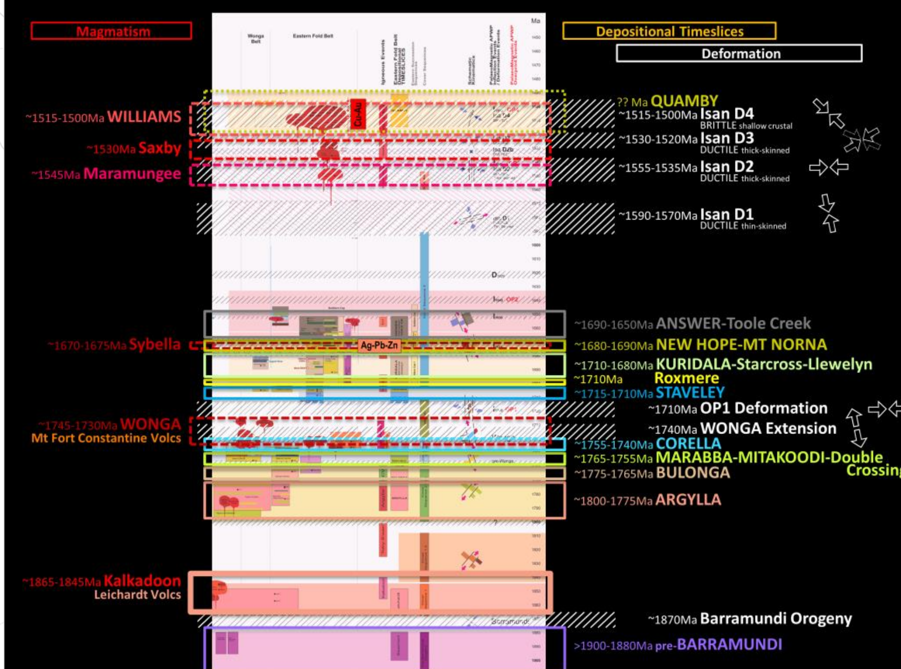


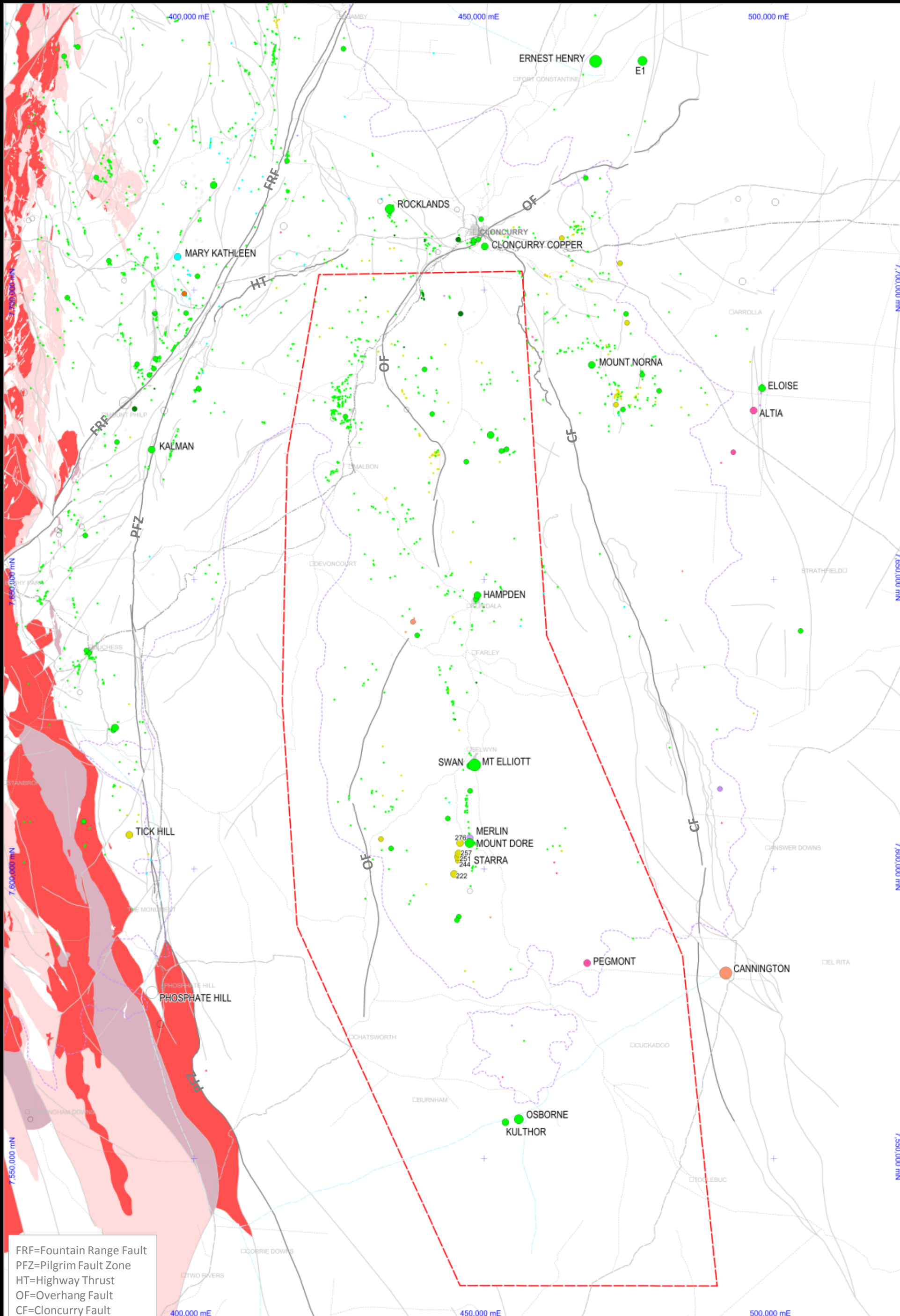
~1865-1845Ma
LEICHARDT

Leichardt Volcanics

Massive-schistose **felsic metavolcanics**, ± quartz-feldspar porphyritic, lesser volcanoclastics, minor meta-sandstones, schist & phyllite

- Post orogenic felsic volcanics
- LEICHARDT timeslice preserved west of the Pilgrim Fault Zone



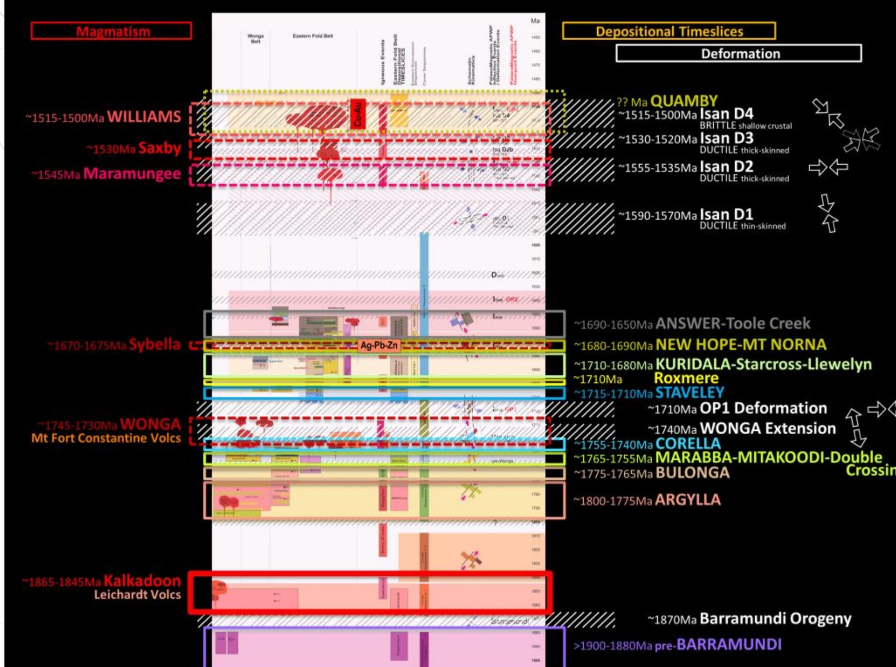


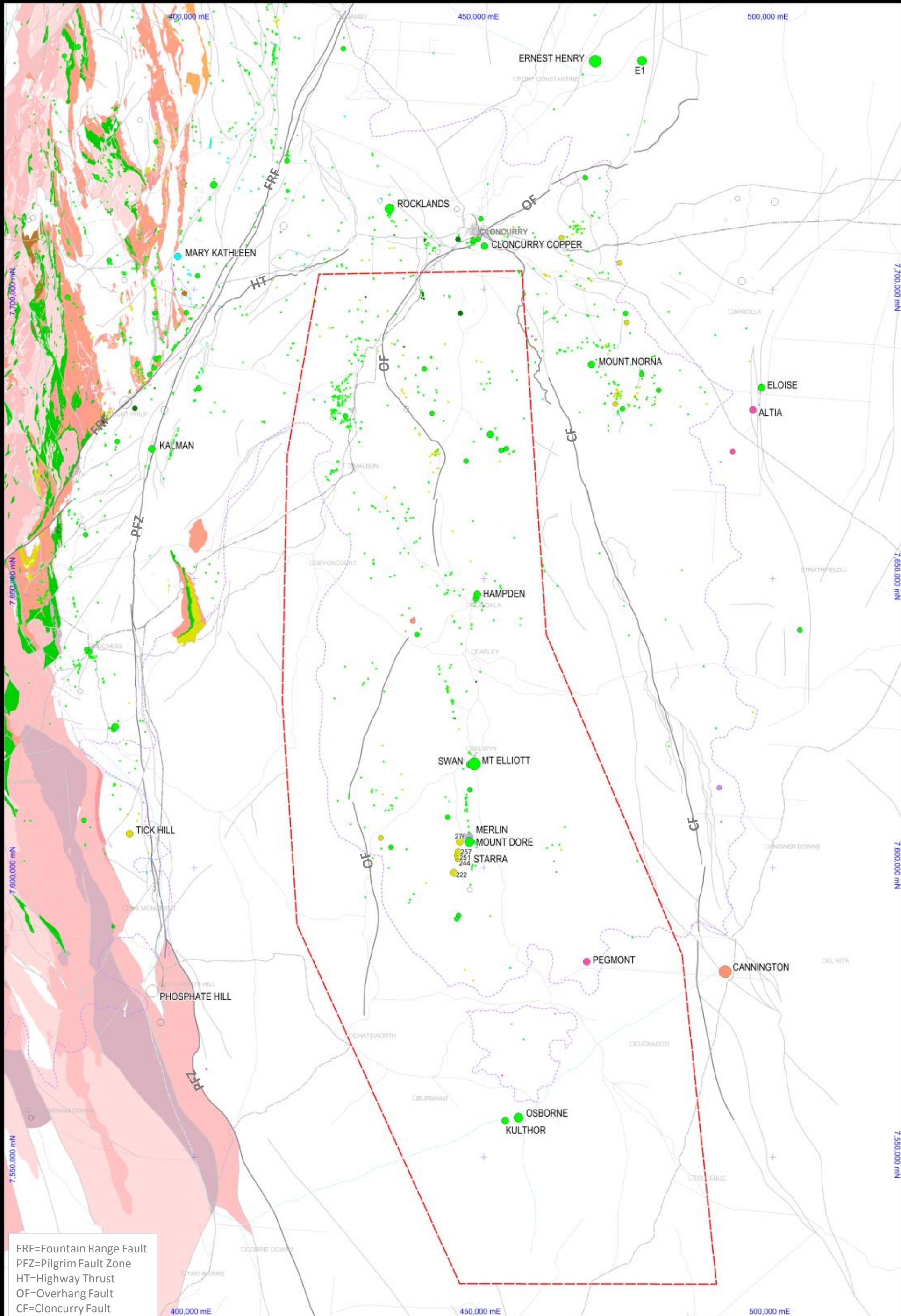
~1860-1845Ma
KALKADOON

Kalkadoon Granodiorite*, Birds Well Granite, Bowlers Hole Granite, One Tree Granite, Saint Mungo Granite*

Massive-foliated-gneissic, medium-coarse, biotite ± hornblende granite to granodiorite

- KALKADOON timeslice preserved west of the Pilgrim Fault Zone



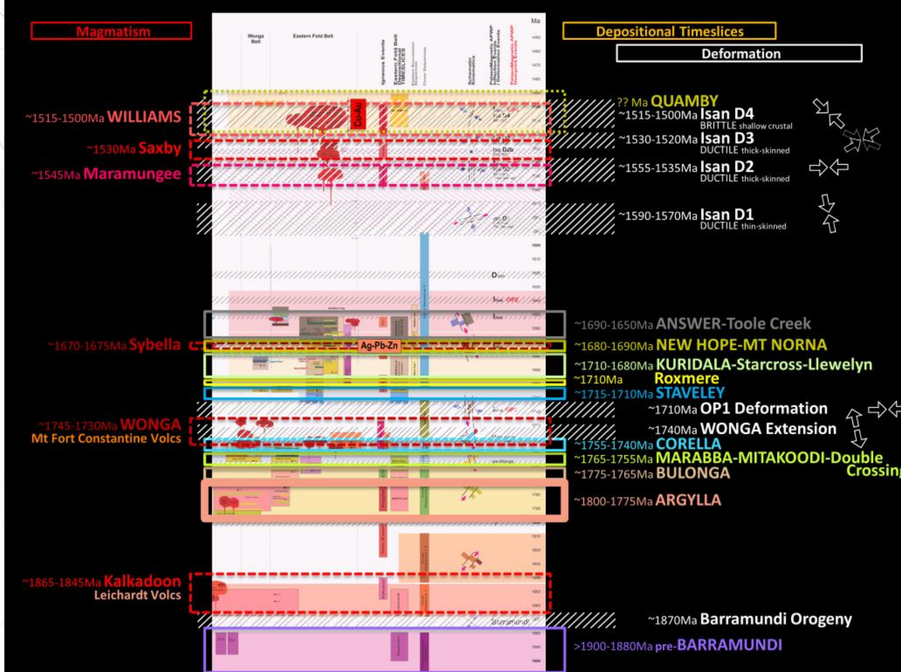


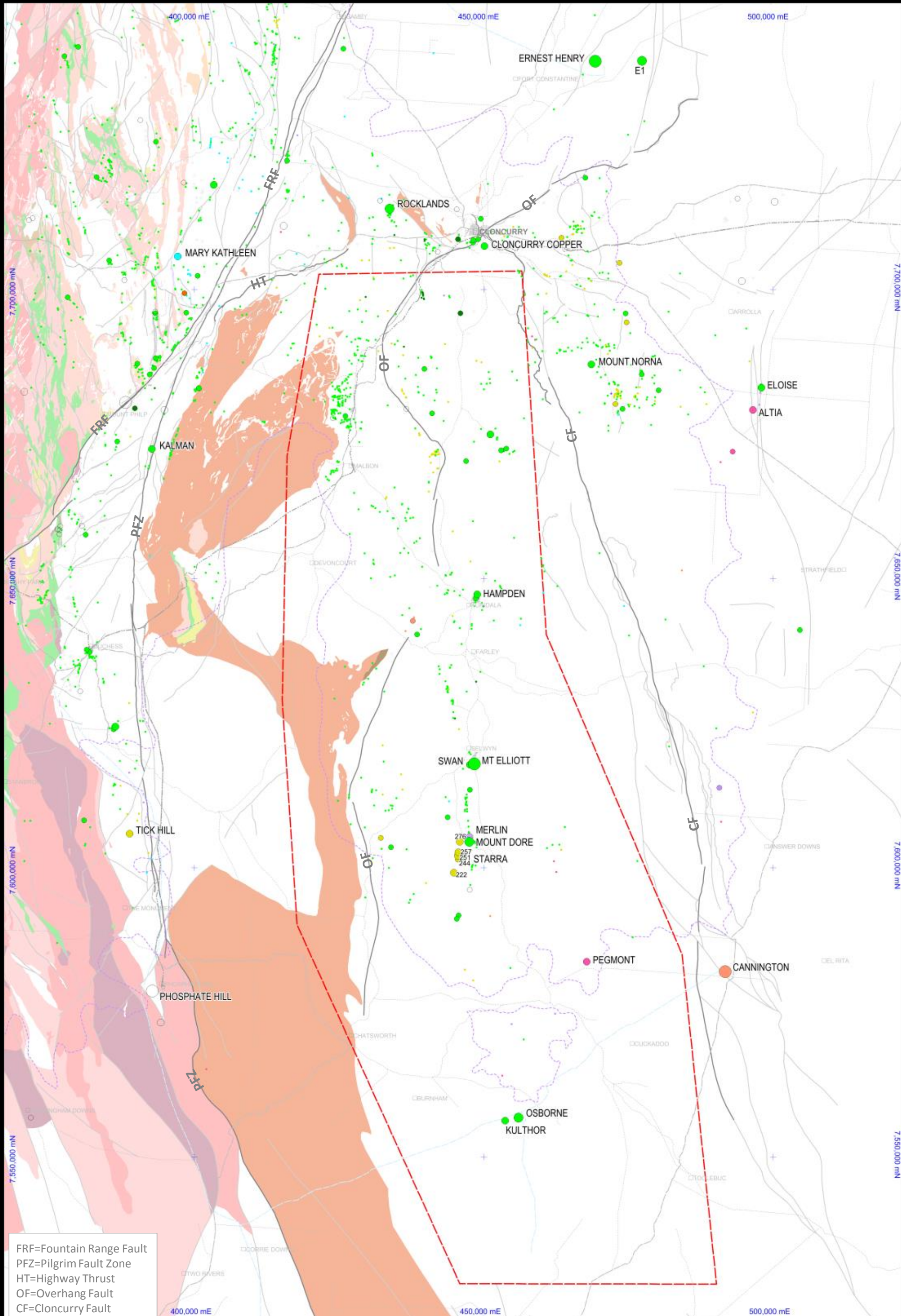
~1795-1775Ma
ARGYLLA

Magna Lynn Metabasalt,
Argylla Formation

Metabasalt, amphibolite, quartzite, meta-arenite;
Felsic-intermediate volcanics-volcanoclastics, ± porphyritic, quartzite, minor meta-sediments, metabasalt

- ARGYLLA timeslice **largely** preserved west of the Pilgrim Fault Zone



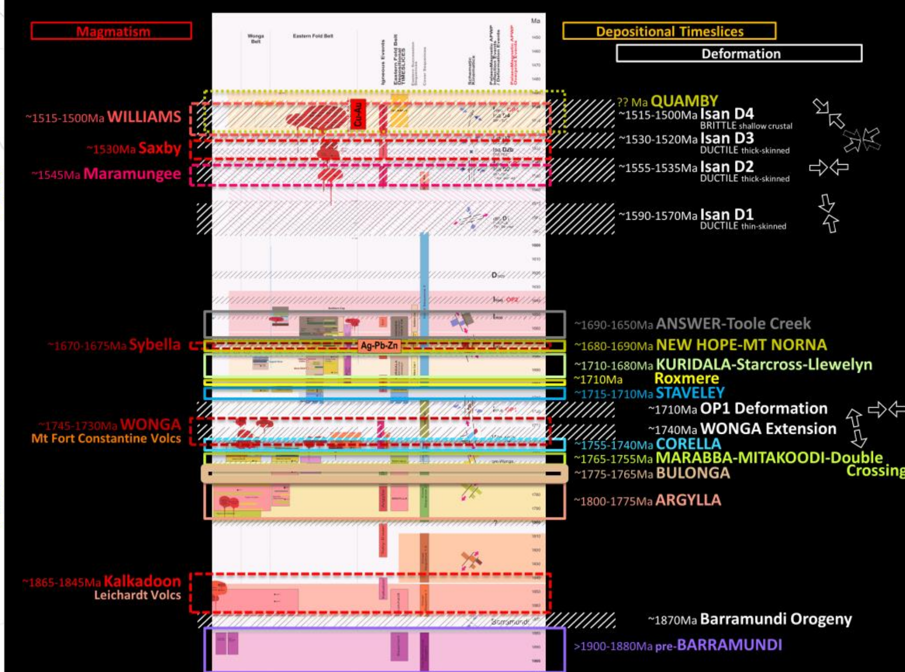


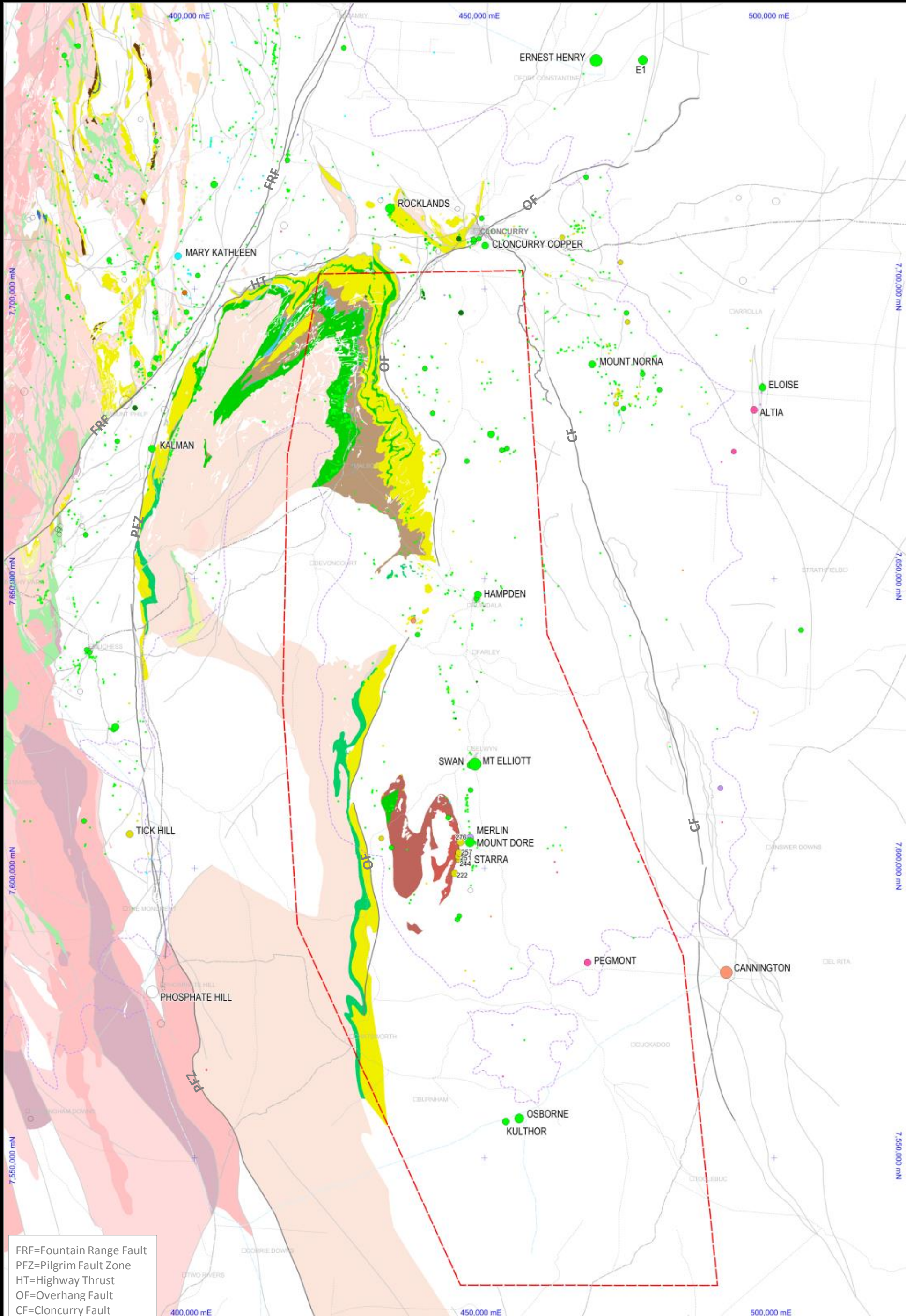
~1775-1765Ma
BULONGA

Bulonga Volcanics

Porphyritic or crystal-rich, **rhyolitic-dacitic metavolcanics**, feldspathic-quartzose meta-psammites

- **BULONGA timeslice preserved <u>east</u> of the Pilgrim Fault Zone ….**
  …. and <u>west</u> (and <u>north</u>) **of the Overhang Fault Zone.**
- **Time equivalent of the Eastern Creek Volcanics** in the Western Succession.



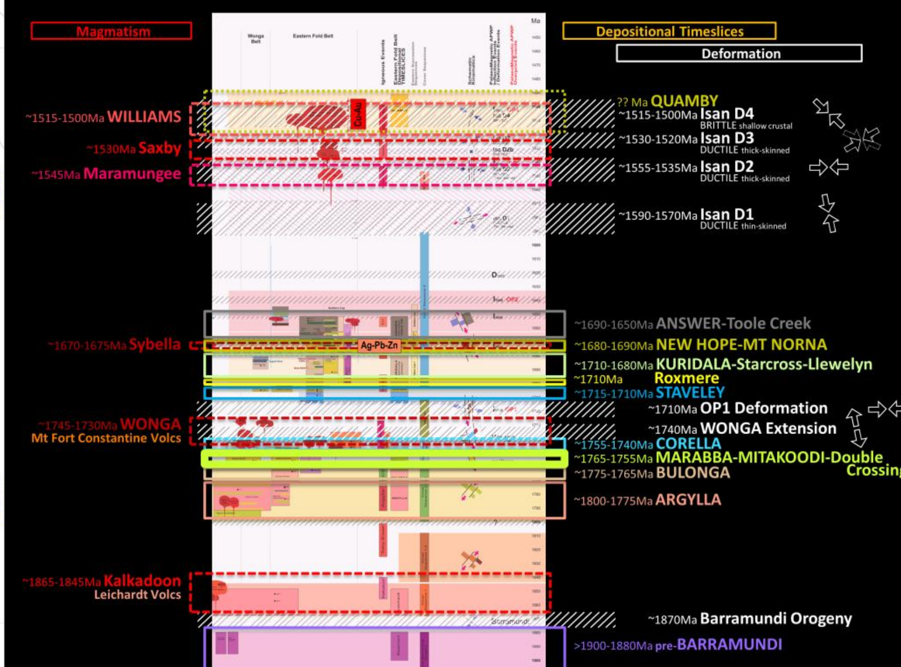


~1765-1755Ma
MARRABA-MITAKOODI-Double Crossing Metamorphics

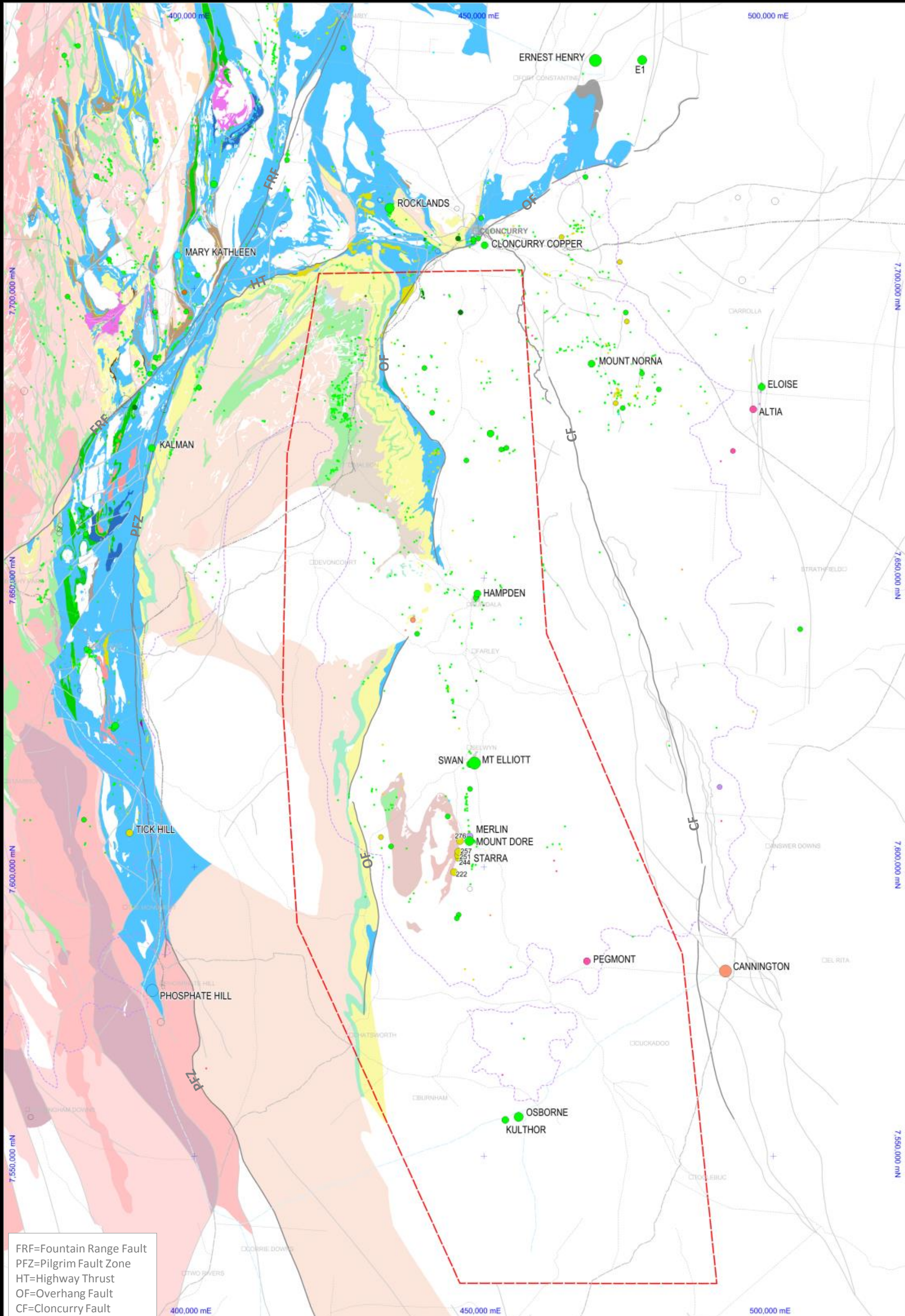
Marraba Metabasalt, *Cone Creek Metabasalt Member; Timberoo Member,*
Mitakoodi Quartzite, *Wakefield Metabaslt Member;*
Double Crossing Metamorphics

Metabasalt, amphibolite, meta-arenite, schist, minor chert;
Siltstones-sandstones, minor carbonates; feldspathic-quartzose sandstones, minor siltstone, conglomerate;
Quartz-feldspar-mica gneiss, ± migmatitic, local quartzite ± feldspathic, local amphibolite & metadolerite

- **MARRABA-MITAKOODI** timeslice **largely preserved west of the Overhang Fault Zone …… apart from up-faulted block of high grade equivalents in the Double Crossing Metamorphics** west of the Overhang Fault Zone.
- **Condensed Ballara Quartzite time-equivalent** west (and north) of Pilgrim-Fountain Range Fault Zones



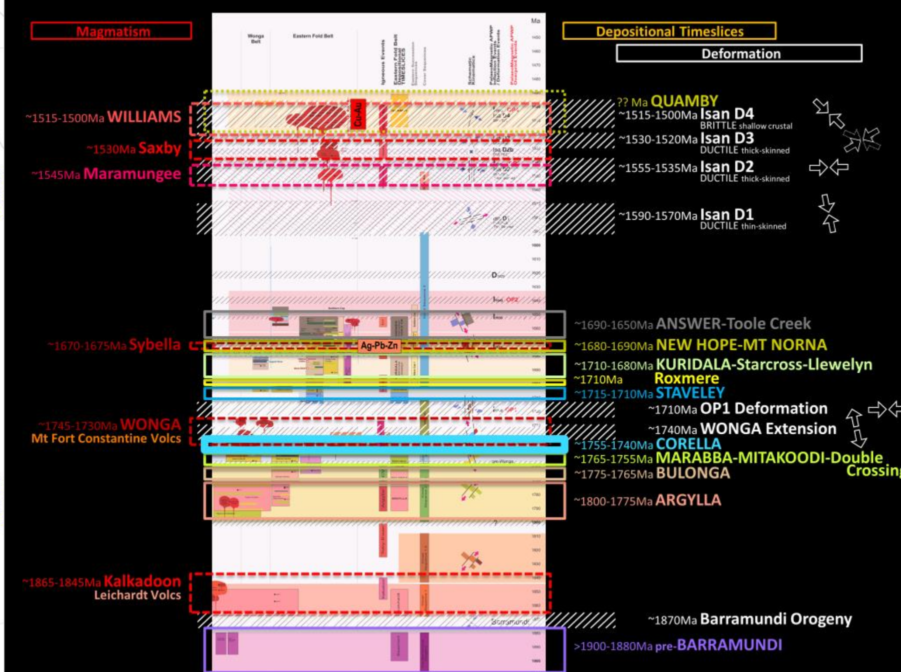
~1755-1740Ma
CORELLA

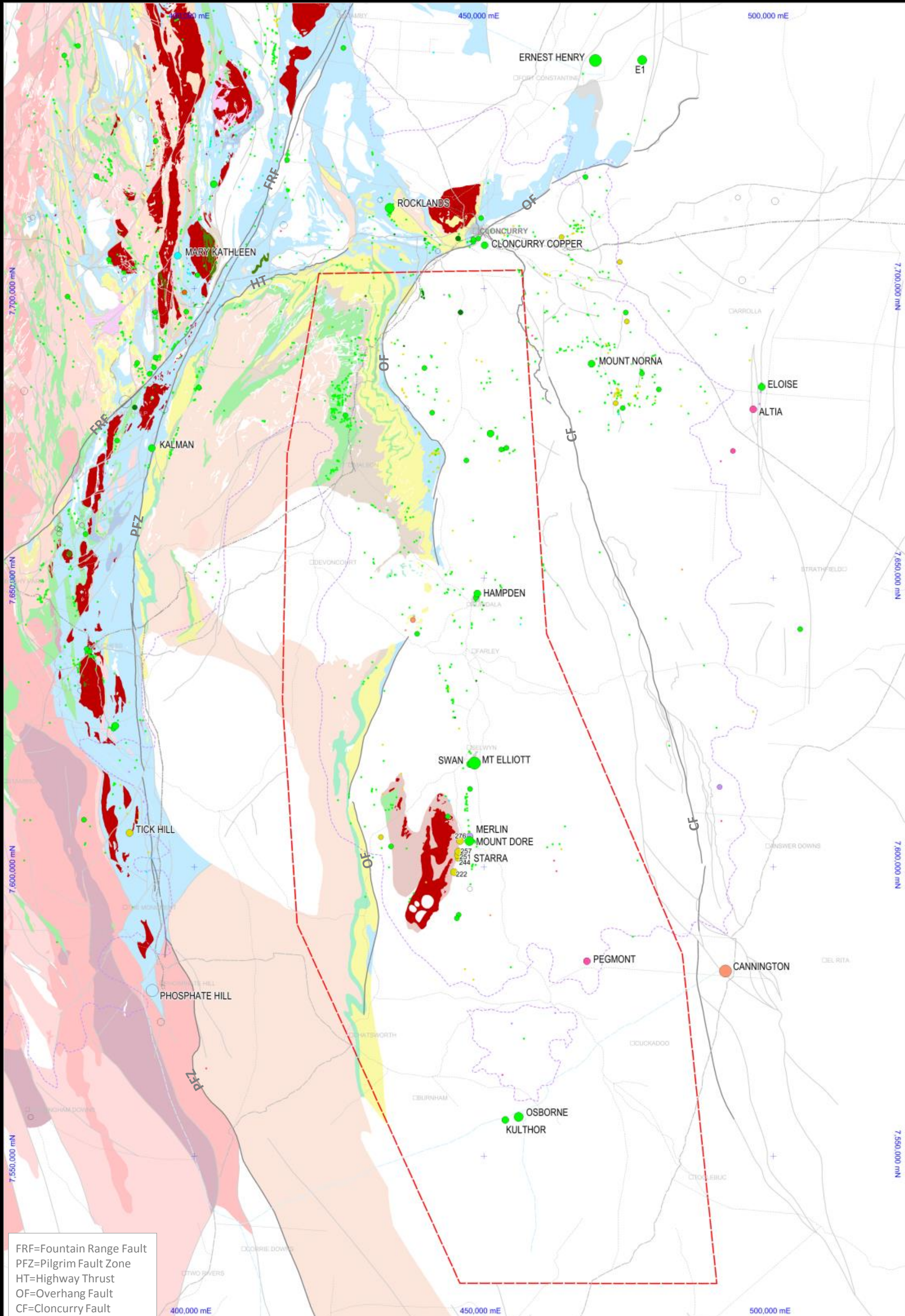


***Corella Formation**, Overhang Jasperlite, Chumvale Breccia, Lime Creek Metabasalt Member*

Calcareous sandstone-siltstone, limestone, calcareous scapolitic granofels, calc-silicates, marble, minor quartzose sandstone, laminated siltstone-jasperlite, metabasalt-amphibolite, schist, shale-pelite, minor feldspathic granofels, minor contact aureole pyroxene hornfels-skarn

- **CORELLA** timeslice **entirely preserved west of the Overhang Fault Zone,** and **north of the NE extension of the Overhang Fault Zone**
- **CORELLA onlaps Ballara Quartzite west and north of Fountain Range Fault Zone**
- **Much of Corella Formation, and all of the Staveley & Doherty Formations removed from CORELLA timeslice** and re-allocated to **later STAVELEY** timeslice





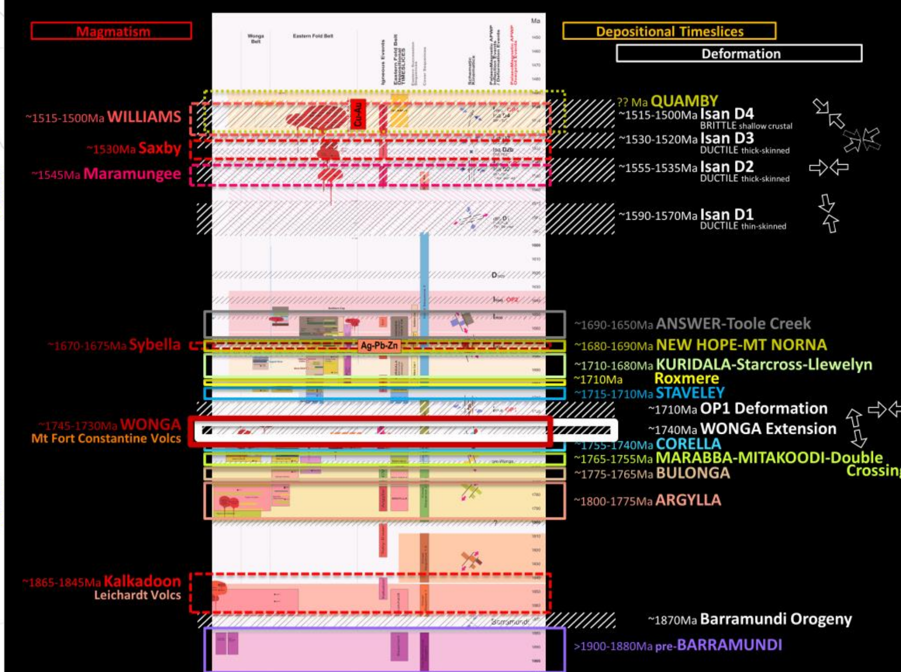
~1745-1735Ma
Wonga Extension
~1745-1730Ma
Wonga Magmatism

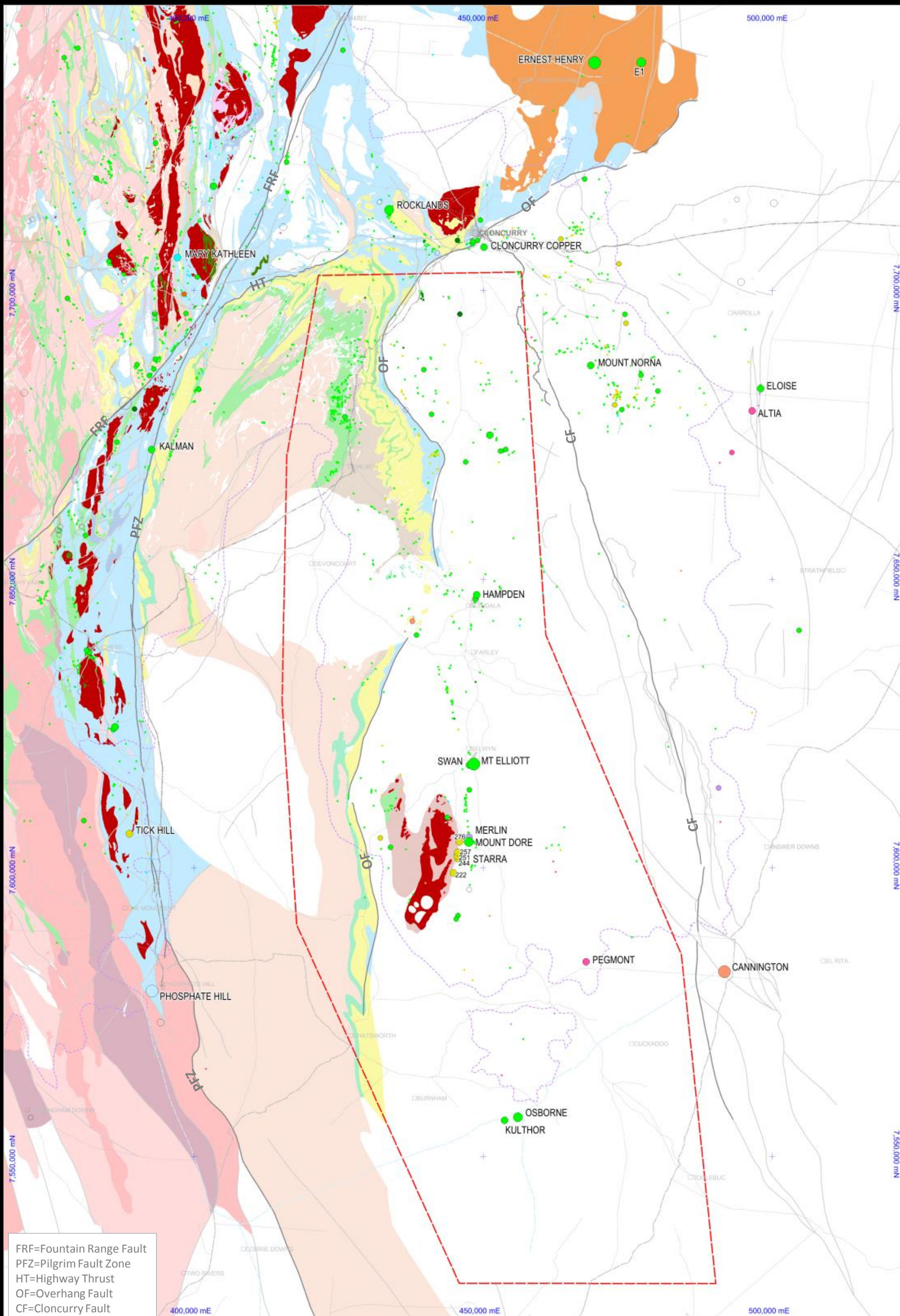
Mid-crustal Extension Event: N-S Extension associated with **extensive mafic to felsic, syn-tectonic magmatism,** and **widespread metasomatism**

Wonga Granite, Burstall Granite, ***Gin Creek Granite****, Levian Granite, Hardway Granite, Overlander Granite, Revenue Granite, Mount Erle Igneous Complex, Mount Philp Breccia, Tick Hill Complex …. and others*

Massive to strongly foliated to gneissic, fine-coarse grained, ± porphyritic, leucocratic, biotite granite, granodiorite to monzogranite; tourmaline-muscovite granite, diorite, dolerite;

- **Exhumed along Wonga Belt,** and in the **DCM Belt where Gin Creek Granite has intruded** the deformed and metamorphosed **Double Crossing Metamorphics**
- In WFB, Wonga N-S extension drives shallow **normal fault tilt blocks** of **Eastern Creek Volcanic** pile that ultimately hosts PRIZE and ISA SUPERGROUP successions





~1745-1735Ma
Wonga Extension

~1745-1730Ma
Wonga Magmatism

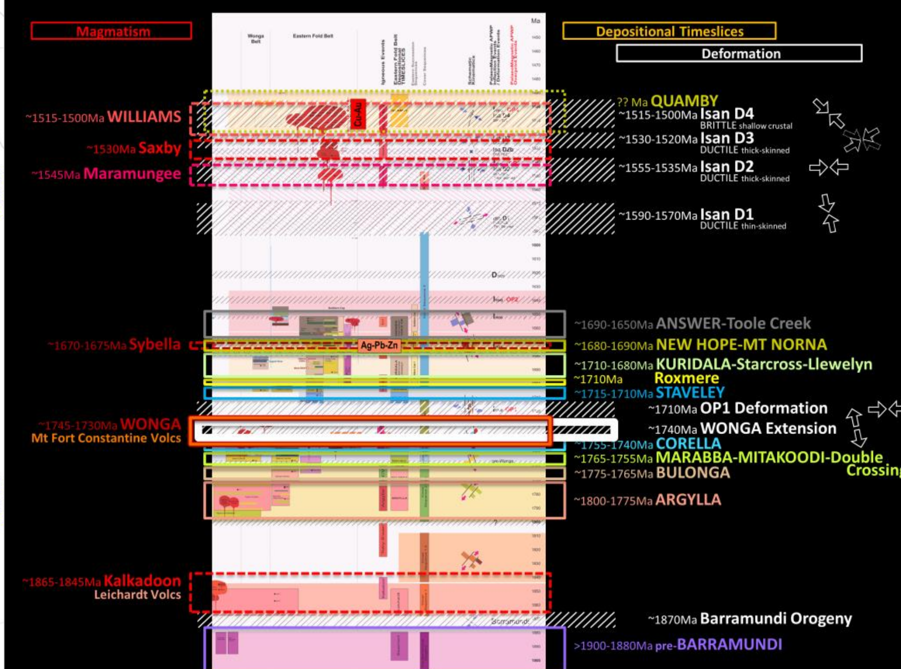
~1745-1740Ma
Mount Fort Constantine Volcanics

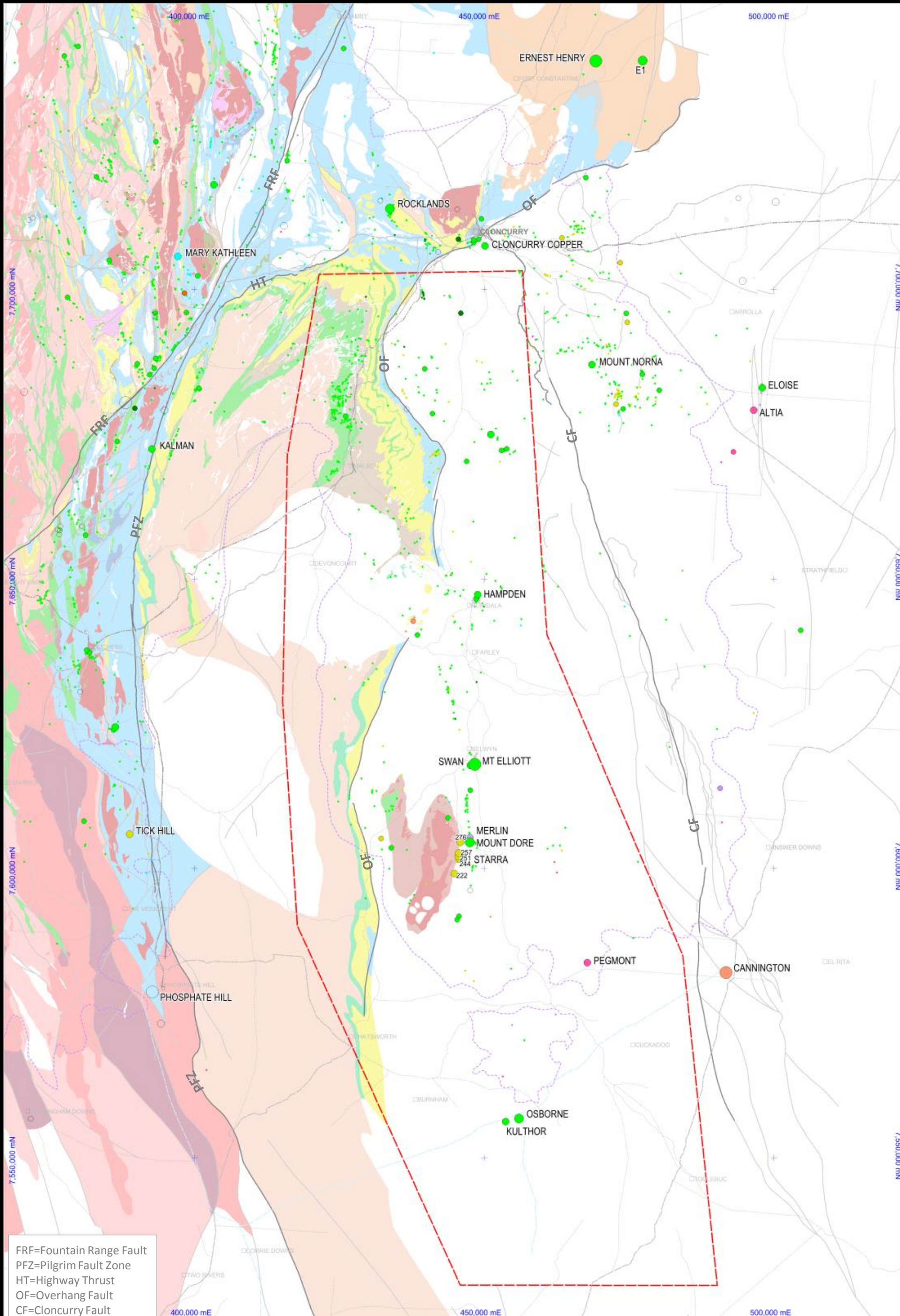
Volcanism associated with Wonga Mid-crustal Extension Event

Mount Fort Constantine Volcanics

Felsic-intermediate volcanics-volcanoclastics, minor carbonate & sediments

- **MFCV are potential surficial expression** of Wonga magmatism at depth
- **MFCV confined to north of NE extension of the Overhang Fault ….. suggesting that this NE portion of the Overhang Fault** may mark some **depositional basin fault margin at Wonga-time**

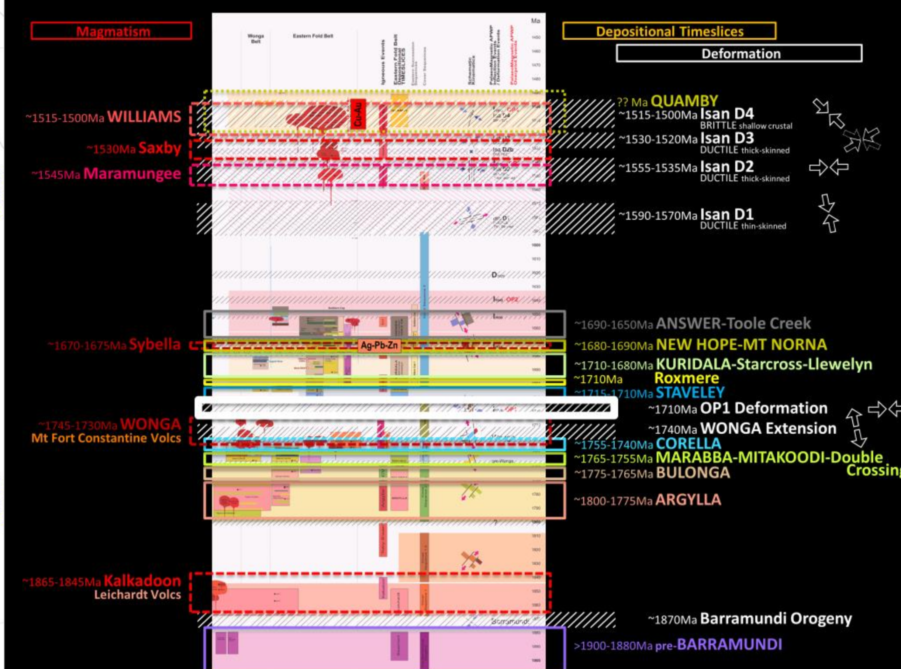


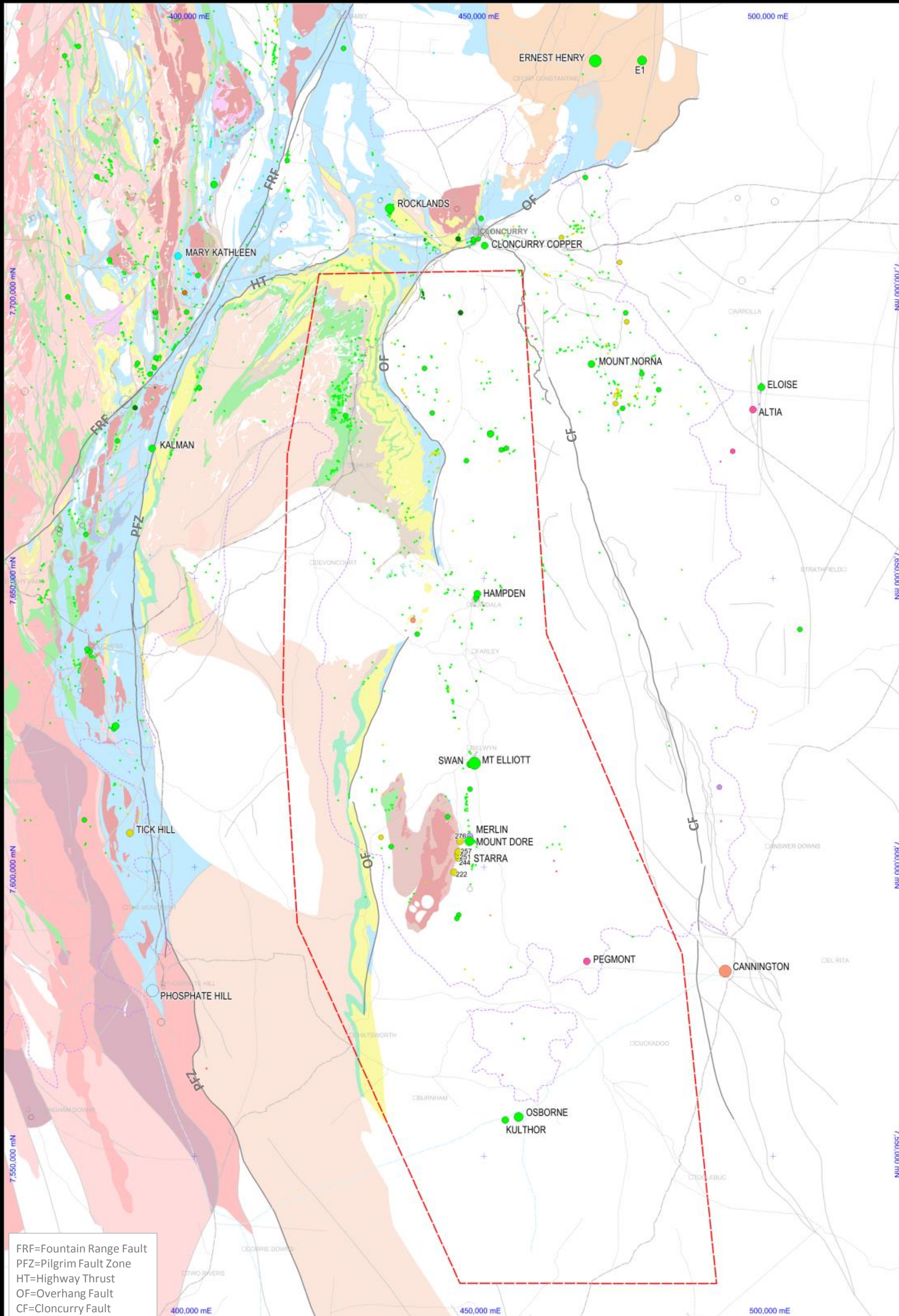


~1710Ma

OP1 Deformation

Little-highlighted, but important OP1 Orogenic/Deformation Event:
E-W shortening event, around 1700-1710Ma

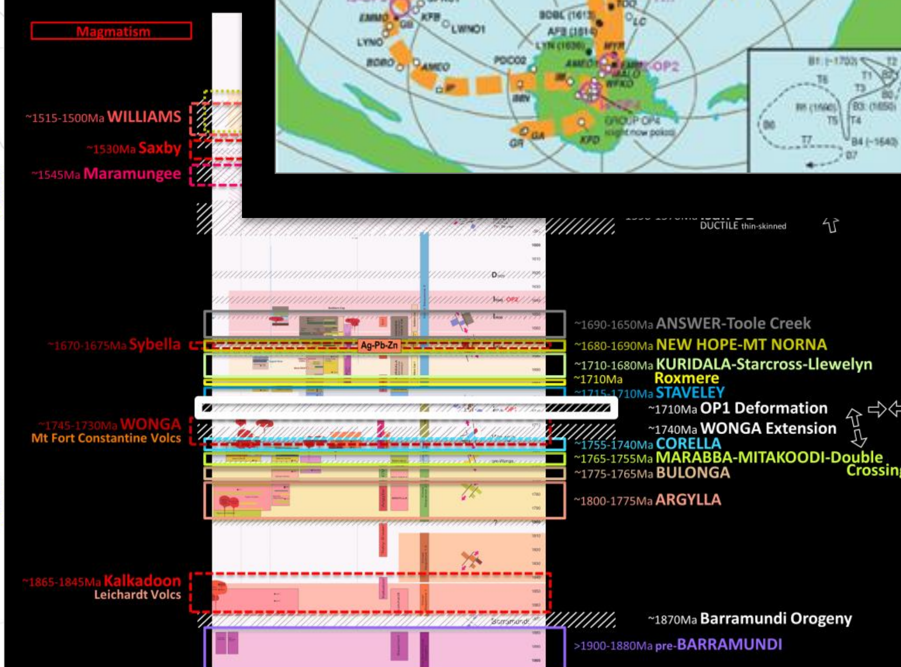


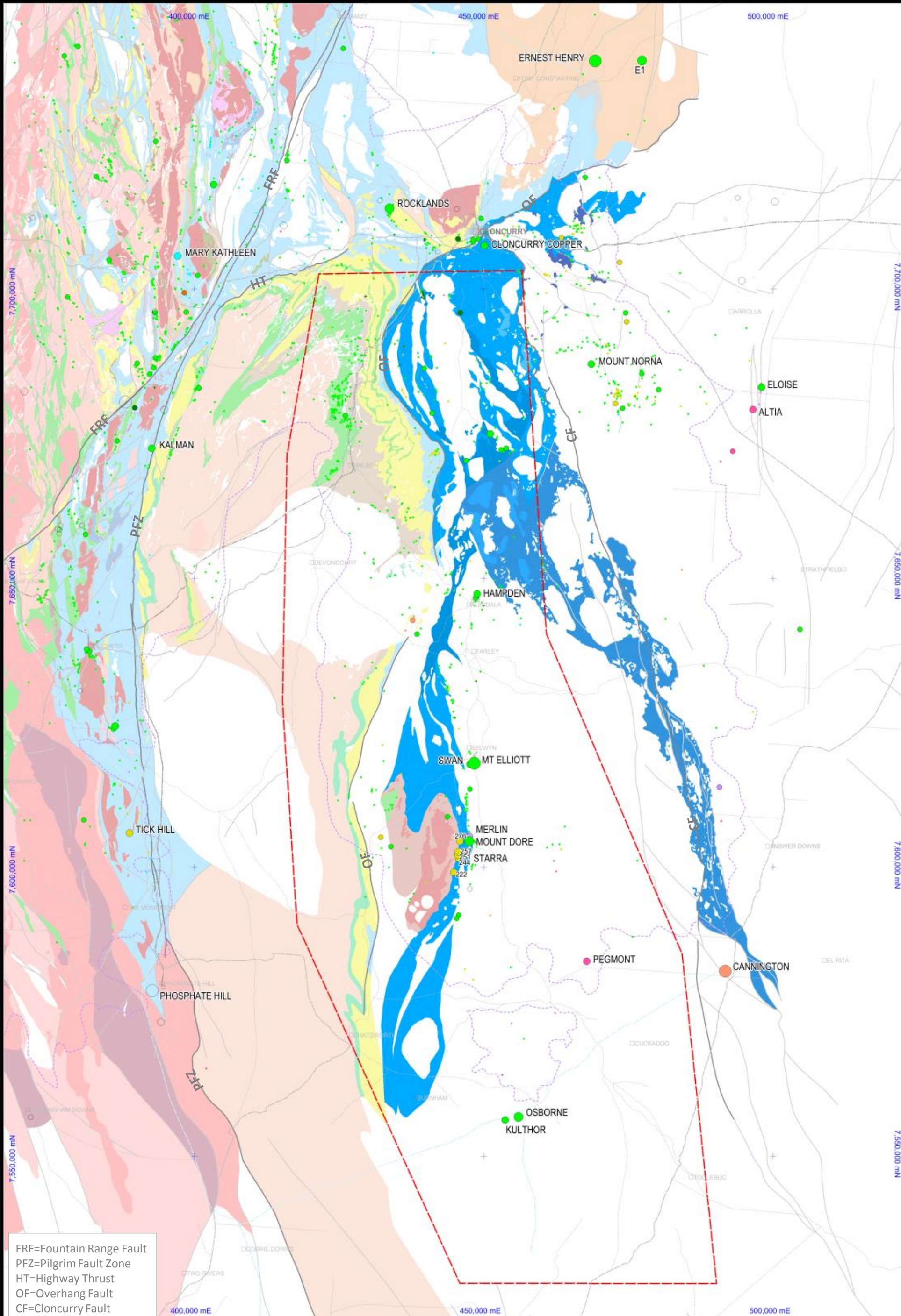


~1710Ma
OP1 Deformation

Little-highlighted, but important OP1 Orogenic/Deformation Event:
E-W shortening event, around 1700-1710Ma

- **OP1 Event suggested by latitudinal hairpin in the North Australian, Apparent Polar Wander Path** (Indurm, 2000) indicating a 180° E-W reversal in plate motion at this time.
- **In EFB, OP1 Deformation Event** suggested to **exhume the high grade, Double Crossing Metamorphics & Gin Creek Granite** to surface to receive **depositional onlap and/or thrust justapostioning** of subsequent **lower grade sequences.**
- In the WFB, OP1 Deformation also folds WONGA-extended Eastern Creek Volcanics tilt blocks prior to PRIZE and ISA SUPERBASIN deposition (NWQMP, 2000)



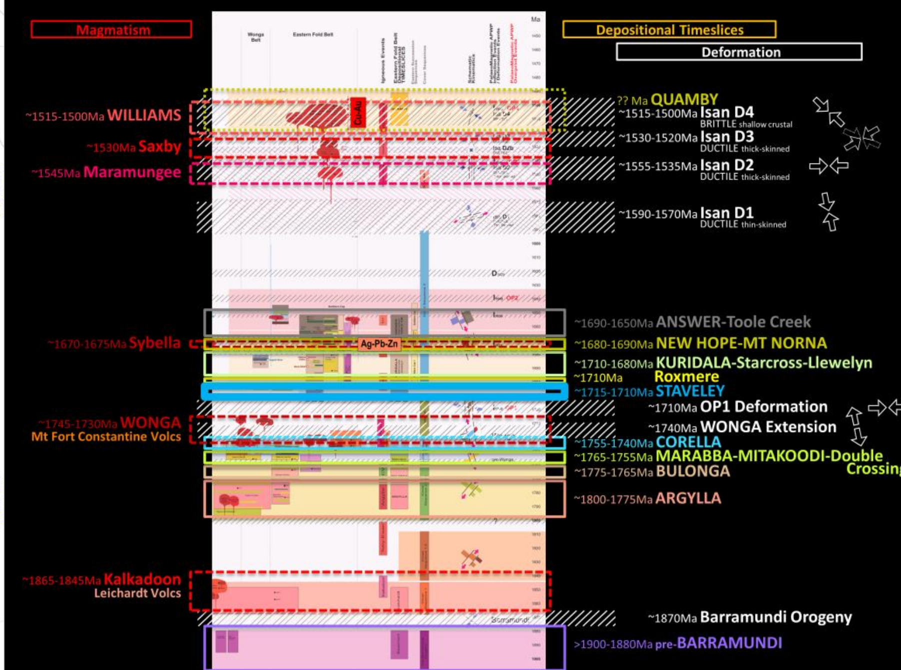


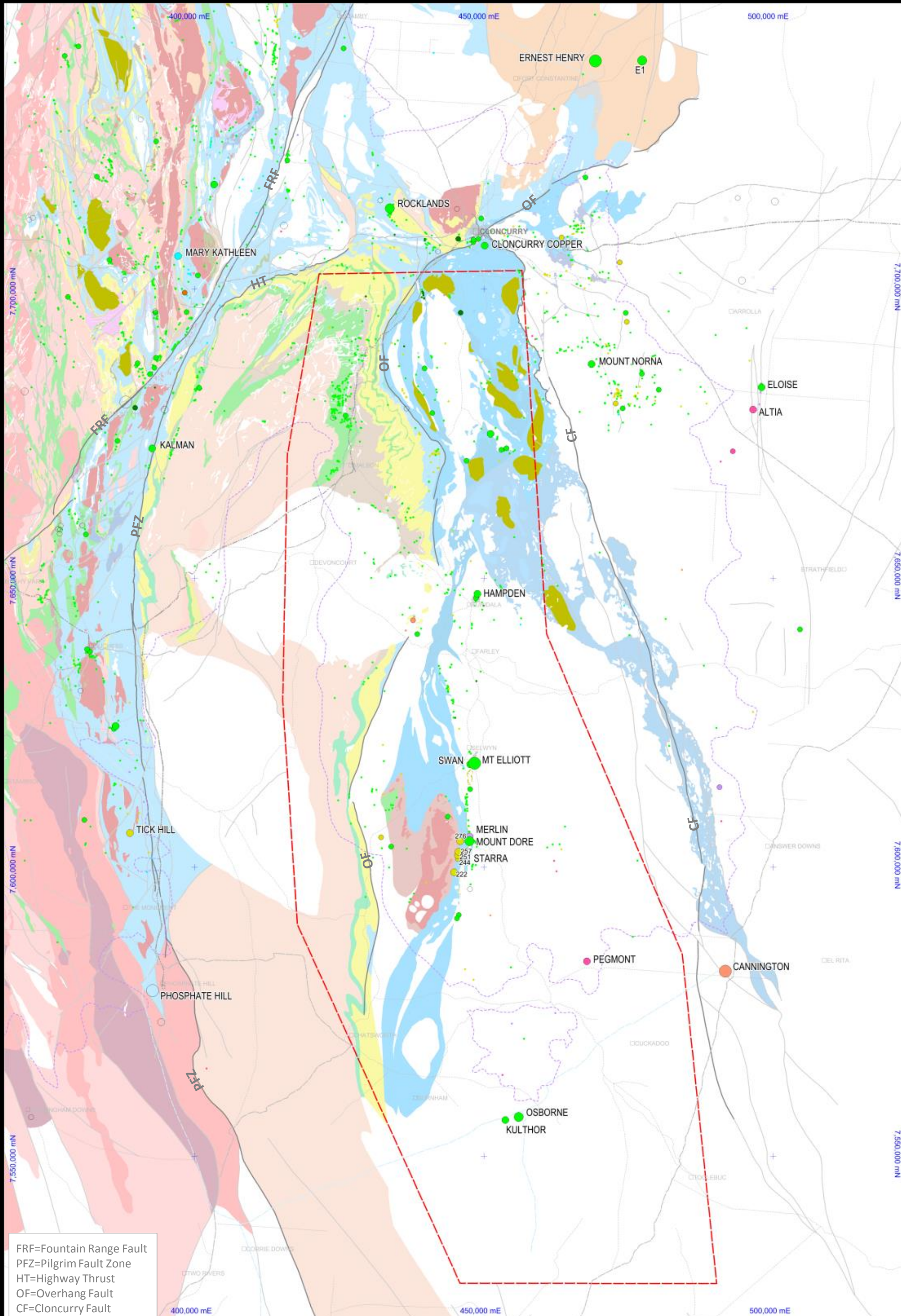
~1715-1710Ma
STAVELEY

Staveley Formation, Doherty Formation, significant parts of Corella Formation

Interbedded, variably calcareous, sandstone-siltstone, calc-silicates, calc-silicate granofels, breccias of all; impure limestone, marble

- **STAVELEY** timeslice includes significant areas of previously-allocated **Doherty** & **Corella Formation** and their brecciated variants
- **STAVELEY** timeslice now found entirely east and south of the Overhang Fault Zone and its NE extension … in sharp contrast with the distribution of the **CORELLA** package
- **Basal STAVELEY obscure.** Underlying packages not identified if conventional wisdom is correct and **lower portions** of STAVELEY are **ubiquitously in fault contact** with older packages along the **Overhang Fault** (against CORELLA and MITAKOODI packages) and along the **Starra Shear** (against 'Double Crossing Metamorphics' & 'Gin Creek Granite')
- An **alternative** that STAVELEY is in depositional (rather than D1 thrust) contact with 'Double Crossing Metamorphics' & 'Gin Creek Granite' around the northern and eastern sides of the Gin Creek Block. **However, high angle** discordances (in detailed geophysics) between **FW metamorphic fabric**, the **STAVELEY-DCM contact** & **HW STAVELEY bedding** around the northern margins of the Gin Creek Block **argue against this interpretation.**



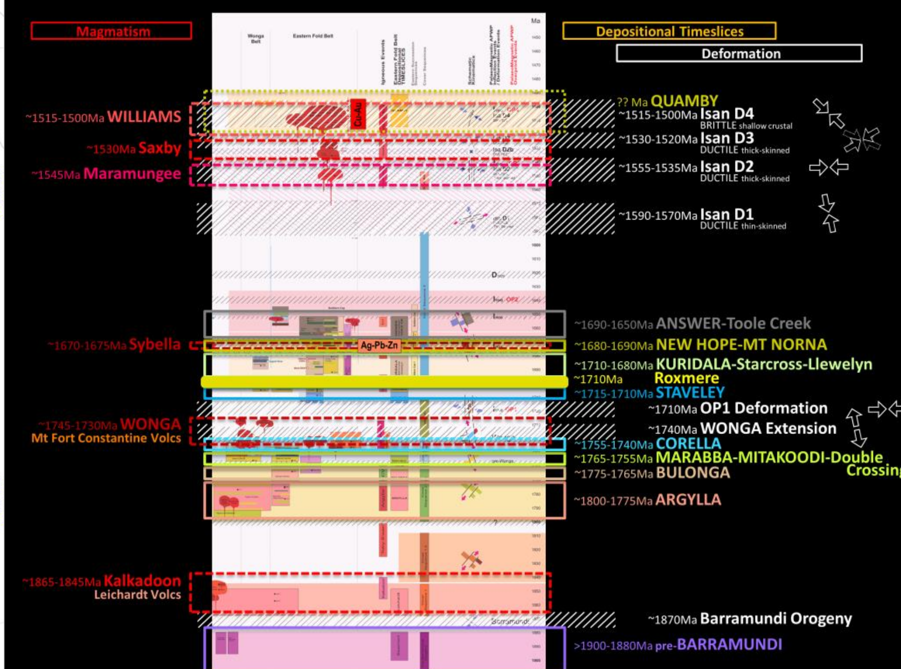


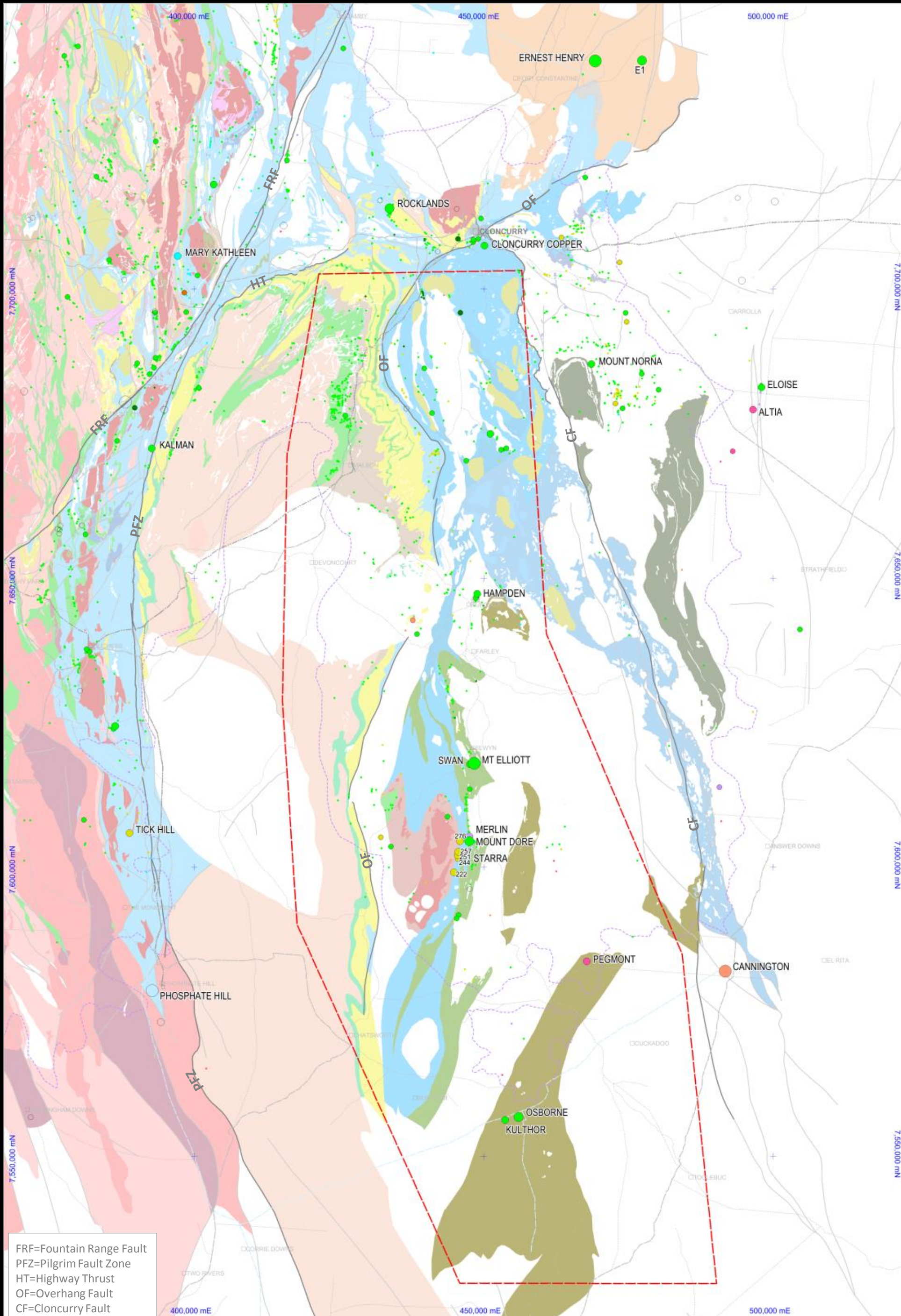
~1710Ma
ROXMERE

***Roxmere Quartzite**, Deighton Quartzite, Knapdale Quartzite*

Quartzose-feldspathic, fine-coarse sandstone, siltstone, locally micaceaous, minor pebble conglomerate

- The **Roxmere Quartzite expresses a clean clastic** re-activation towards the end of STAVELEY carbonate accumulation, and marks **some tectonic re-activation** and the **onset of basin deepening**
- The Roxmere Quartzite is known south to Merlin-Mount Dore and beyond
- At Merlin-Mount Dore the Roxmere Quartzite is called the 'SQT' and has been interpreted as a Mount Dore Fault due to its moderate degree of deformation overprint. Sedimentary cycles are still mappable within it and transitions into and out of Roxmere Quartzite are sedimentologically-gradational (*from drillcore*).





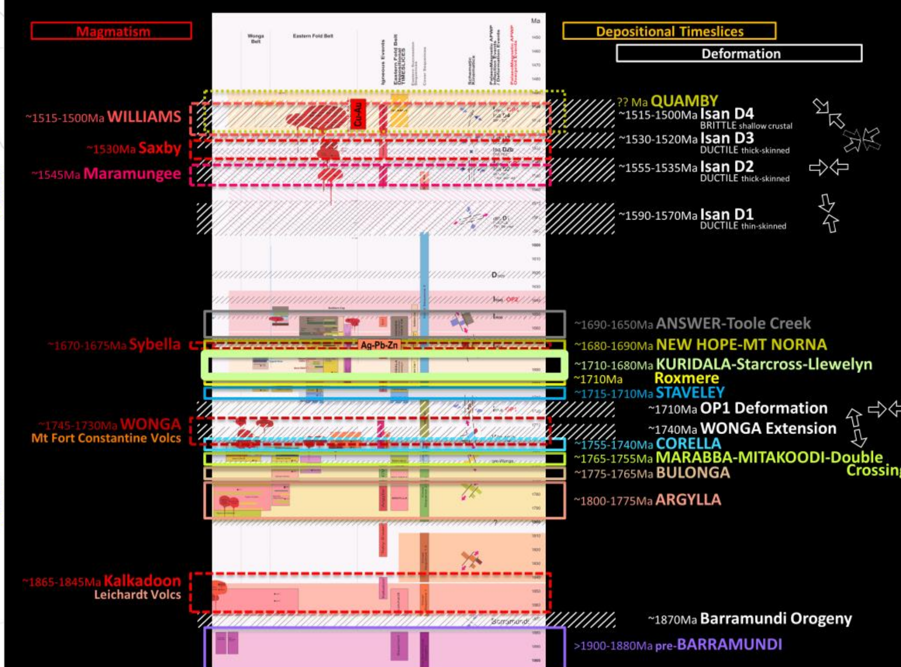
~1710-1680Ma

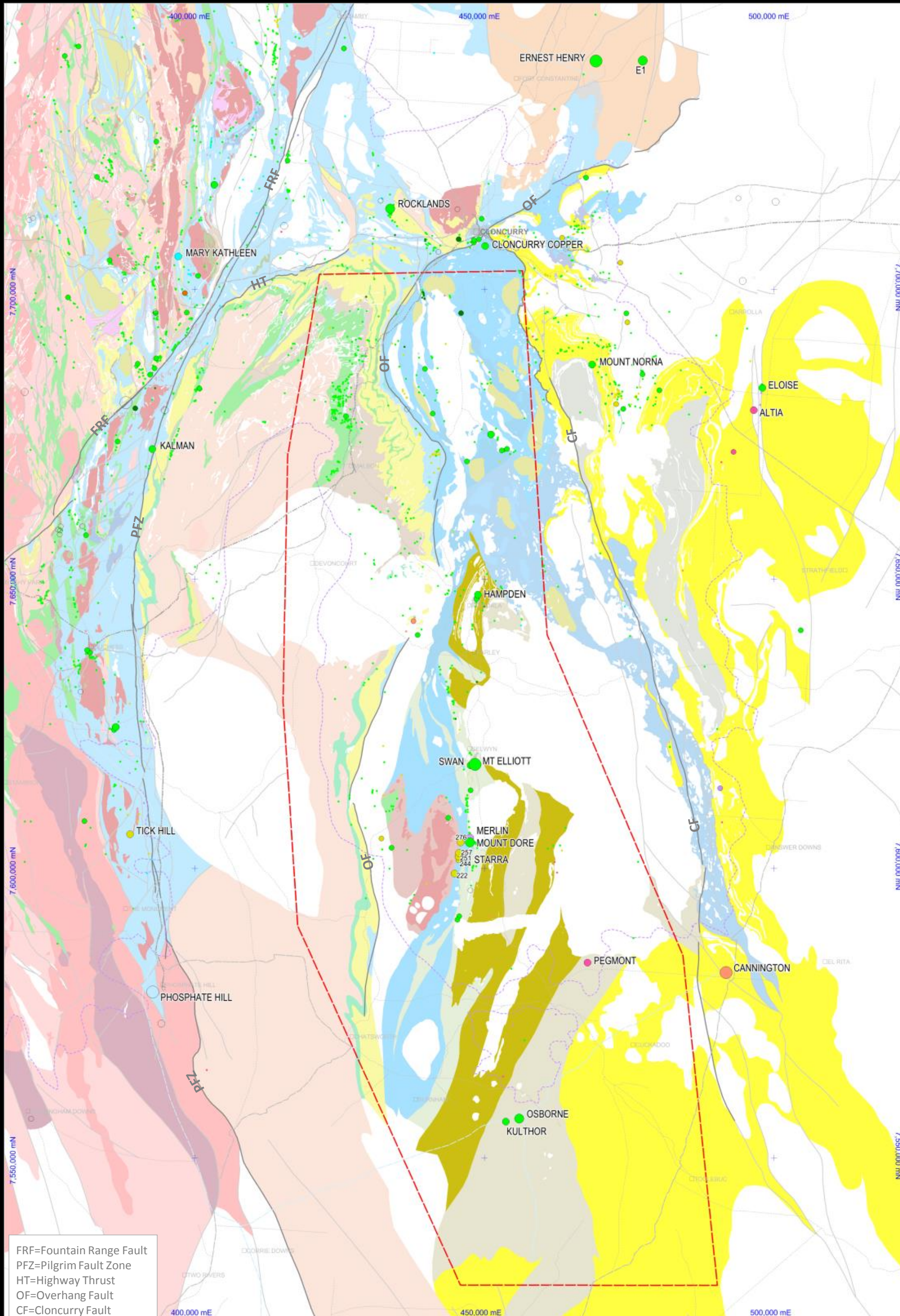
KURIDALA-Starcross-Llewelyn

Kuridala Formation, Starcross Formation, Llewelyn Creek Formation, part Hampden Slate

Psammitic-pelitic schists, phylllite, metagreywacke, carbonaceous siltstones, graphitic slate, minor quartzite; (some schists garnet, staurolite & andalusite-bearing)

- KURIDALA packages reflect basin deepening characterised **by fine-sediment dominated, turbidite deposition**
- KURIDALA preserved largely east (and south) of Overhang Fault Zone apart from potential time-equivalents in the Mary Kathleen Belt (& around Dugald River) suggesting deepening basin eastward



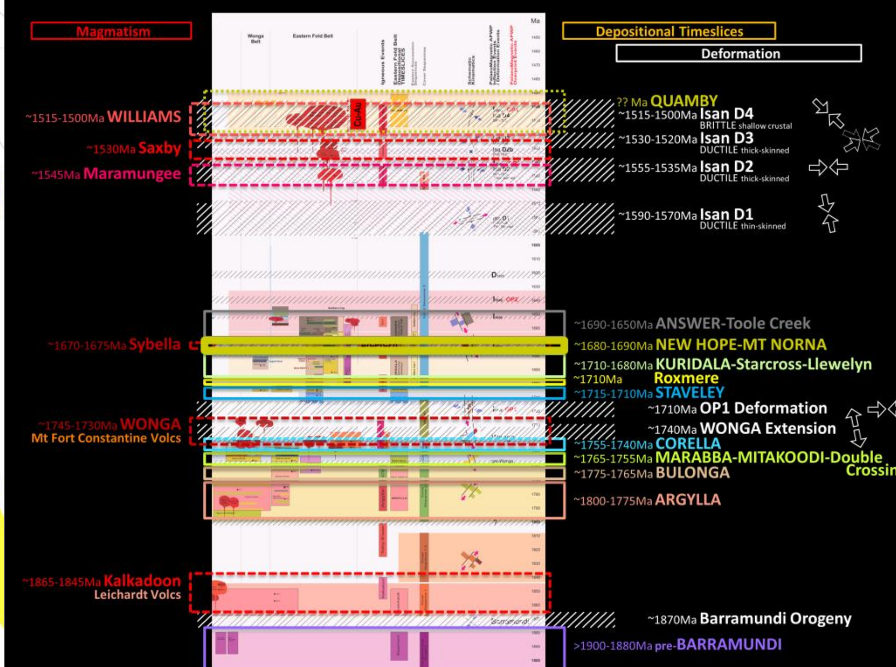


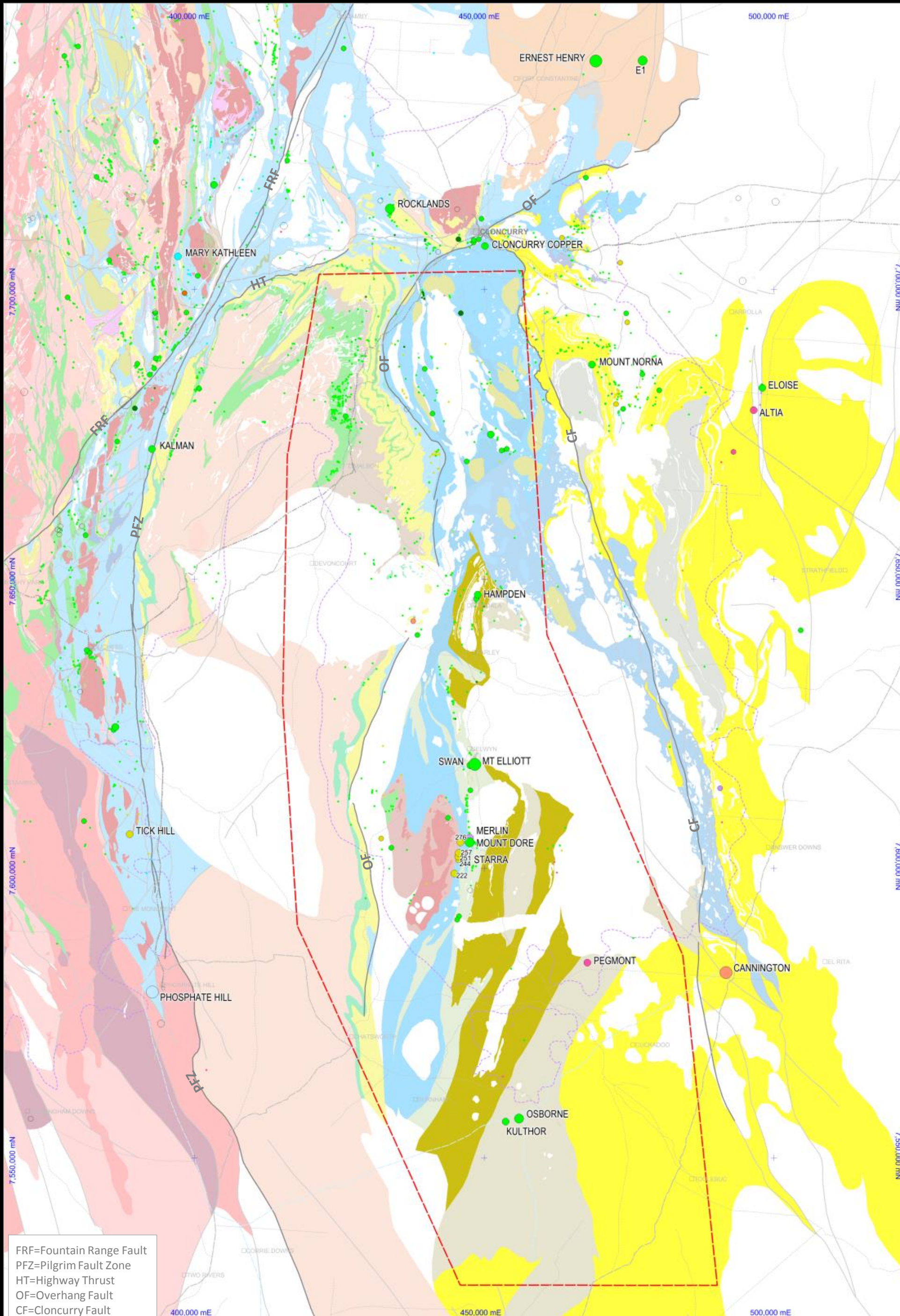
~1680-1670Ma
NEW HOPE-MOUNT NORNA

New Hope Sandstone-Mount Norna Quartzite

Quartzose(-feldspathic), fine-grained, meta sandstone, siltstone, mudstone, locally schistose, minor chert

- The **NEW HOPE-MOUNT NORNA** timeslice comprises **coarser grained, ongoing turbiditic deposition …. reflecting basin/rift re-activation**
- The **NEW HOPE-MOUNT NORNA** timeslice is also preserved largely east (and south) of Overhang Fault Zone
- East of Overhang Fault Zone, STAVELEY, KURIDALA, and NEW HOPE-MOUNT NORNA packages show an overall eastward younging in map distribution





~1680-1670Ma

NEW HOPE-MOUNT NORNA

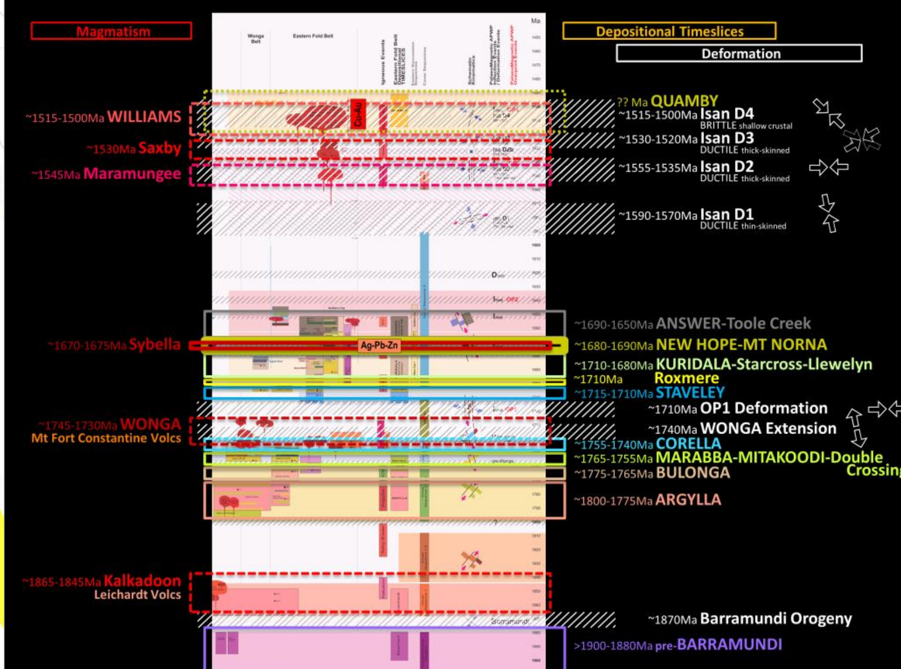
~1675-1670Ma

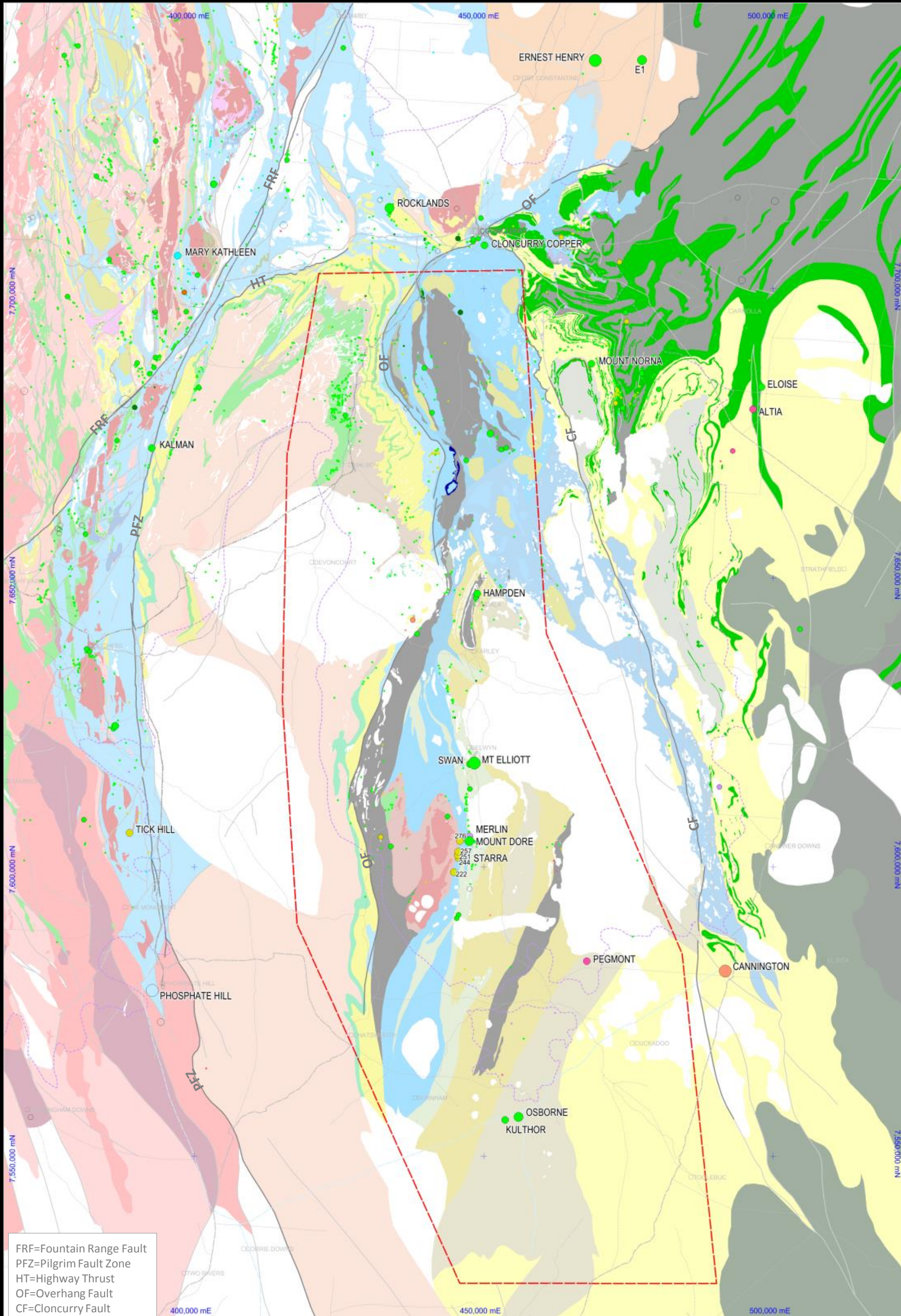
WFB Sybella-EFB *'Hot Rift'*

Ag-Pb-Zn Mineralisation

MOUNT NORNA ……. associated with significant Metadolerite silling

- **Metadolerite silling** combined with the **coarsening NEW HOPE-MT NOR**NA rift packages **east of the Cloncurry Fault** suggests the **possibility of a localised thermal input into the basin …… ('Hot Rift') ….. that drives sediment-hosted Ag-Pb-Zn mineralisation (Cannington, Maronan)**
- **Architectures are unclear but NNW-SSE extension has been suggested** (NWQMP 2000)
- **This period is characterised by non-deposition in the Western Fold Belt** and **significant intrusive input** in the form of the **Sybella Batholith.**





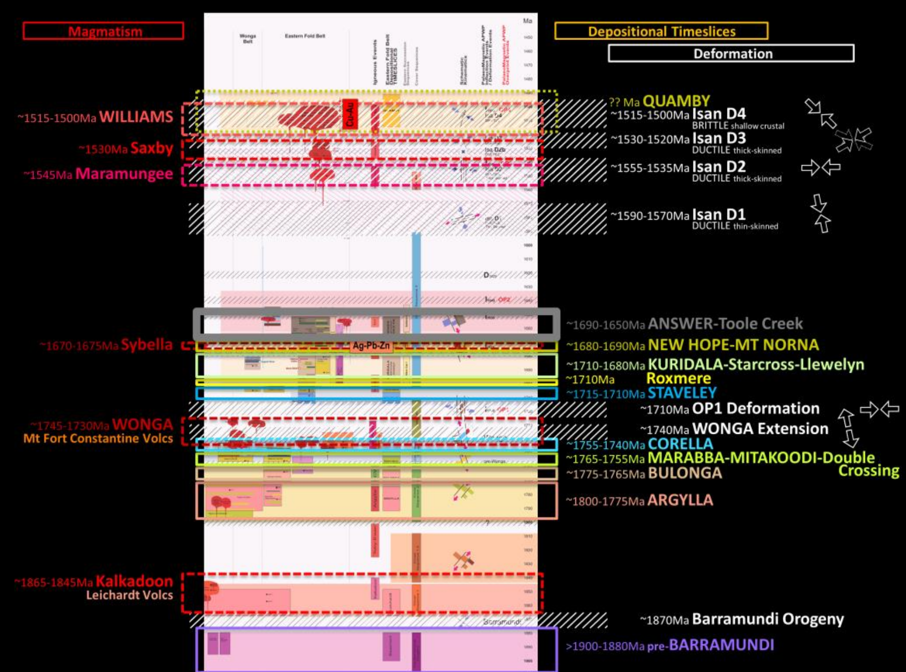
~1670-1650Ma

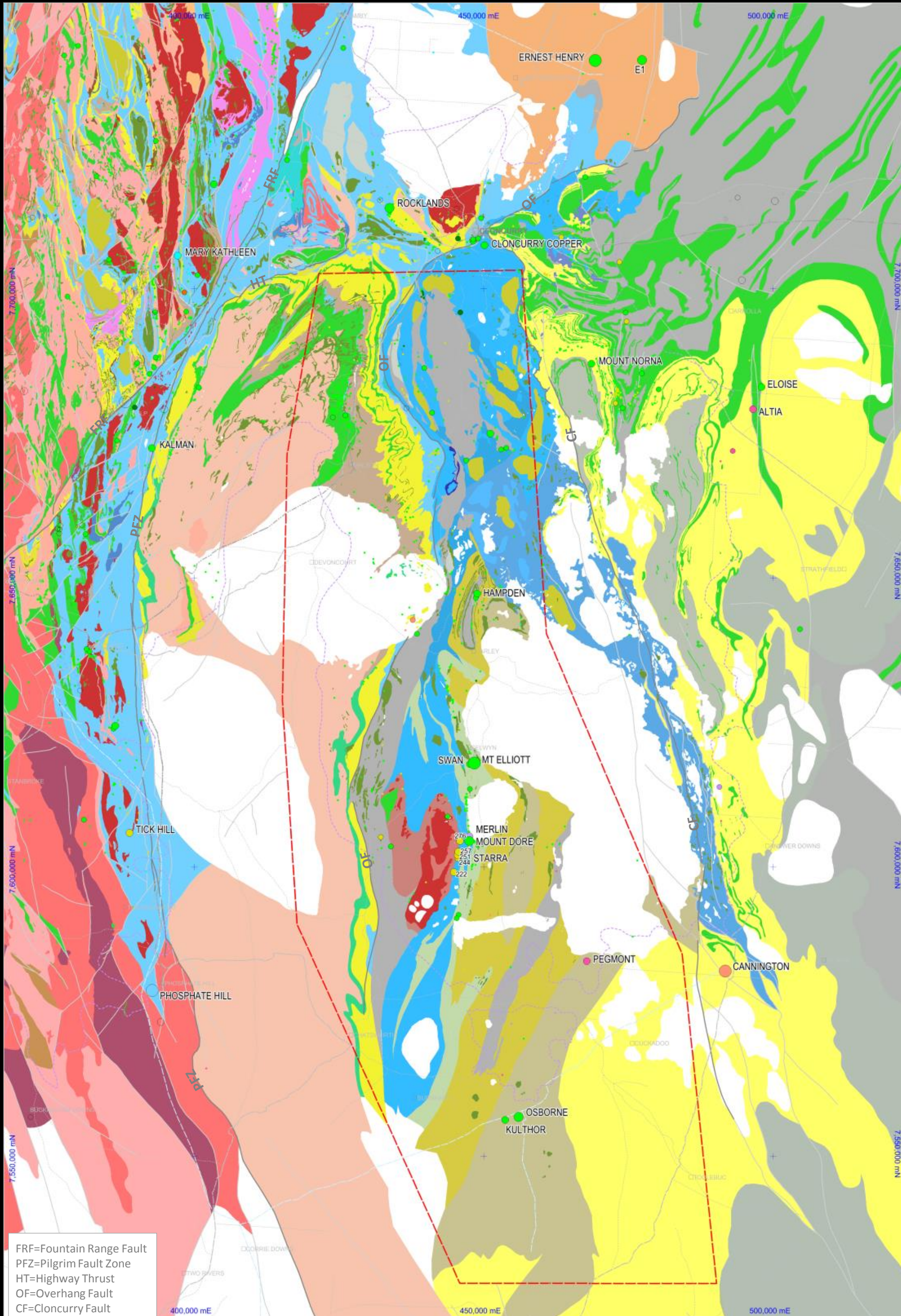
ANSWER-TOOLE CREEK

Answer Slate , <u>parts of Hampden Slate</u>, Toole Creek Volcanics

Slate, phylllite, metasiltstone, mica schist, graphitic slate, minor feldspathic quartzite; carbonaceous mudstone, metabasalt, metadolerite, amphibolite, chert

- **ANSWER-TOOLE CREEK timeslice represents a period of significant basin deepening**.
- There is an **apparent westward step in deposition** perhaps reflecting more regional drowning associated with post-rift sag.
- **Toole Creek Volcanics** contain a **very significant component of mafic magmatism** (volcanics, sills, dykes) **east of the Cloncurry Fault** suggesting significant crustal attenuation associated with a sag phase of accumulation.
- Answer Slate west of the Cloncurry Fault Zone contains lesser mafic magmatic input compared with the Toole Creek Volcanics.
- Both the **Answer Slate** (in the west) and parts **Toole Creek Volcanics** (in the north east of Cloncurry) **also** in **thrust contact with older packages** … and have been **<u>thrust</u>** from their sites of deposition (**to the south and east**) during the Isan Orogeny
- **Timeslice terminates around 1650Ma** ….. minor felsic magmatism around this time: Ernest Henry Diorite, Tommy Creek Microgranites and possibly SWAN Diorite *(date pending)*





~1650Ma

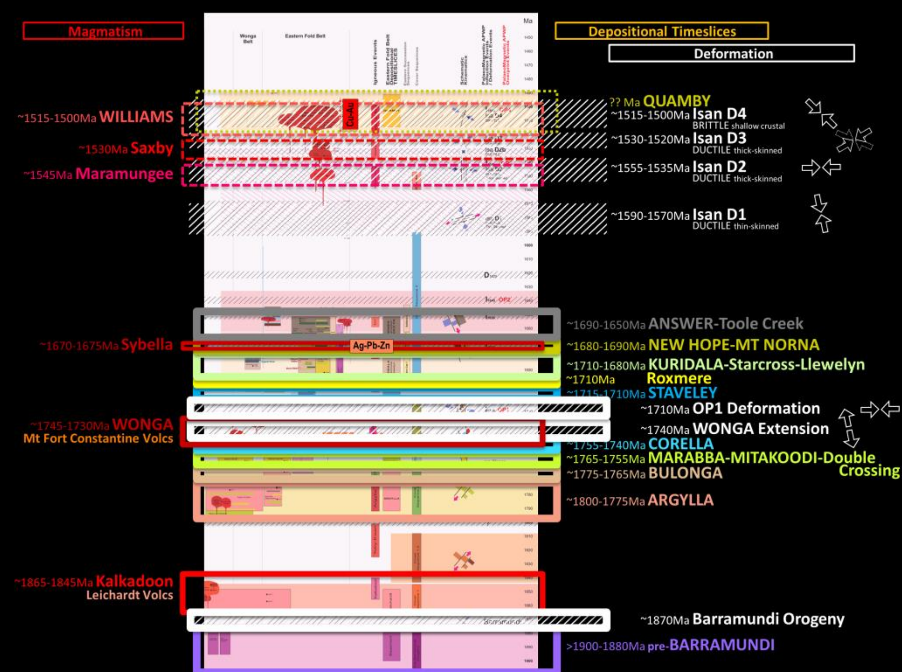
End of Accumulation

By 1650, accumulation in the Eastern Fold Belt had ceased.

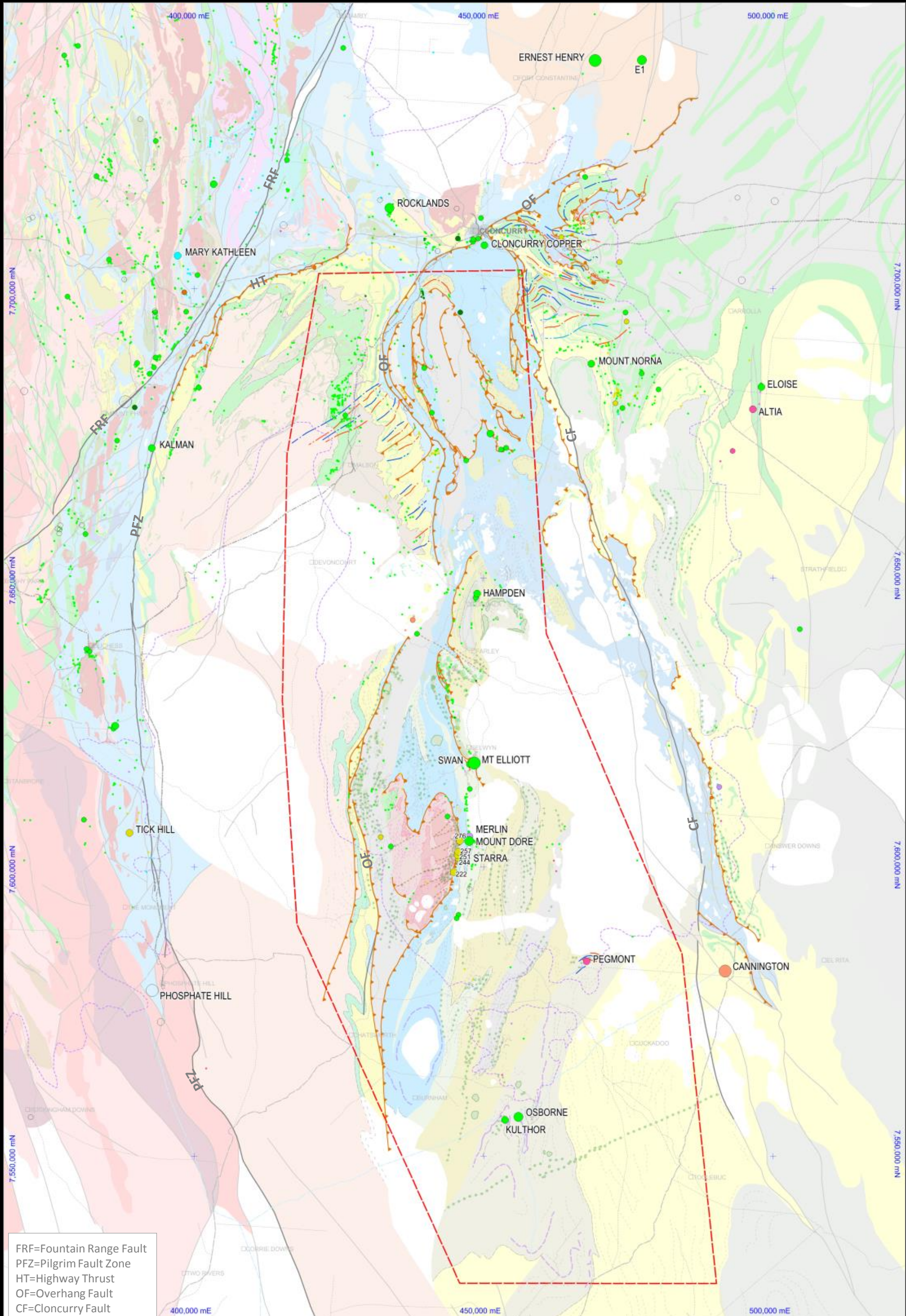
Rock relations at this time would have incorporated the deformation and magmatic effects and inputs of …

- the **Barramundi Orogeny**
- the **Wonga Extension** including **mid-crustal extensional detachments** with associated magmatism and possible **upper-crustal extensional faulting, tilt blocks and basin compartments** (MFCVs)
- significant **E-W shortening** during the **OP1 Deformation/Orogeny** that in the EFB is implicated in the exhumation of Double Crossing Metamorphics & Gin Creek Granite to surface, or at least upper crustal levels.

In addition, spatially-focused magmatic input in the form of syn-depositional metadolerite silling is present in the NEW HOPE-MOUNT NORNA and TOOLE CREEK packages.

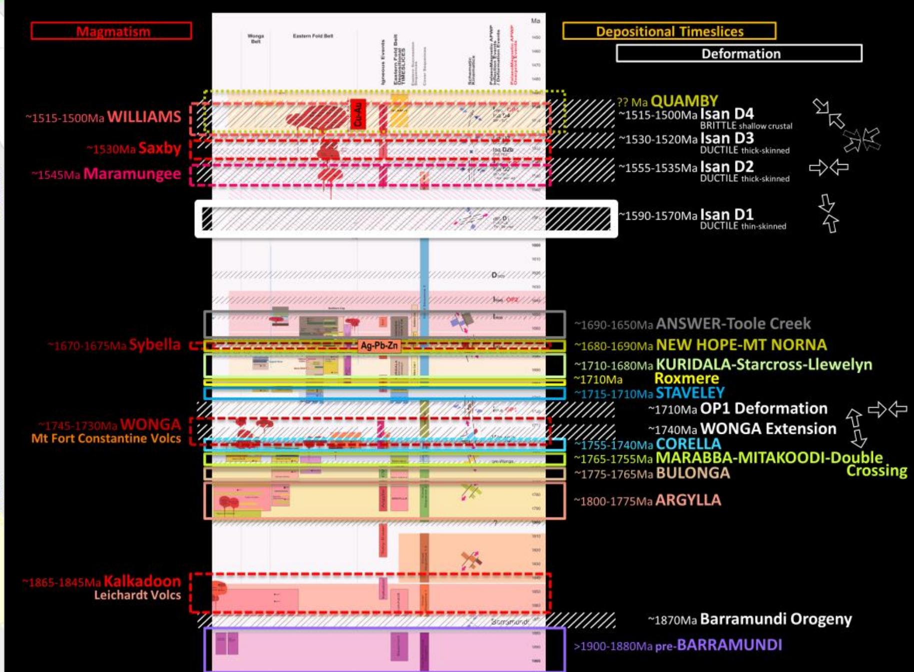


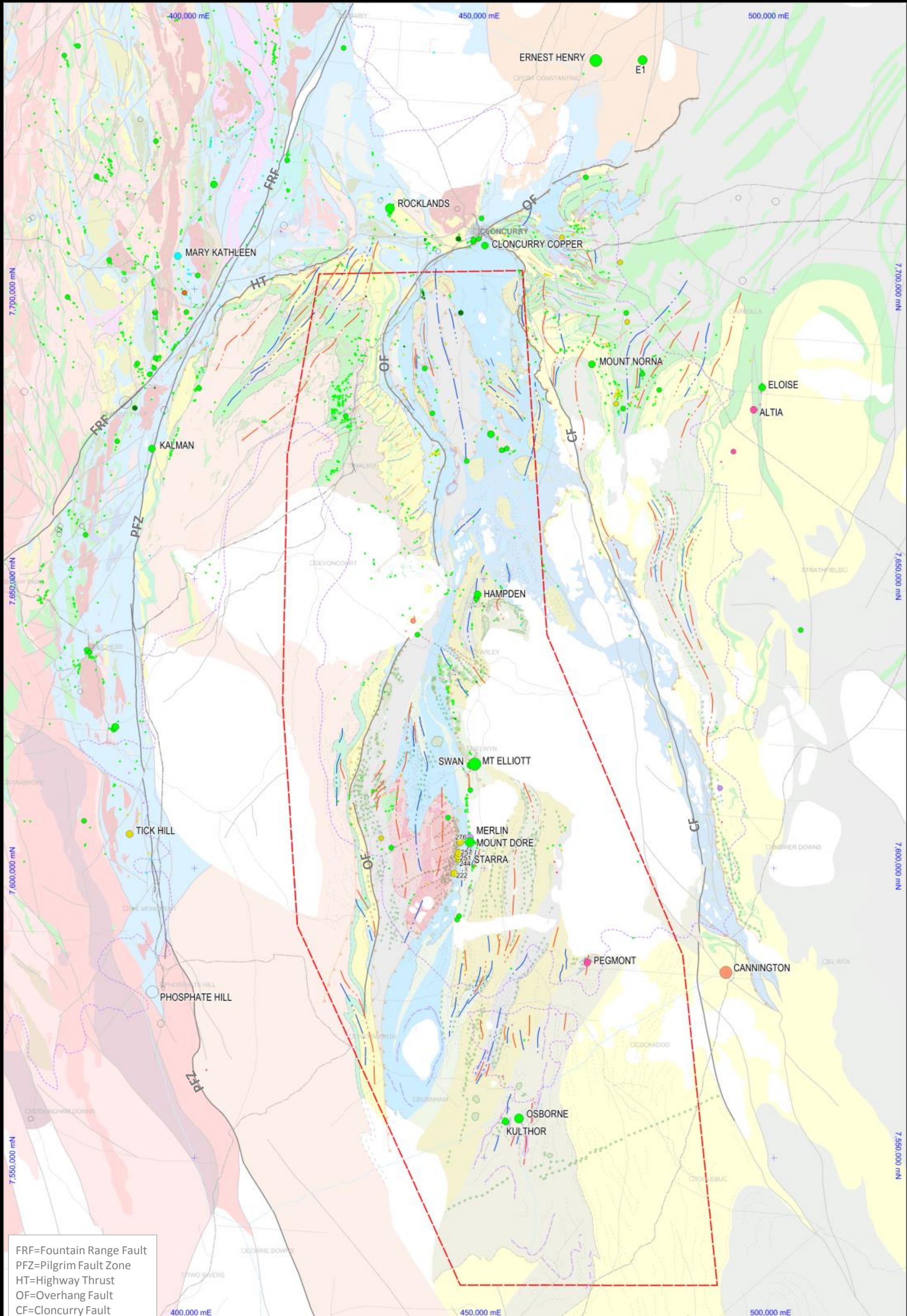
~1600-1570Ma
thin-skinned, **D1 Folding** & **Thrusting**



<u>50Ma later</u>, **Thin-skinned Isan D1** characterised by **N-S to NNW-SSE shortening** with **N(NW)-directed movement on major, sub-horizontal thrusts** (and potential ramps) and is associated with, locally-preserved **F1 folding**.

- **Overhang Fault** including NE extension, **Starra Shear** (following conventional wisdom), **Marimo Thrust** & associated structures, the **Mount Elliott-Hampden Fault** ….
- **Cloncurry THRUST** (distinct from the Cloncurry FAULT) have been **assigned to D1** on basis of …..
  ….. **D1 folding** (folded by D2) is well developed in the **hanging wall of the Cloncurry D1 Thrust** over windows of **footwall STAVELEY** north of Snake Creek Anticline.
- D1 thrust surface may itself be folded in D1 shortening. These geometries may be influenced by their proximity to the Overhang Fault extension which marks some form of Mount Fort Constantine Volcanic (MFCV) basin margin
- **F1 folding** is also well developed in **footwall of Overhang Fault** (O'Dea et al., 2006) on the west side of the project area.
- **North-south trends** of the D1 Thrusts reflect larger-scale, meridional D2 folding of the earlier flatter-lying D1 structures.
- Many D1 thrusts, folds and linked-ramp structures likely **remain unidentified**; in particular within highly deformed and metasomatised STAVELEY packages (Marshall, 2003)



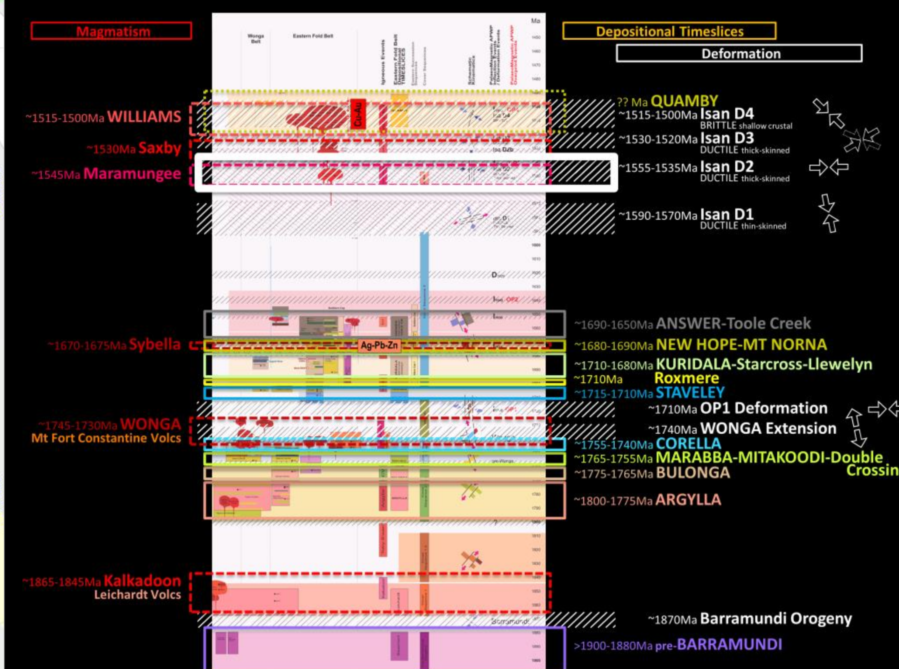


~1555-1535Ma thick-skinned, **D2 Folding**

Isan deformation evolves into **thick-skinned, mountain-building, D2 orogeny with EW shortening.**

Initial Isan D2 folding is characterised by **regional-scale, N-S meridional folds** of stratigraphy and D1 folds & thrusts.

- **Anomalously oriented D2 folding** is likely associated with re-activation of older, more fundamental, crustal penetrating and persistent structures. For example, the more NNE-trending Mitakoodi Culmination fold axes are potentially influenced by a NE-oriented structure which has been multiply re-activated from Barramundi-times
- Mountain building at D2-time is associated with **advancing regional (highTemp-highPress) metamorphism** (Rubenach et al., 2008) in a significantly thickening crust.

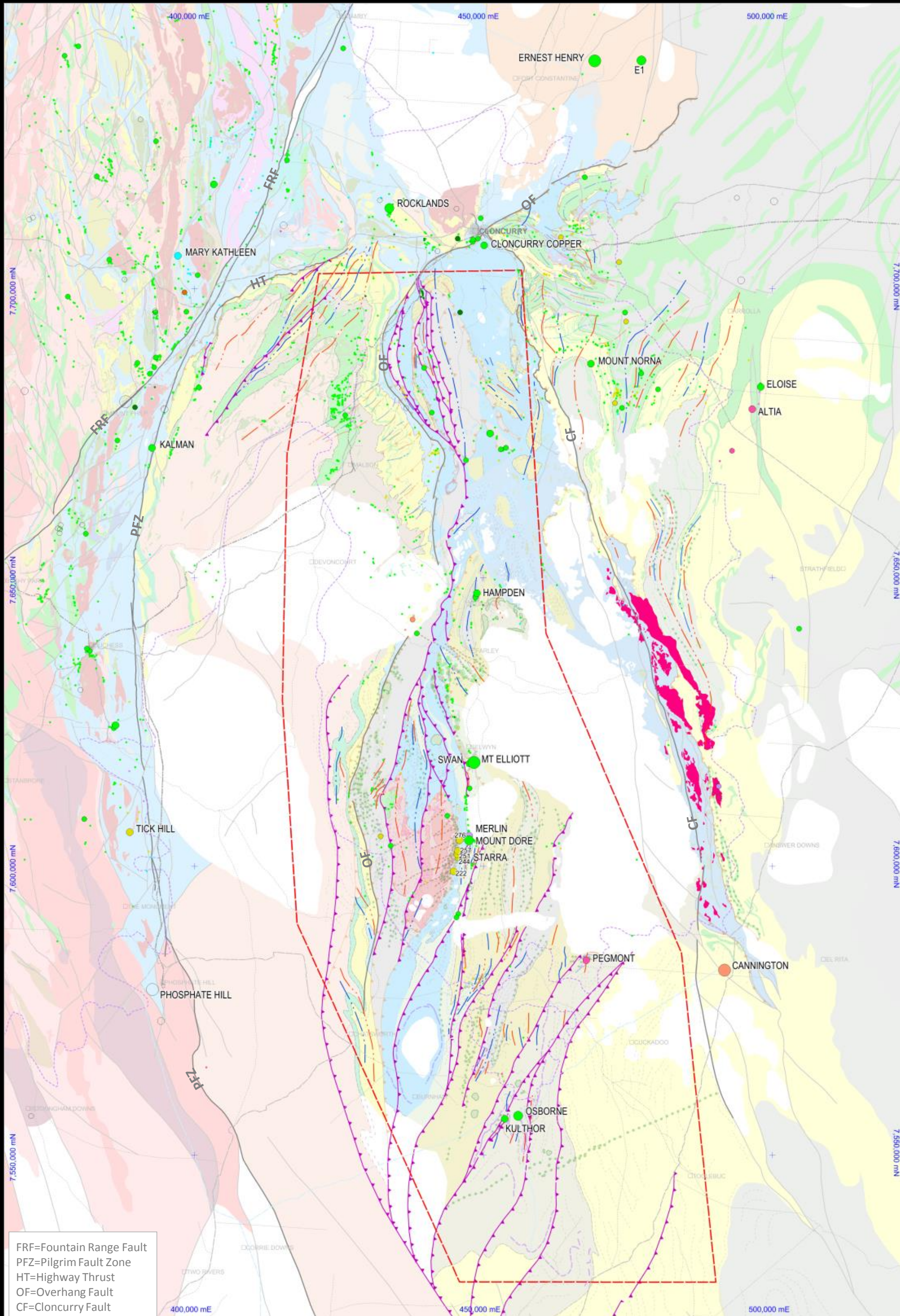


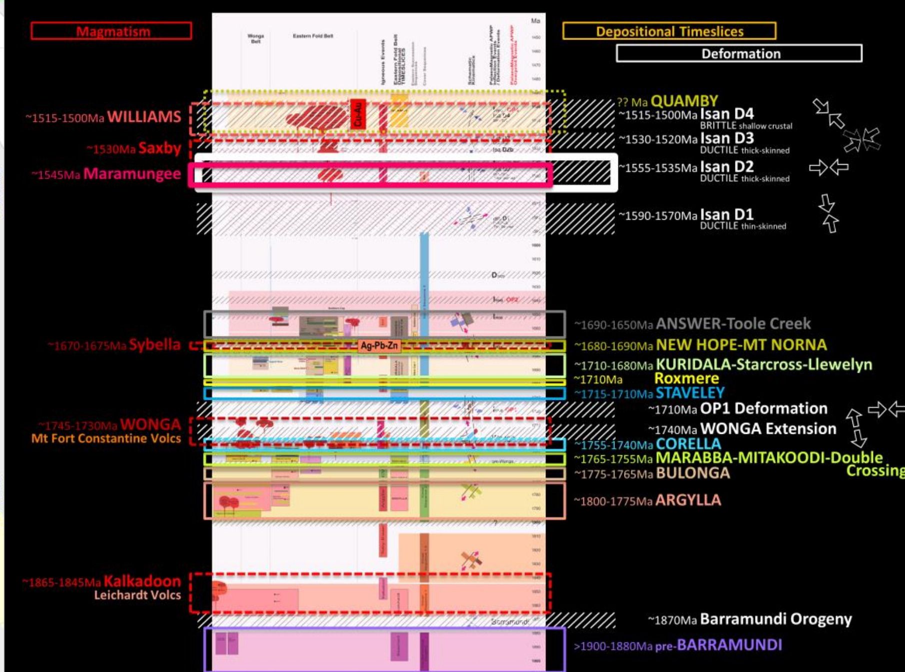
~1555-1535Ma thick-skinned, **D2 Faulting**

~1555-1535Ma **Maramungee Magmatism**

Continued EW D2 shortening is not able to be accommodated by further folding and/or fold tightening and **D2 reverse fault failure** occurs.

- **D2 reverse faults are widespread and are ubiquitously W-vergent**
- They have **very significant strike lengths and major throws**, juxtapositioning packages of contrasting ages and compositions.
- **Progressive highTemp-highPress metamorphism** at this time yields some syn-deformational intrusives east of the project area … the **Maramungee Suite.**





~1535-1530Ma

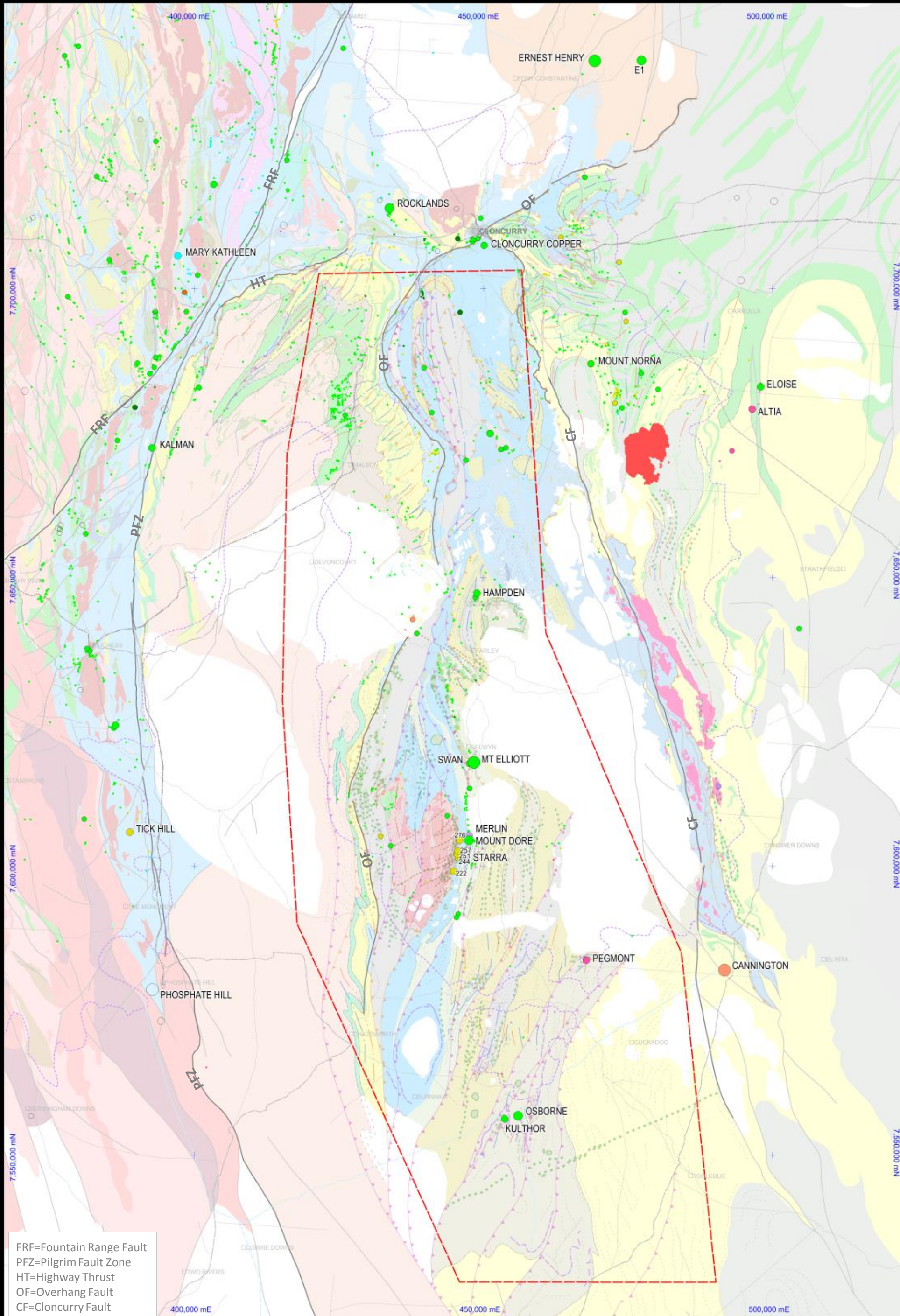
D2b Orogenic Collapse

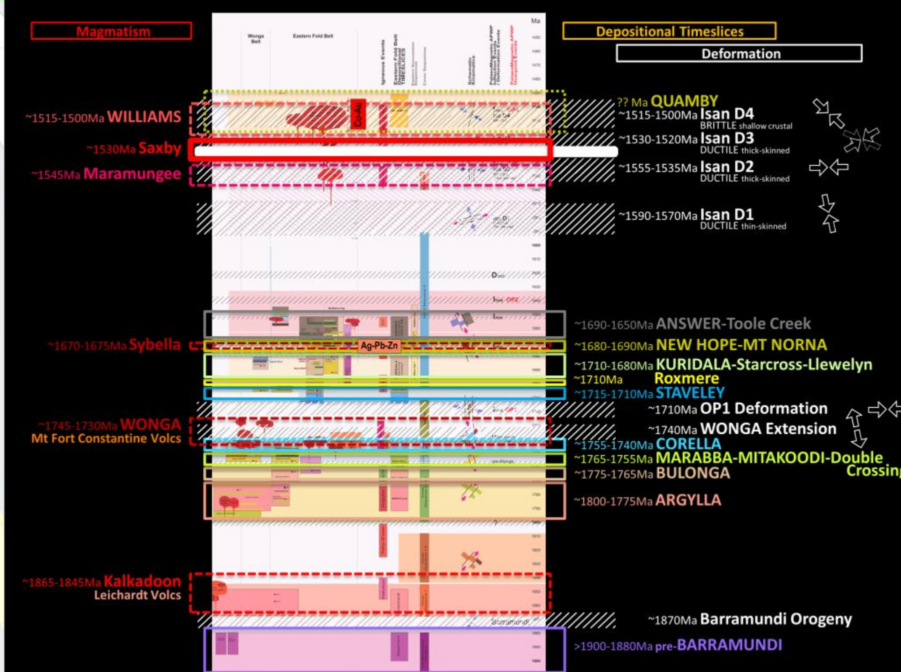
~1535-1525Ma

Saxby Magmatism

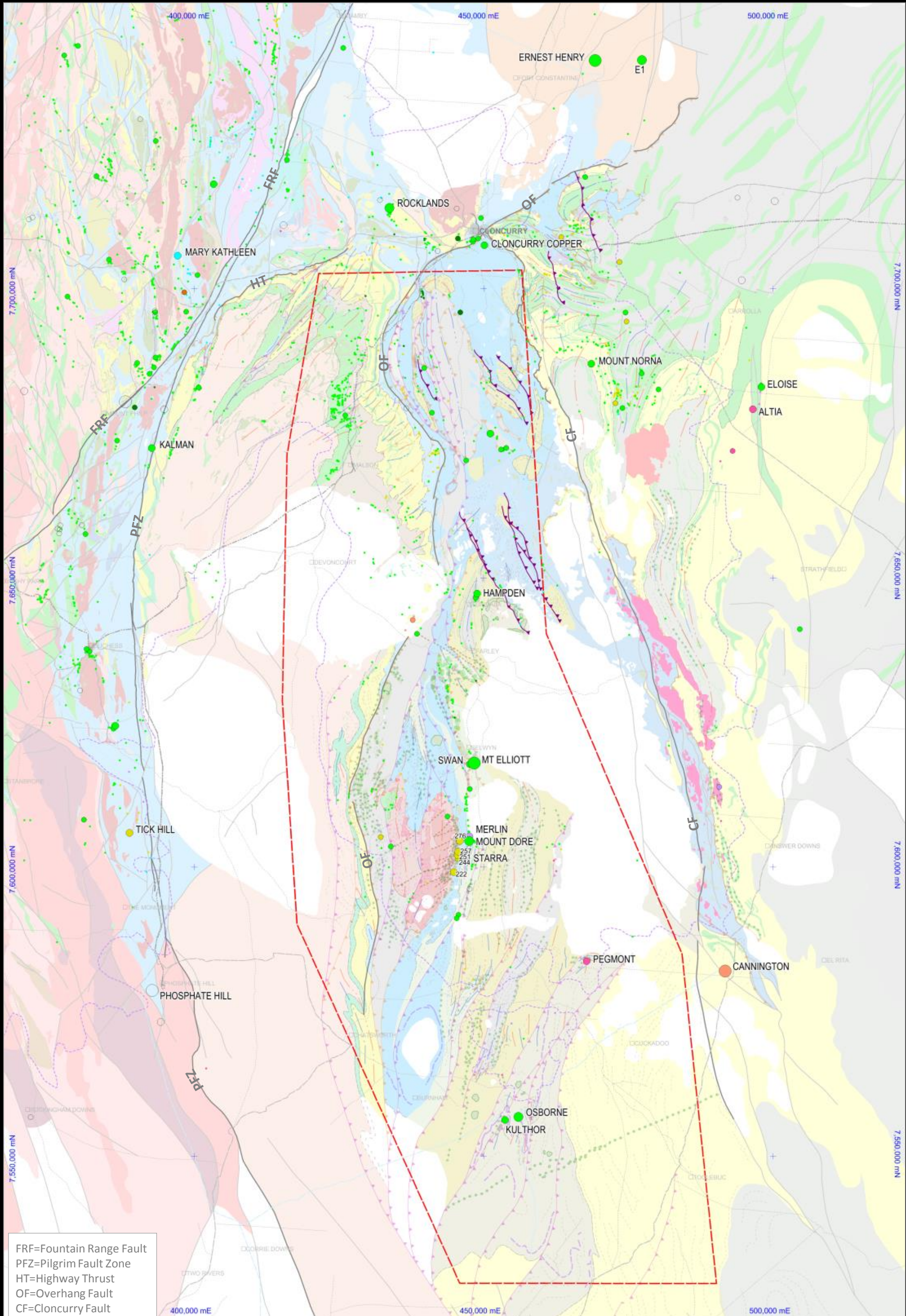
In **a post-D2 relaxation phase**, **orogenic collapse** occurs and results in a **flip in the regional stress regime to a subvertical σ1 and subhorizontal σ3.**

- This orogenic re-arrangement results **in subhorizontal fabrics** and localised, minor refolding of earlier folds (Bell & Hickey, 1998; Murphy, 2004). **No D2b structures have been identified in the DMQ interpretation.**
- Importantly, a **subhorizontal σ3 significantly influences the geometry of intrusion** within the crust at this time. It facilitates the emplacement of classical, equidimensional, hourglass-shaped, plutons and batholiths. The **Saxby** and **Mount Margaret granites** whose geochronology suggests potential synchronicity with D2b, may be plutons intruded under these Isan D2b Orogenic Collapse conditions



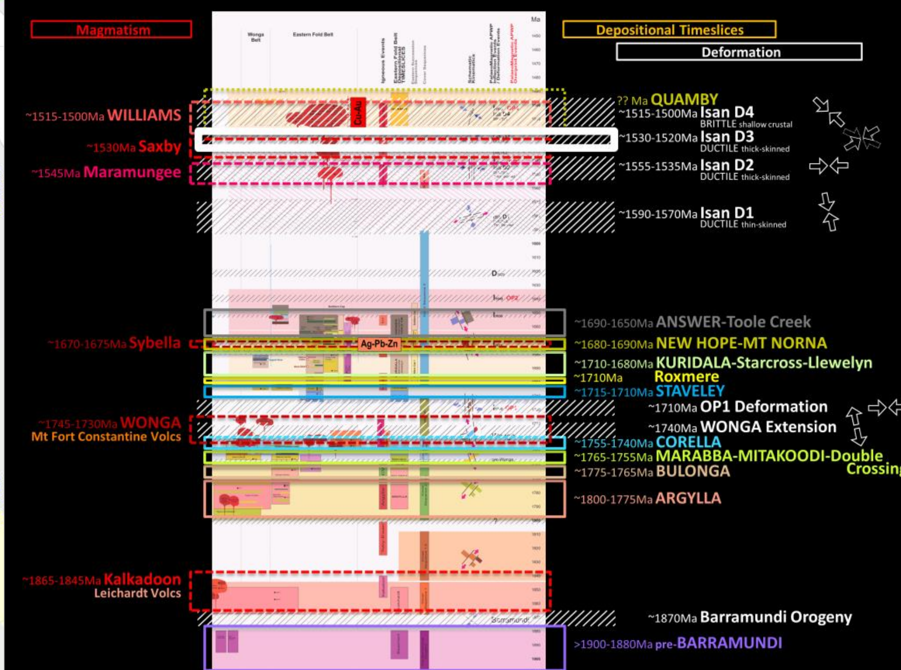


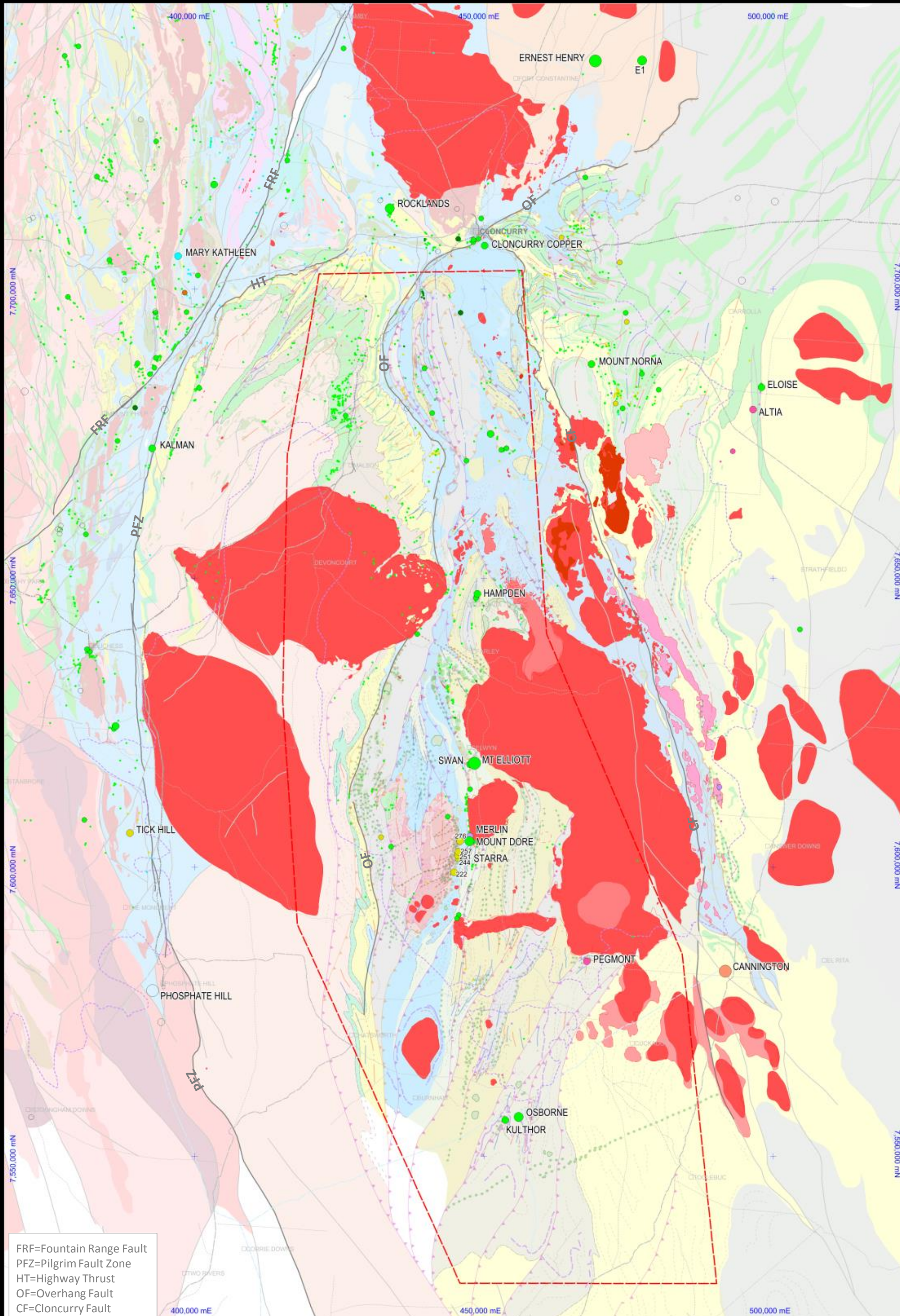
~1525-1520Ma
thick-skinned, **D3 Faulting**



Renewed E-W'ish shortening within a significantly thickened crust resulted in **continued ductile deformation with local variations in structural orientations.**

- D3 folding has been identified in detailed mapping exercises in both the Western Succession (Bell, 1983; 1991; Bell & Hickey, 1998; Murphy, 2004) and the EFB (Austin & Blenkinsop, 2008), however, none have been specifically identified in the DMQ regional interpretation.
- D3 fold orientations are **variable from NNW to NNE trending**. This variation appears to be a result of **local heterogeneity** during thick crustal shortening resumption post-D2b
- **A number of D3 Faults** have been identified and tagged in the DMQ interpretation based largely on their **cross cutting relationships with D2 folds** and their overall orientation. A fault that truncates the northern end of the D2 Hampden Synform is pre-Williams and is assign to D3.
- **Ongoing highT-highP metamorphism and partial melting in deep crustal levels at this time generates voluminous magma.**



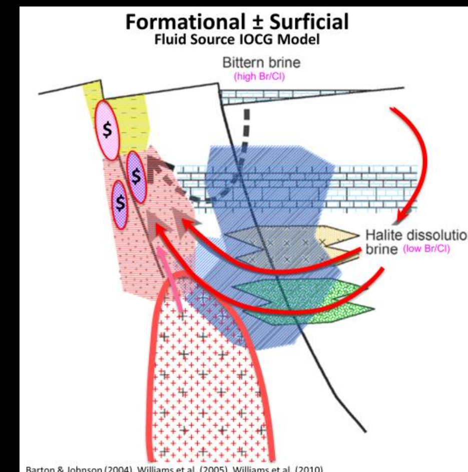


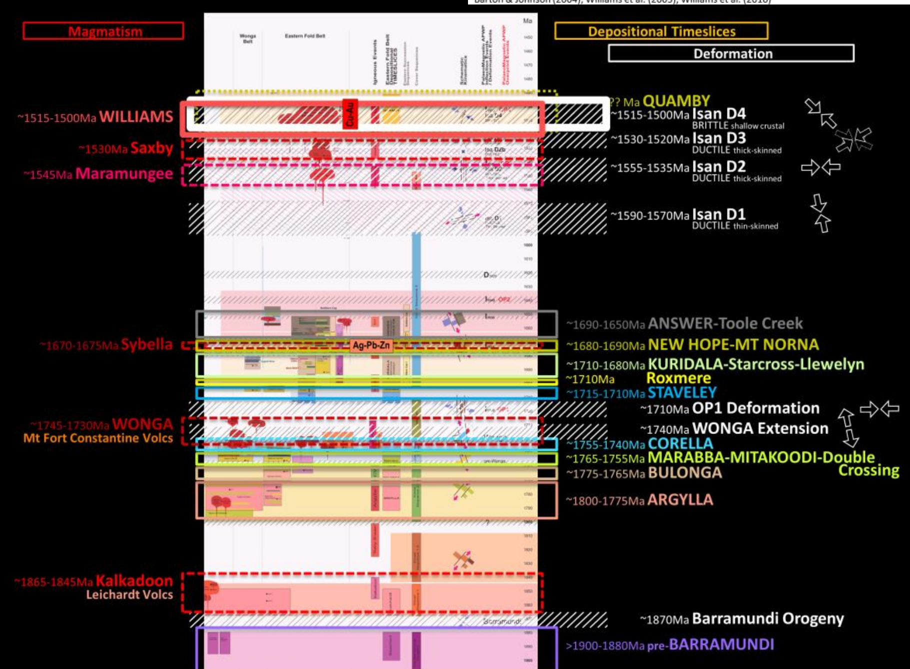
~1515-1500Ma early **D4 Shortening**

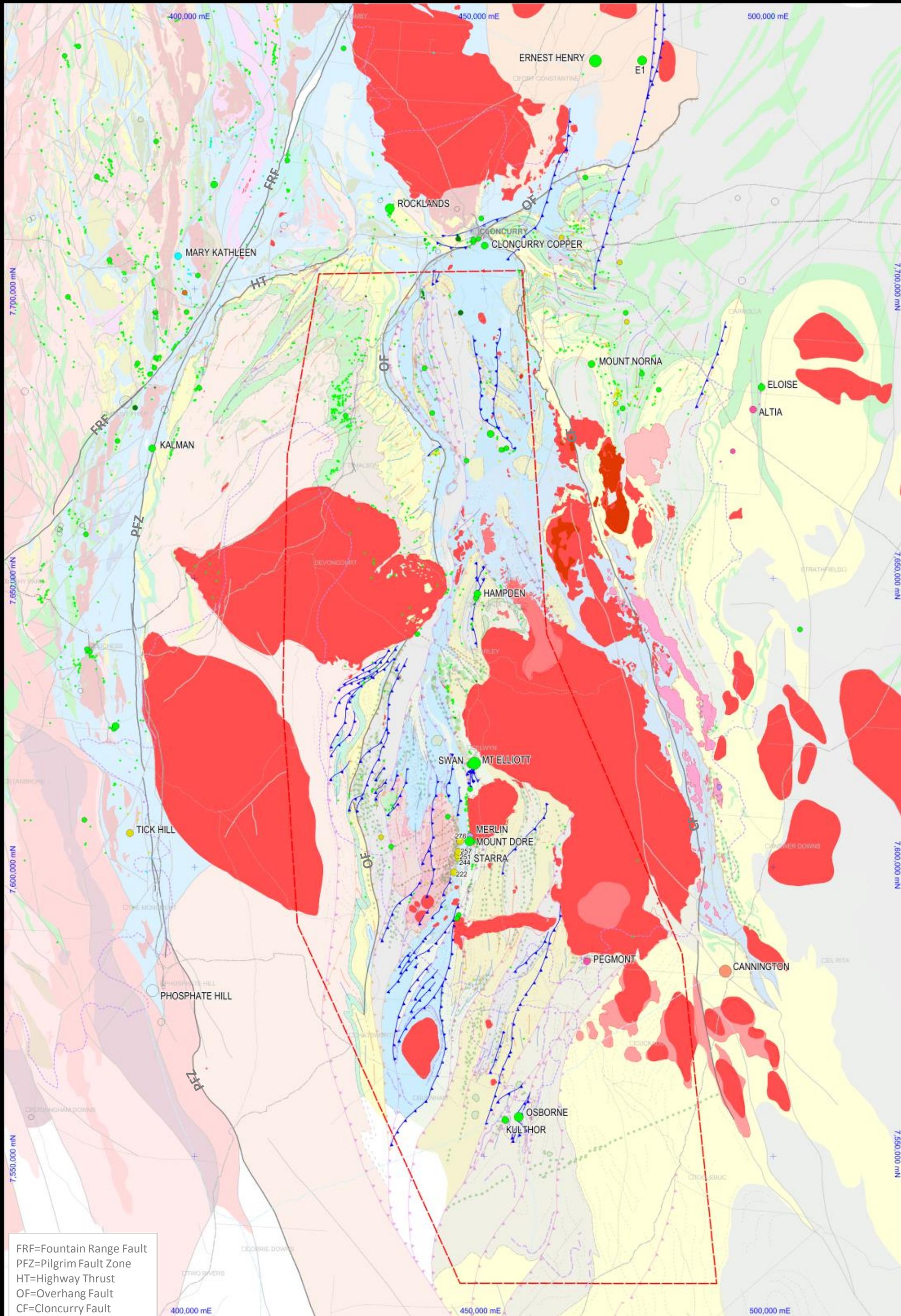
~1515-1500Ma **WILLIAMS Magmatism (Cu-Au, Au-Cu, Mo-Cu)**

By 1510Ma, after major erosion, **significant WILLIAMS intrusion** into shallower crustal levels has begun under **D4 NW-SE shortening**.

- Intrusions take thick, sheet-like forms under the influence of a **subvertical σ3**.
- **D4 strain partitioning** around crystallising granites, results in **early fracturing & brecciation** in appropriate rock types that focuses early, **circulating mineralising fluids** to form early IOCG-style Cu-Au-Mo mineralisation.





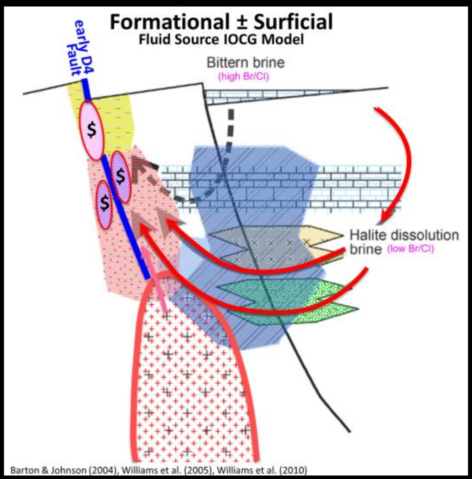


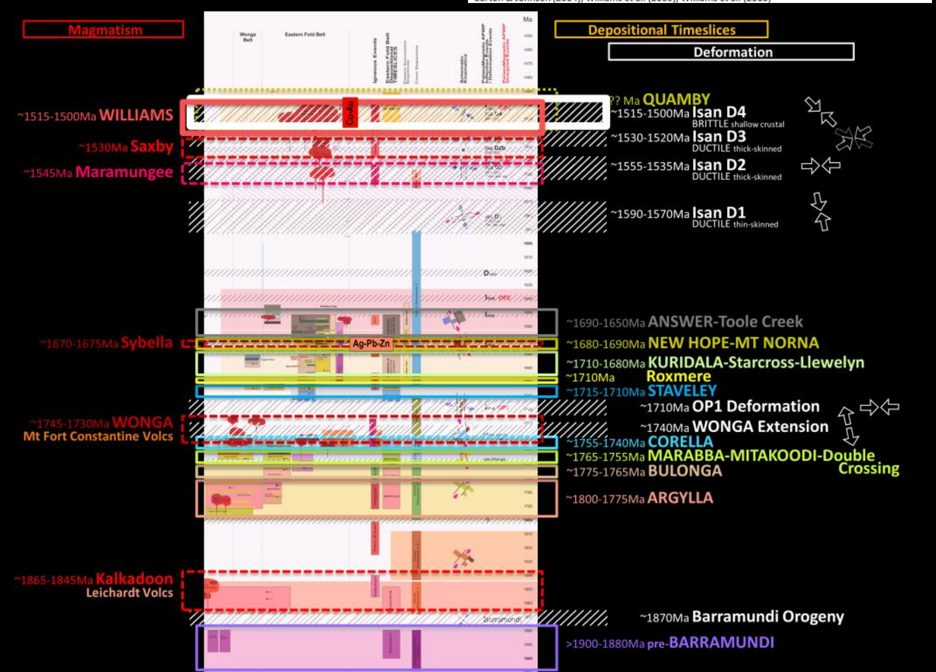
~1515-1500Ma early **D4 Faulting/re-Activation**

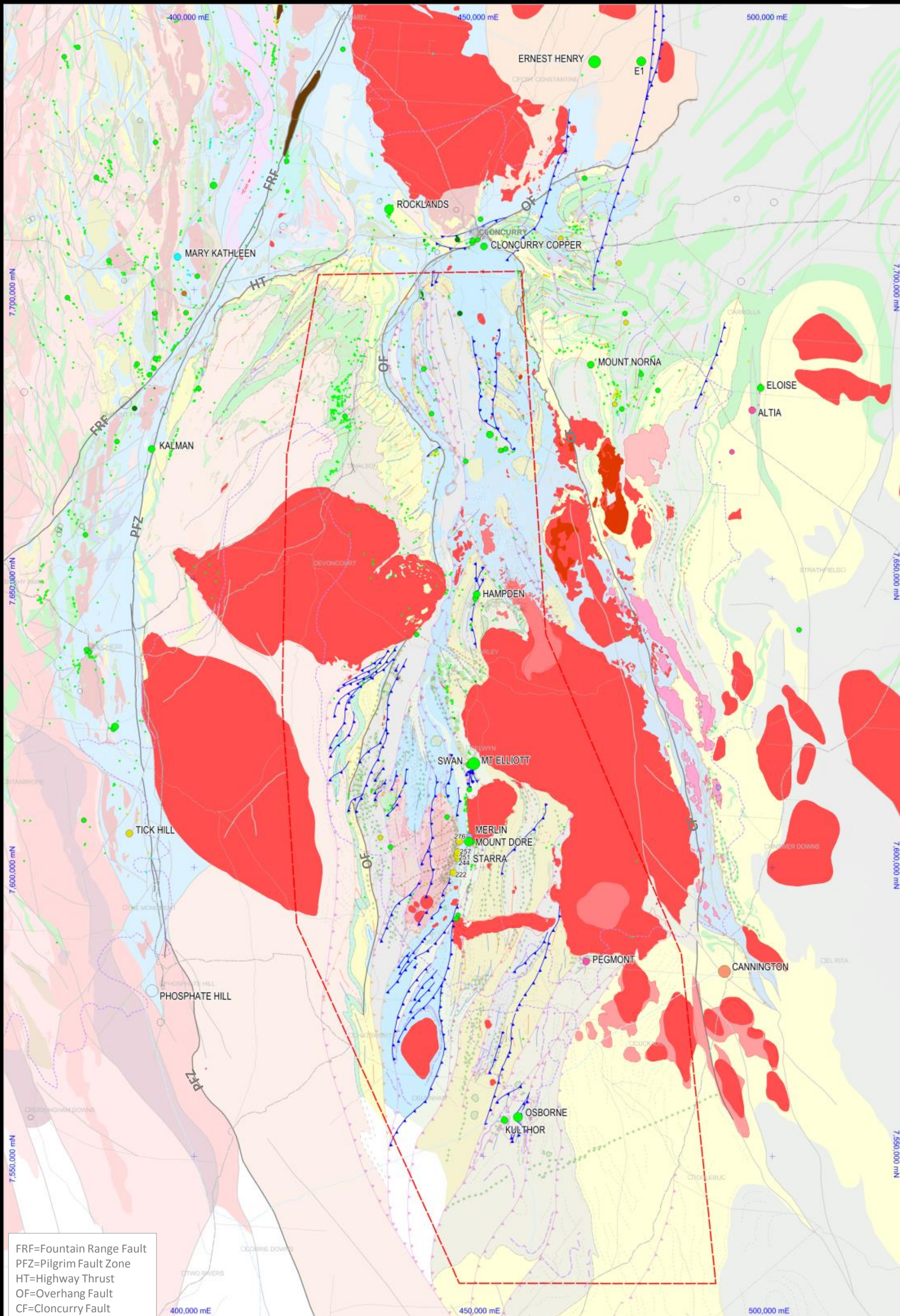
~1515-1500Ma **WILLIAMS Magmatism Cu-Au, Au-Cu, Mo-Cu**

Ongoing shortening results in **early D4 Faulting/re-Activation** of older structures which focuses **Cu-Au-Mo mineralisation**

- **D4 Faults** (cf D1-D2-D3) **are small scale with small displacements; some interpreted,** BUT many so small that not mapped.
- **Thermally-circulating, HighTemp, oxidised brines** that have **scavenged metal** are focused in **BRITTLE fracture-breccia zones** to form …
- **Spectrum** of **Cu-Au-Mo** deposits as function of **scavenged metal** content, **magmatic metal** input, **reduced S available** at site of deposition and **P-T-x conditions** en route and at site of deposition.







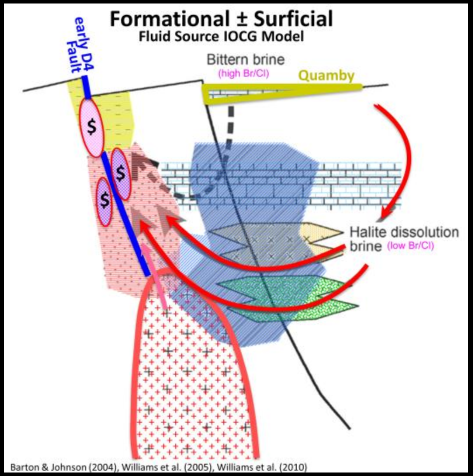
~1515-1500Ma
early **D4 Faulting/re-Activation**

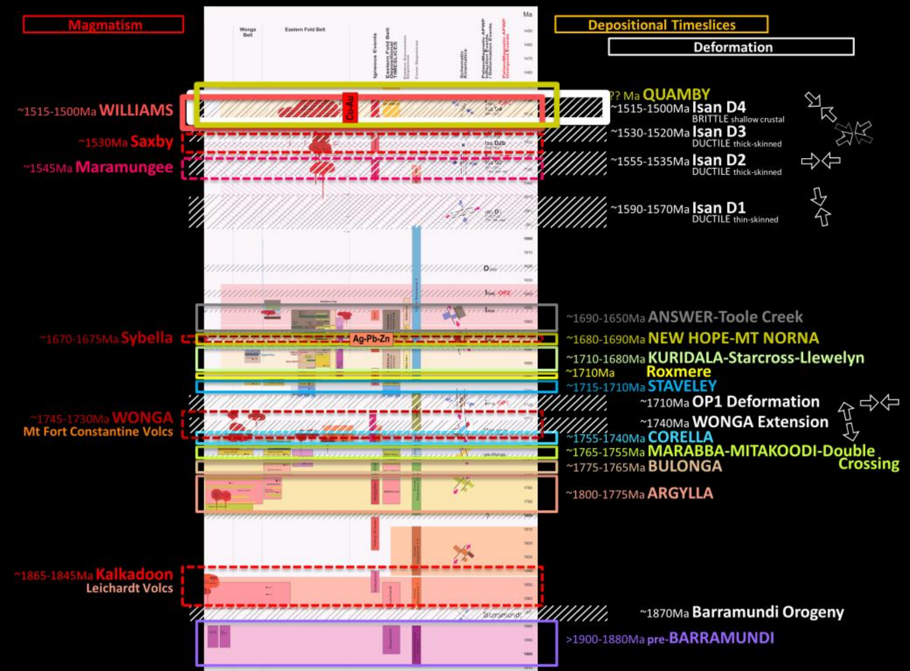
~1515-1500Ma
WILLIAMS Magmatism
Cu-Au, Au-Cu, Mo-Cu

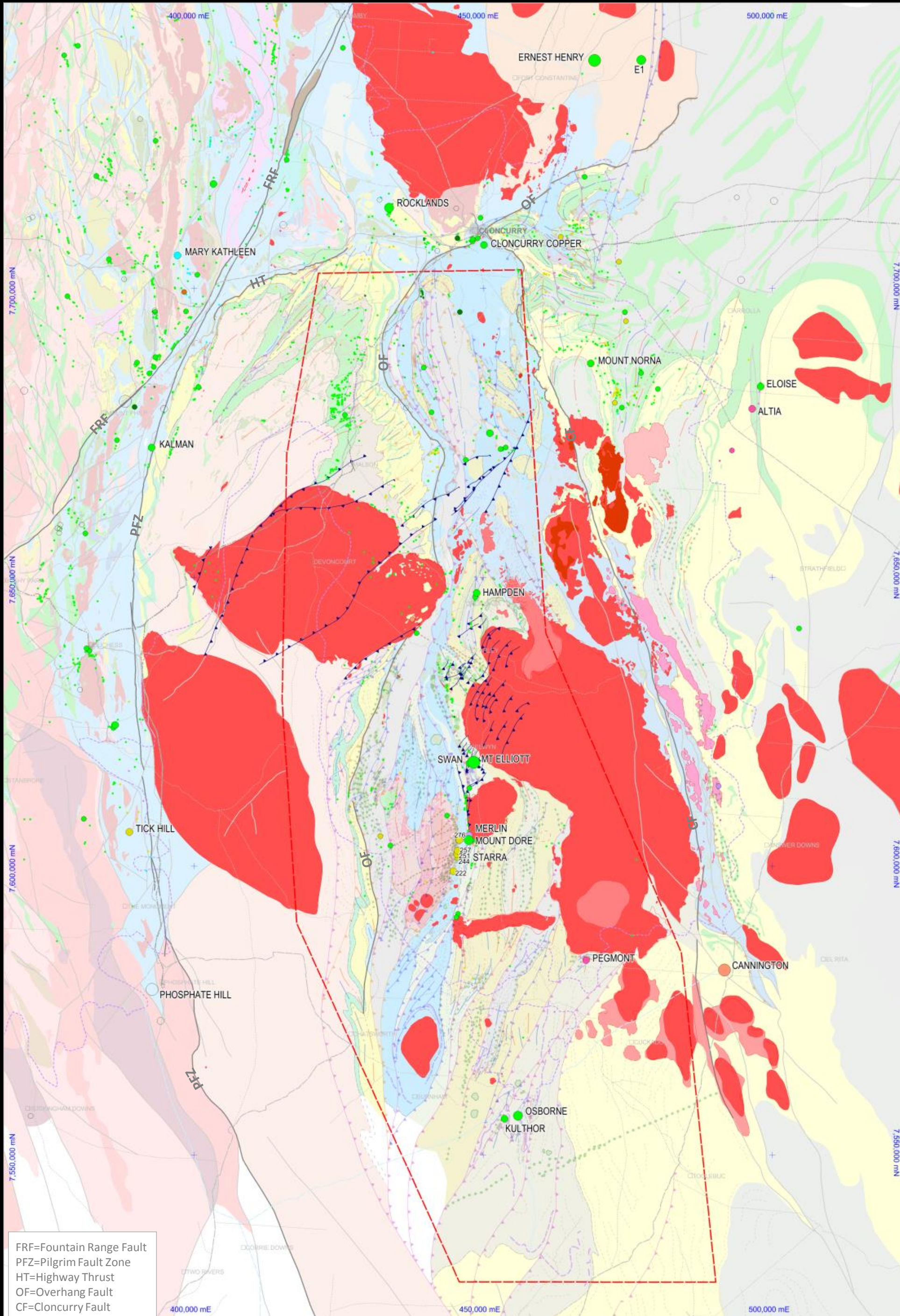
~????Ma
QUAMBY

At same time, DMQ speculates that **overlying or subjacent, Quamby Basin** may **contribute oxidised brine** to the systems in the crust beneath it

- **Formational CORELLA & STAVELEY salinity UNAVAILABLE … tied up in peak metamorphic assemblages**
- Scant geochron on QUAMBY …. but likely time-equivalent of South Nicholson Basin with this timing in west.



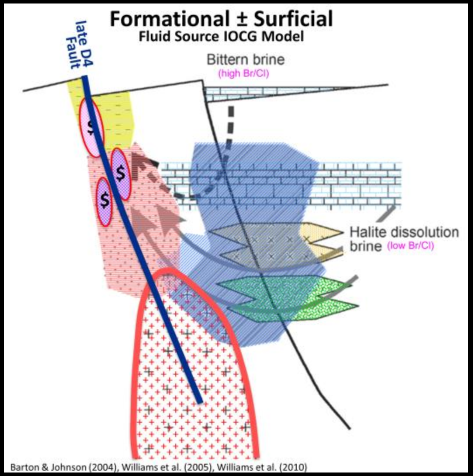


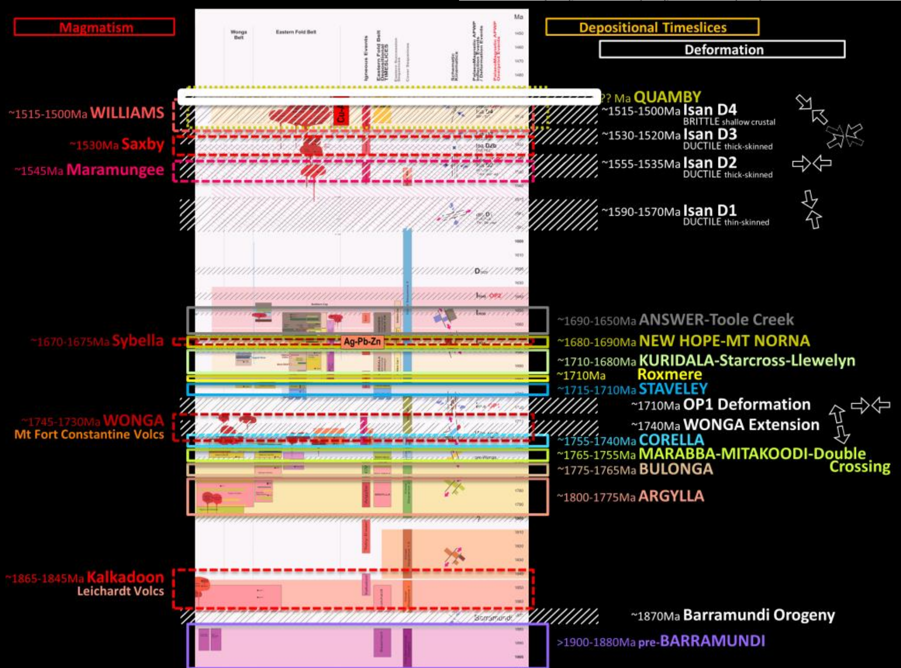


~1500-1495Ma
late **D4 Faulting**

(syn)-late-
WILLIAMS Magmatism
(Cu-Au, Au-Cu, Mo-Cu)

When granites substantially solidified, late D4 Faulting cuts and deforms previously-formed mineralisation and cuts WILLIAMS suite granites.





Magmatism

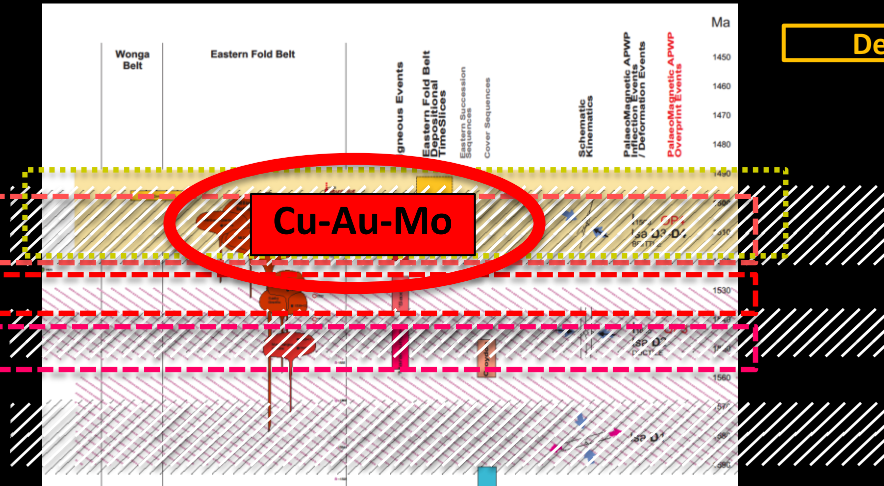
Depositional Timeslices

Deformation

~1515-1500Ma **Williams**

~1530Ma **Saxby**

~1545Ma **Maramungee**

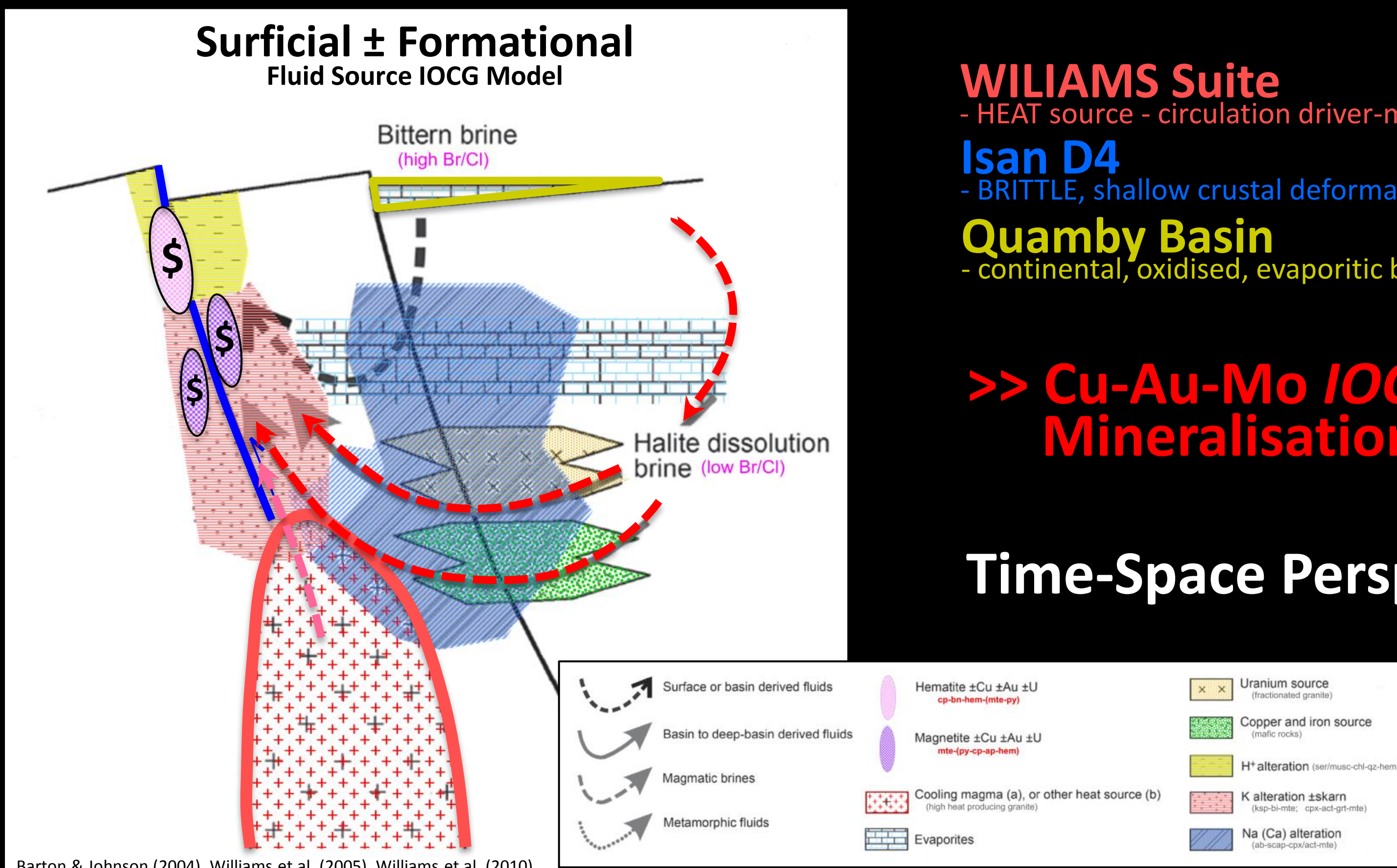


?? Ma **Quamby**

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

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

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



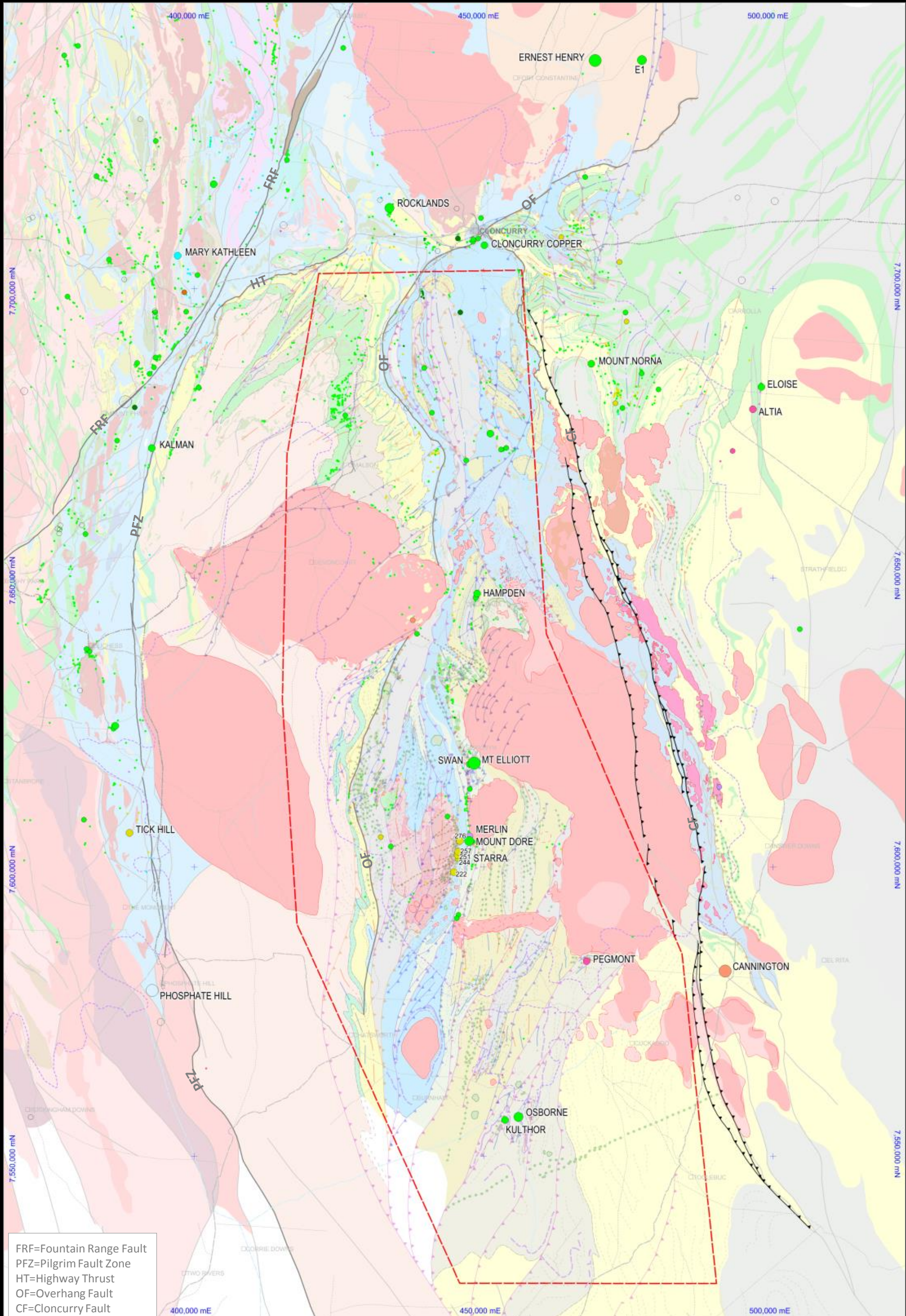
WILIAMS Suite
- HEAT source - circulation driver-metal contribution

Isan D4
- BRITTLE, shallow crustal deformation > permeability

Quamby Basin
- continental, oxidised, evaporitic brine source

>> Cu-Au-Mo *IOCG/ISCG* Mineralisation

Time-Space Perspective

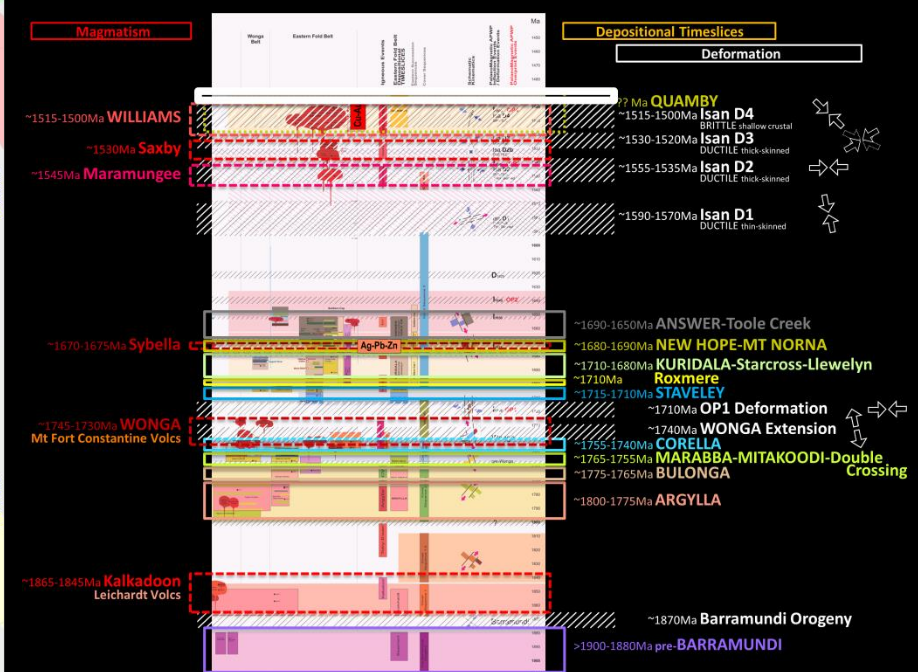


~1495-1490Ma
later **D4 Faulting**
post-
WILLIAMS Magmatism

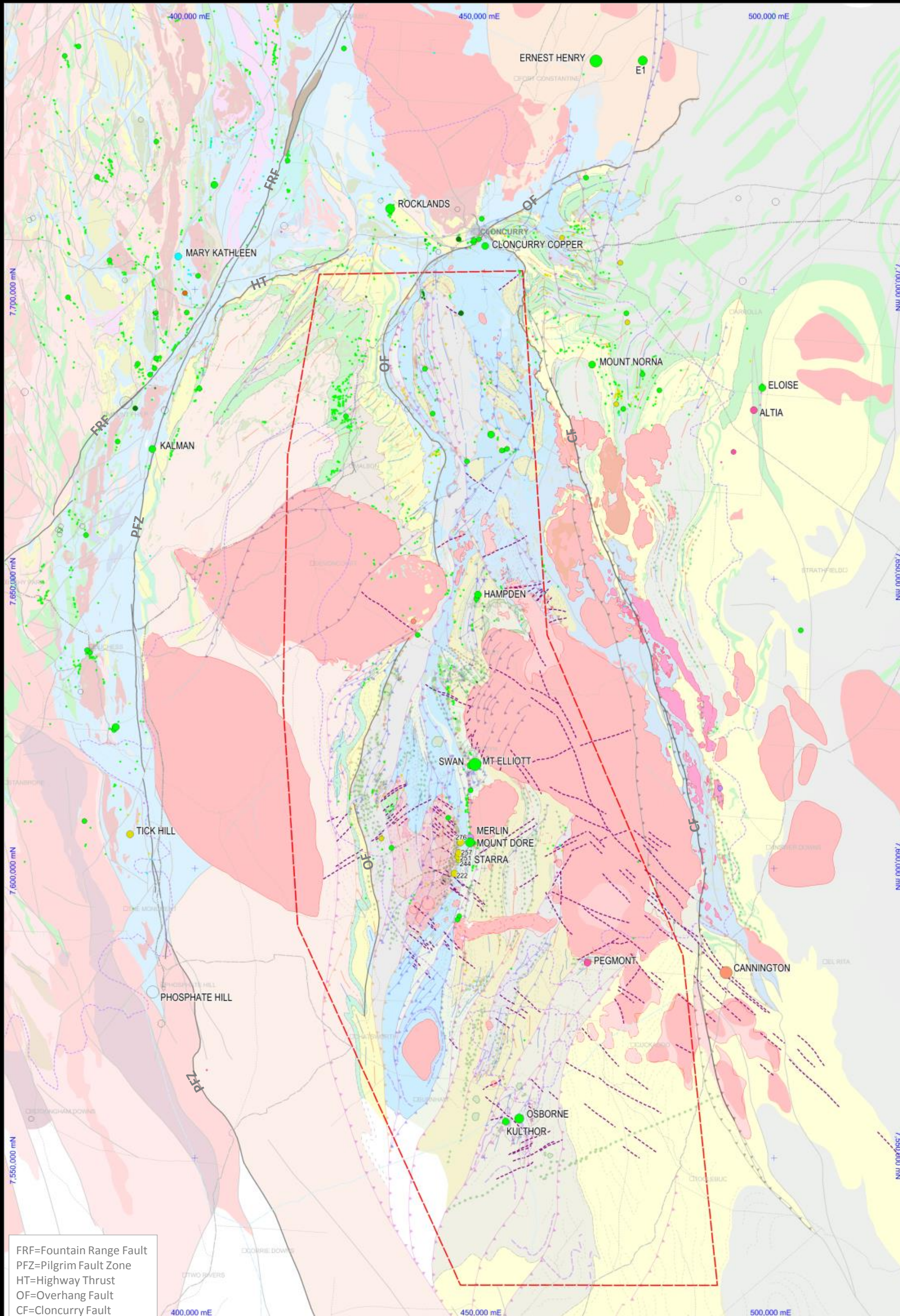
The mapped Cloncurry Faults cut fully-solidified WILLIAMS suite intrusions.

- Completely distinct set of structures compared with the D1-family of **Cloncurry Thrusts**
- Other workers (Austin & Blenkinsop, 2008) have argued for earlier fabrics and faults formed during ductile D3 deformation and later brittle D4-5 sinistral strike-slip faulting.
- **DMQ argues that the mapped traces of the Cloncurry Faults are essentially post WILLIAMS (very late D4),** brittle transpressive fault systems with greater component of reverse movement to the south compared with in the north where displacements are very minor.

The **Cloncurry Thrust-Fault Domain** does appear to mark some sort of depositional divide but the **complexity of D1 thrusting within and across the domain ….**
…. makes it difficult to assert that the Cloncurry Fault Zone specifically represents a re-activated basin bounding fault (cf. Austin & Blenkinsop, 2008).



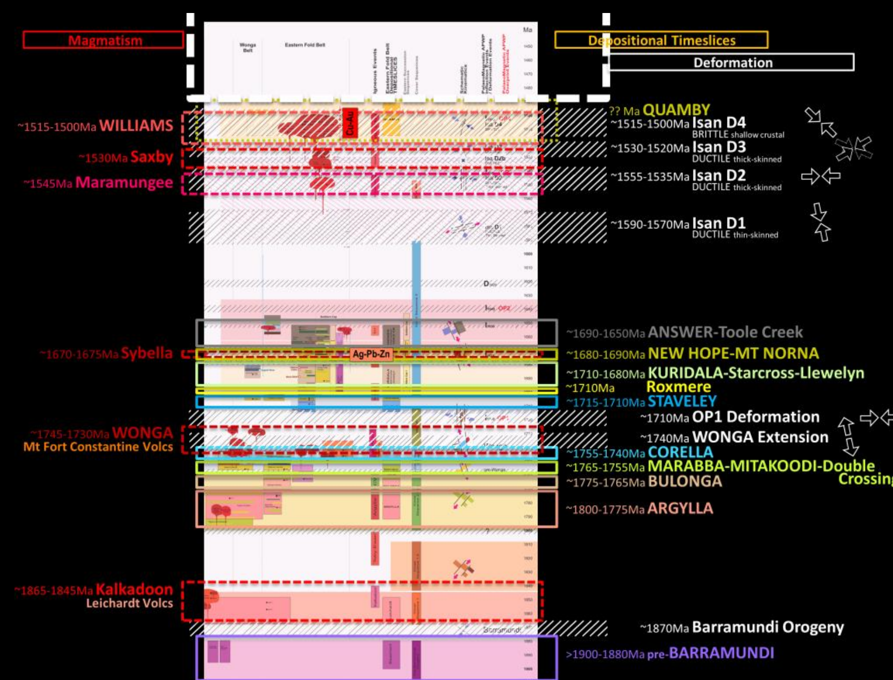
~????-????Ma post Isan **X-cutting Faulting**

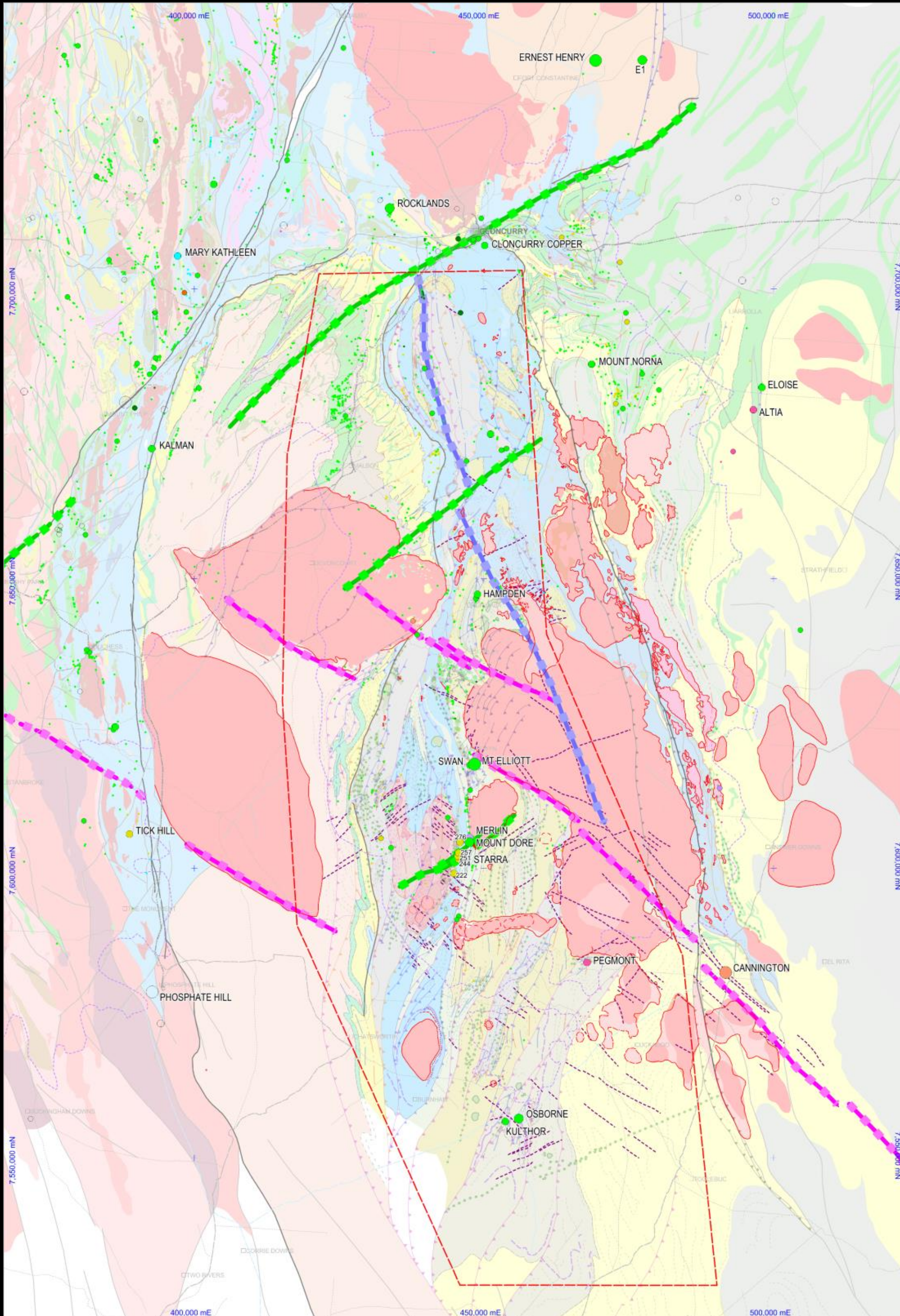


Post orogenic faulting is widespread … where detailed magnetics allow interpretation and/or prospect-scale mapping has revealed.

- Commonly cross-cutting to the regional trends, cross-cuts all Isan structuring
- **Falls into three groups:**
  broadly NE-SW, broadly NW-SE and **NNW-SSE**. In places these orientations form the local joint patterns but fault offsets are interpretable in the detailed Chinova magnetics.

Some domains of post-Isan faulting are hypothesised to reflect old, pre-orogenic architectures (both depositional and inversion) that likely have significant crustal penetration and temporal persistence.





~????-????Ma
post Isan **X-cutting Faulting**

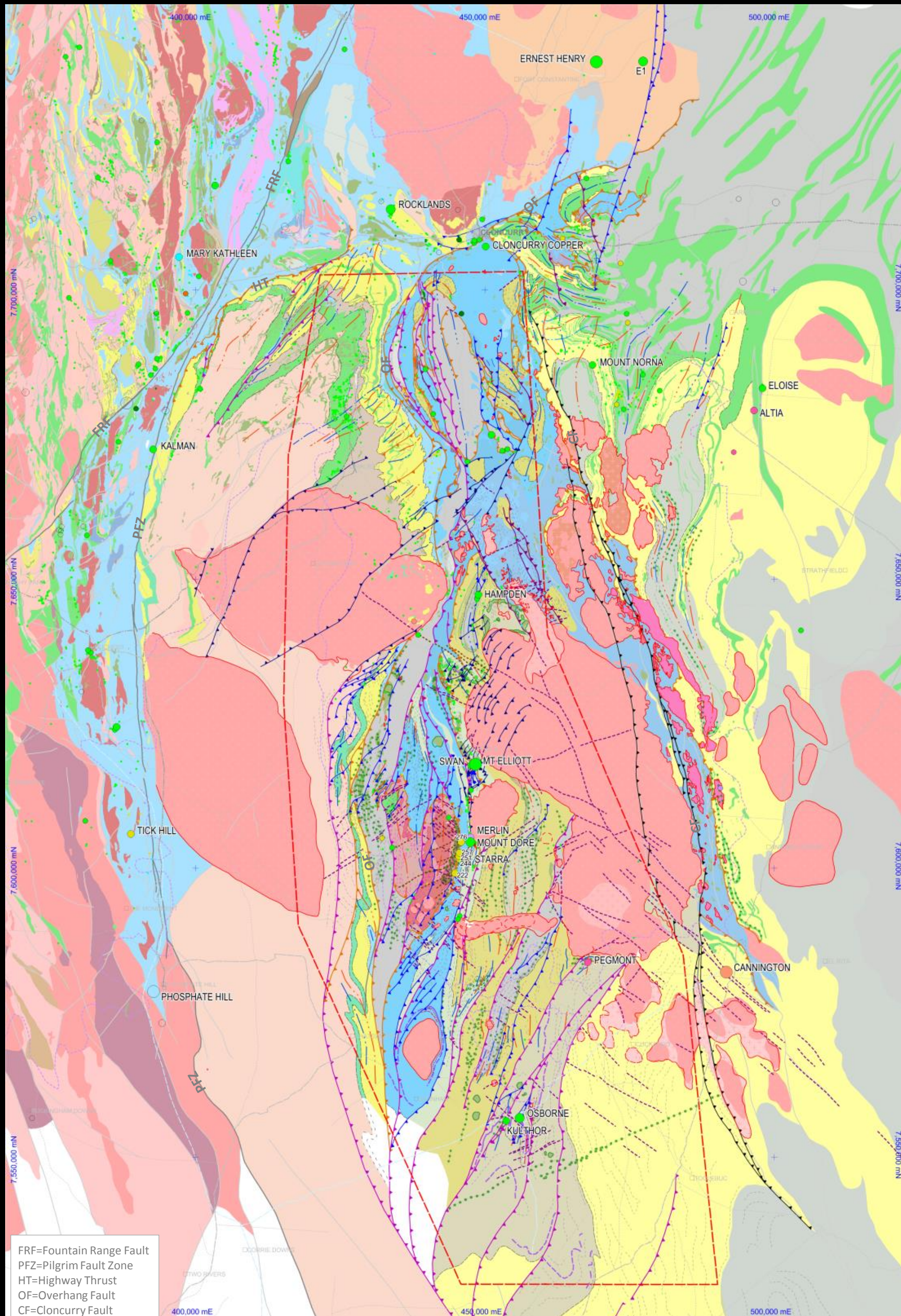
- Widespread …. but in corridors
- **Significant crustal penetration & persistence**
- Potentially reflect older, **pre-orogenic**, depositional and/or inversion **architectures**

NE architecture
Barramundi/Wonga-reactivation > MFCV margin
Mitakoodi culmination D2 folding
D1 & D2 deformation partitioning
post-WILLIAMS reactn … **Faults cut WILLIAMS**

NW architecture
Williams margins
D2 deformation partitioning
Potential depositional architecture at Cannington
post-WILLIAMS reactn … **Faults cut WILLIAMS**

older NNW architecture
Controls D2 dismemberment of Marimo Synform
post-WILLIAMS reactivation… Faults cut WILLIAMS

>> influence on intrusion geometry
>> compartmentalise deformation
>> influence on IOCG/ISCG system geometries

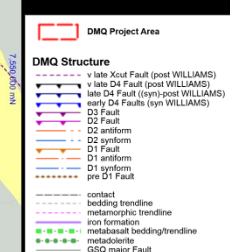


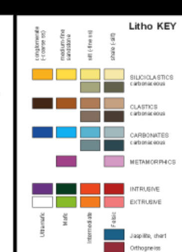
Assembly of the southern Cloncurry Belt is captured in the …

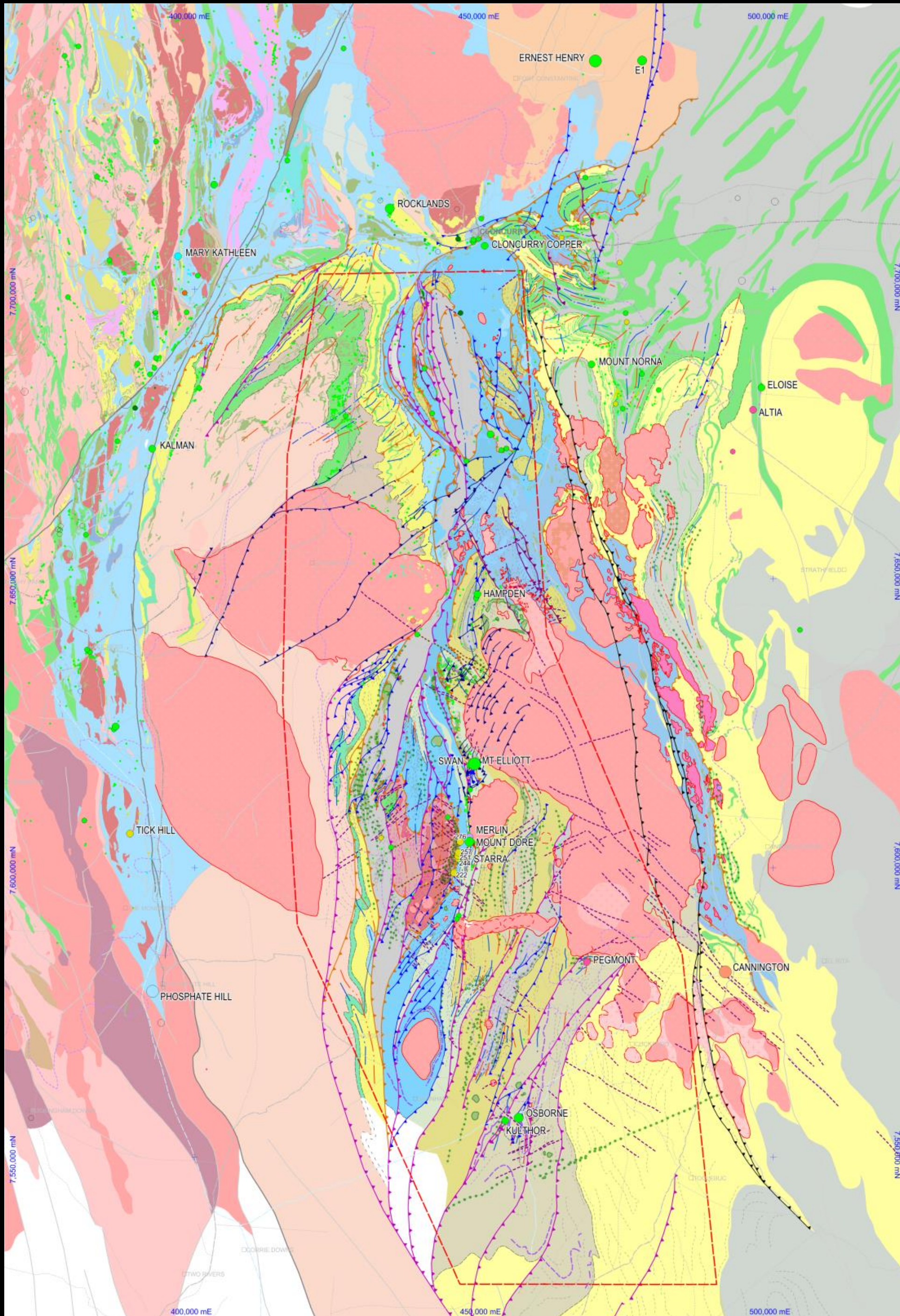
DMQ Solid Geology

… in particular, the <u>critically-important</u> and <u>complexly-variable</u> juxtapositioning of <u>oxidised</u> packages with more <u>reduced</u> packages …. essential for Cu-Au-Mo mineralisation

Now into 3D!







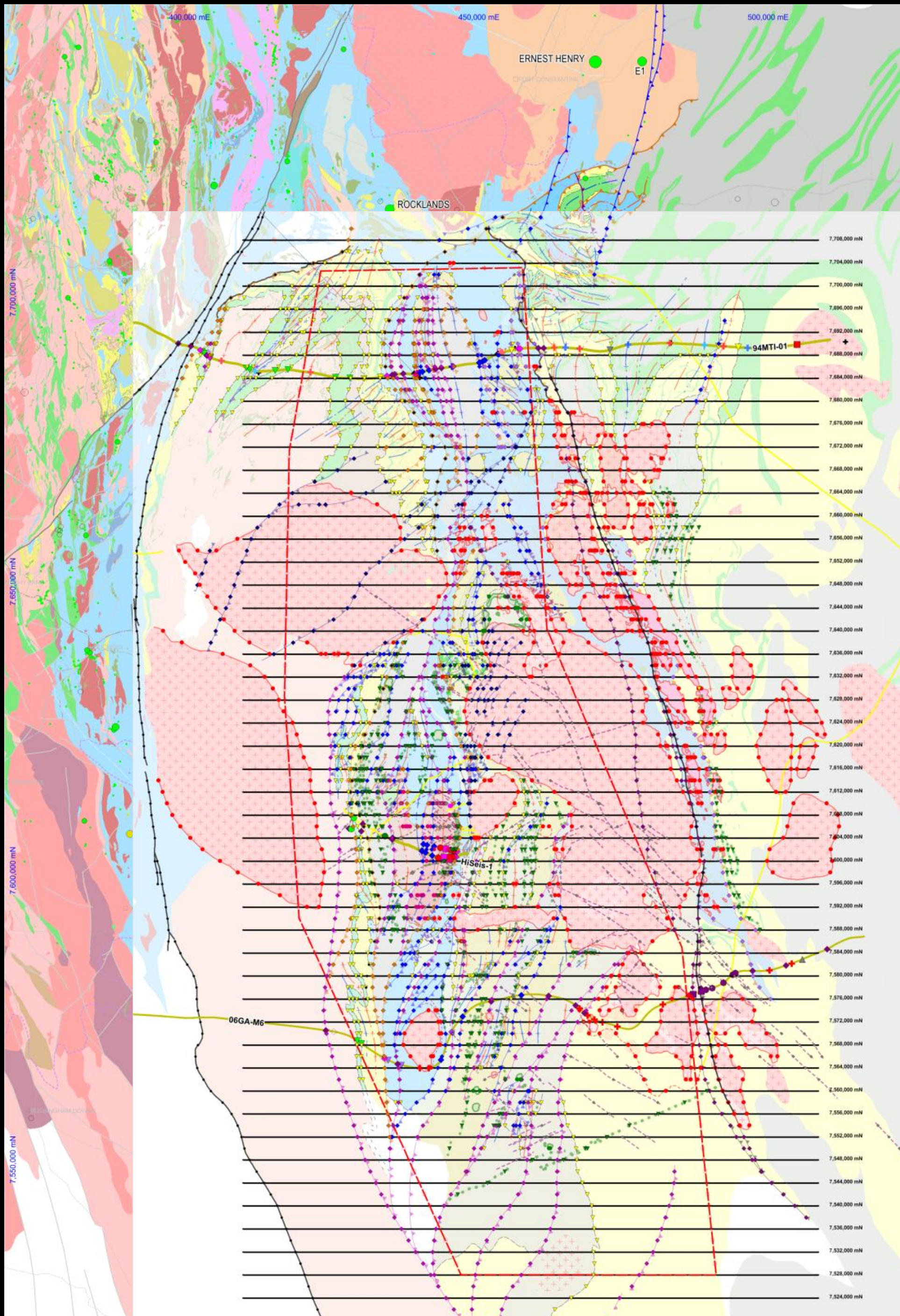
DMQ 3D Geological Model

DMQ Particular Focus on …

- **Exploreable Depths** .. 0-2km
- **Production of a robustly-constrained 4D-Prospectivity Analysis**
- **Purposefully NOT a crustal-scale Analysis …**

… but given importance of upper crustal architecture and mid-upper crustal magmatism …

Held FOCUS within a 6-12km deep volume



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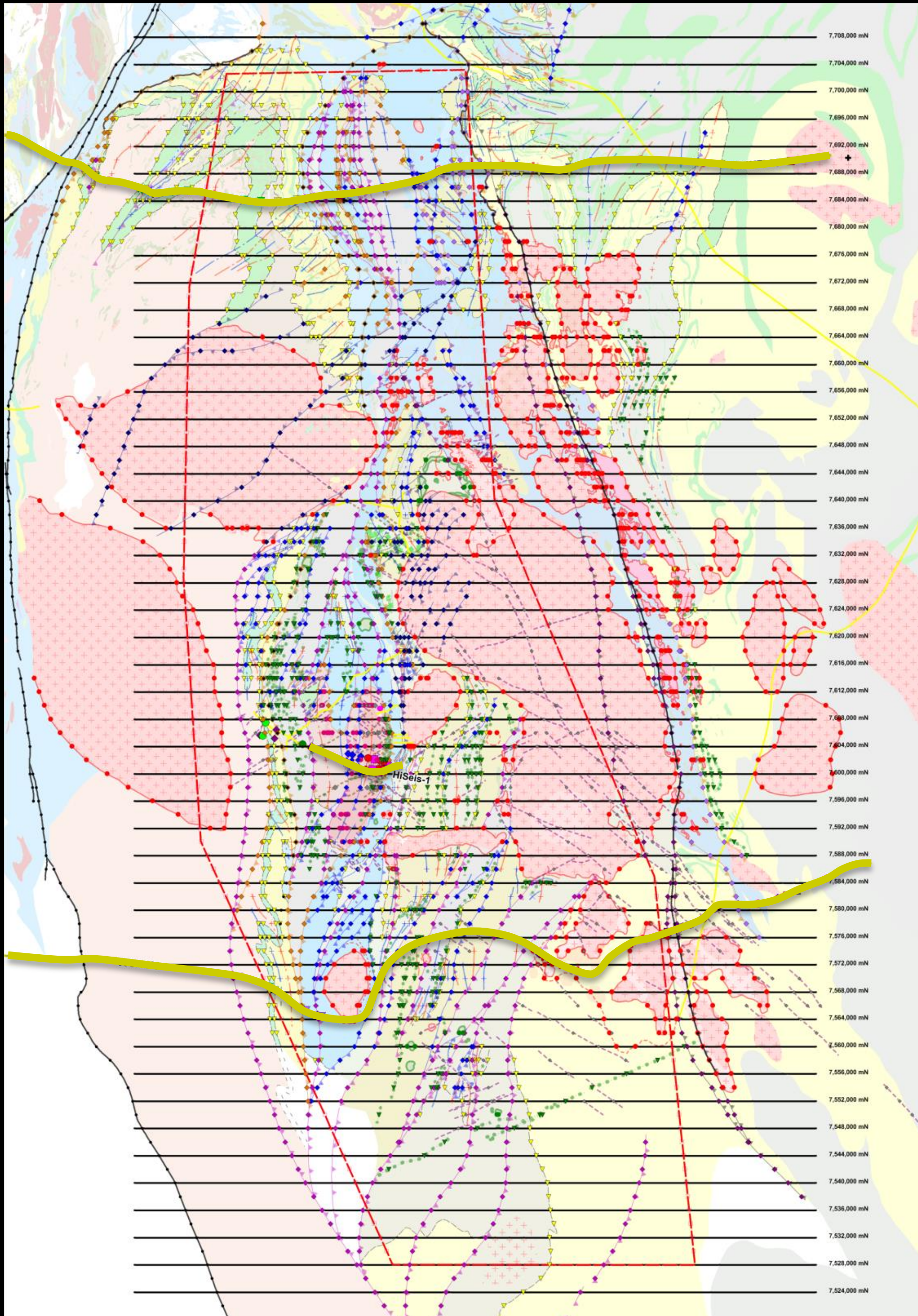
DMQ Produced …

Forty-seven, 4km-spaced SECTIONS

… heavily leveraged Solid Geology
… and 3 Seismic Lines

… control points shown



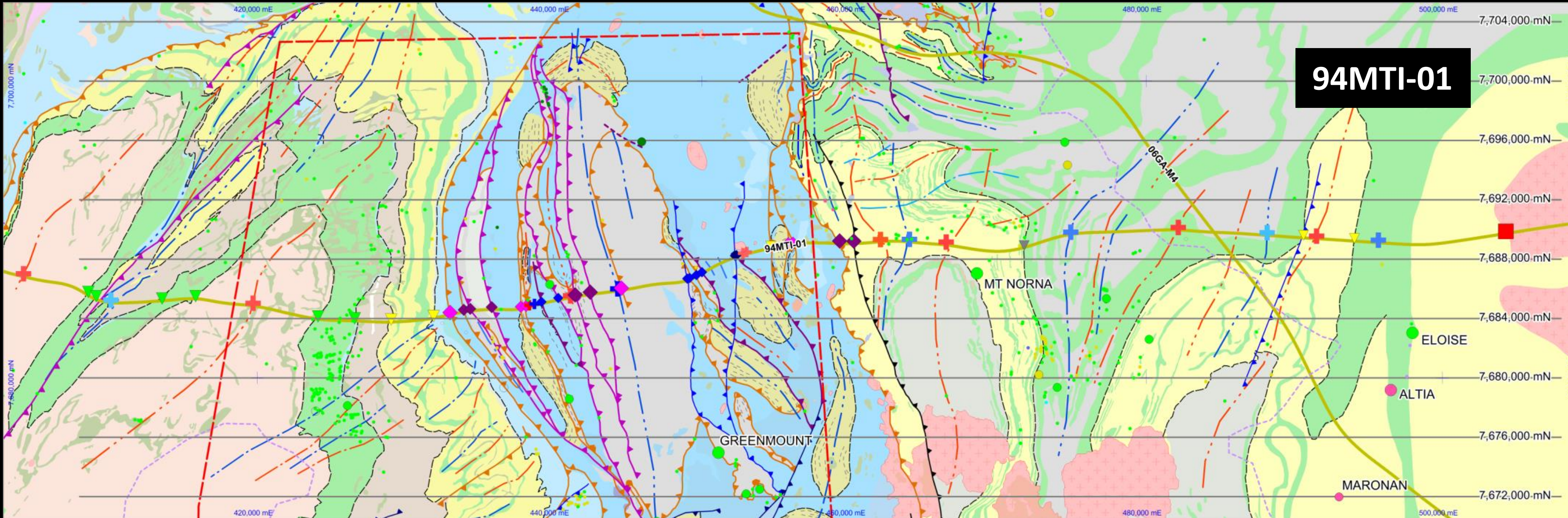
Three Seismic lines …

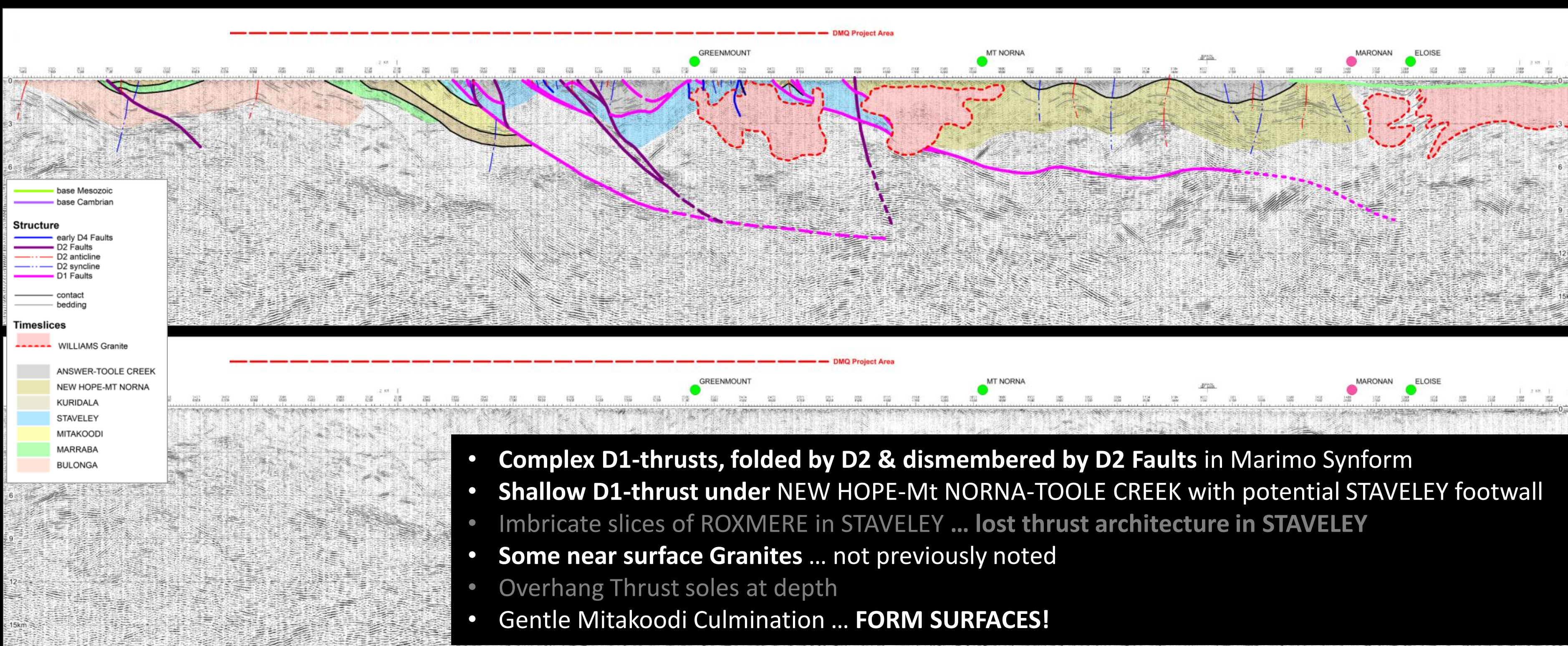
Line 94MTI-01 shot in 1994 (Isa Transect)

Line 06GA-M6 shot in 2006

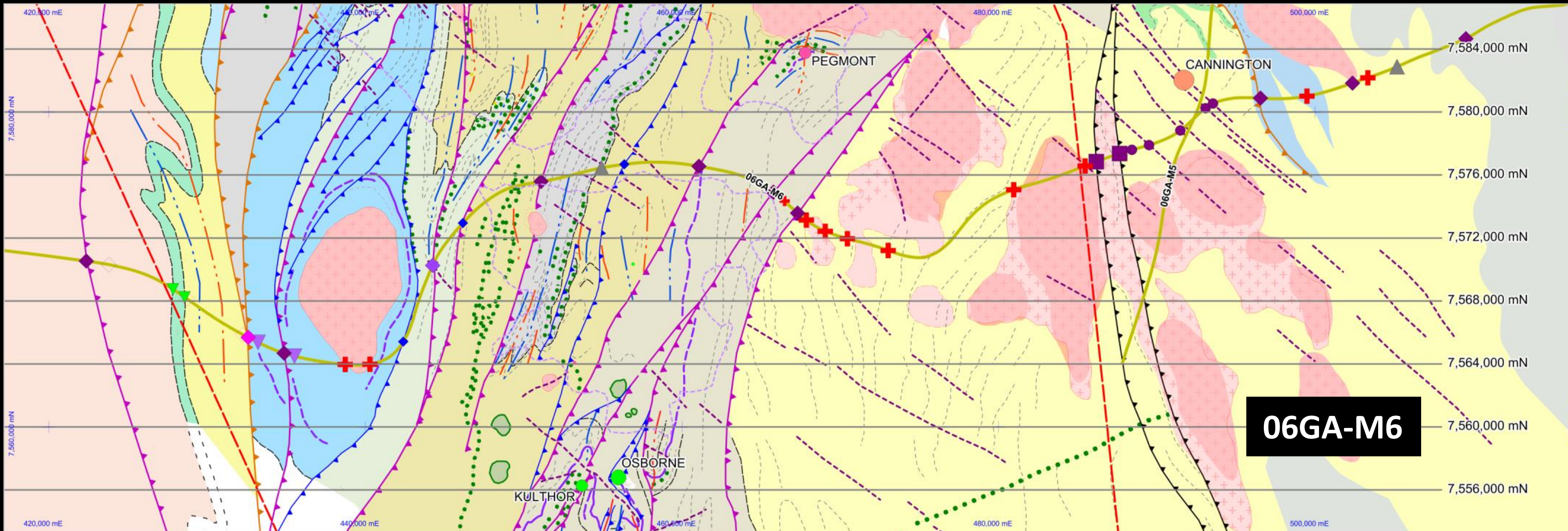
Portion of Ivanhoe Line shot in 2008 that Chinova agreed to have reprocessed by HiSeis ..
Line IVA-HiSeis-1

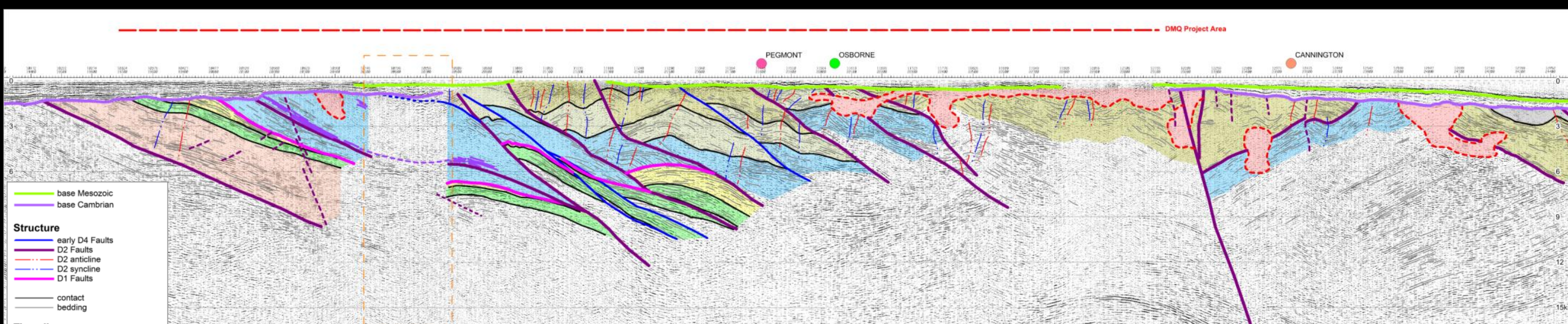
Seismic Interpretation also heavily leveraged the DMQ Solid Geology …

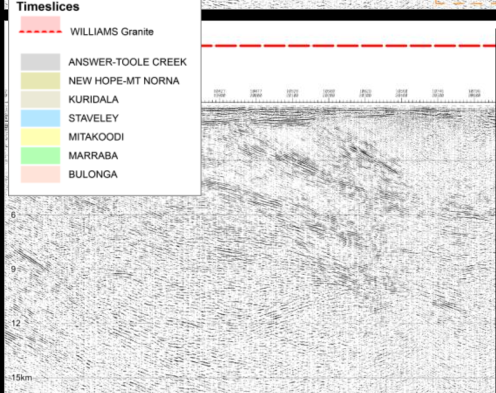




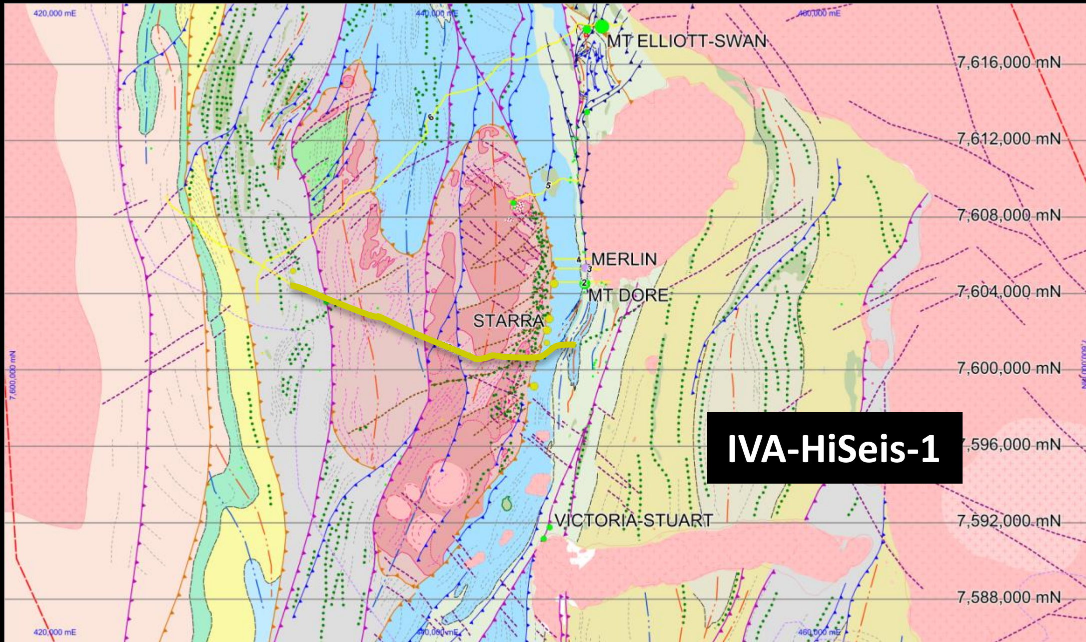
- **Complex D1-thrusts, folded by D2 & dismembered by D2 Faults** in Marimo Synform
- **Shallow D1-thrust under** NEW HOPE-Mt NORNA-TOOLE CREEK with potential STAVELEY footwall
- Imbricate slices of ROXMERE in STAVELEY **… lost thrust architecture in STAVELEY**
- **Some near surface Granites** … not previously noted
- Overhang Thrust soles at depth
- Gentle Mitakoodi Culmination … **FORM SURFACES!**

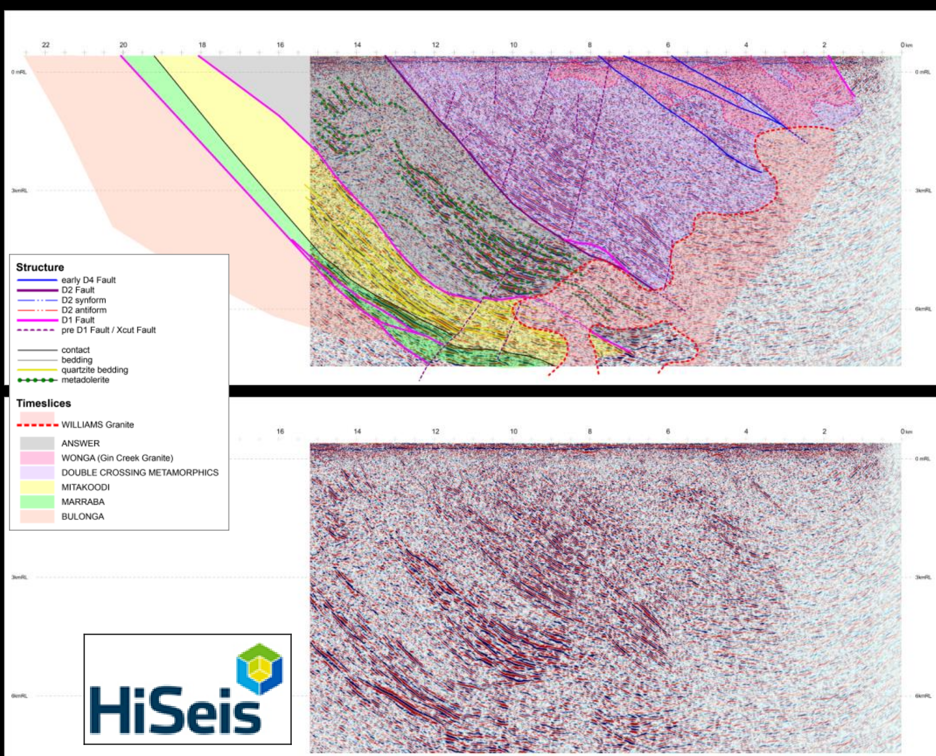






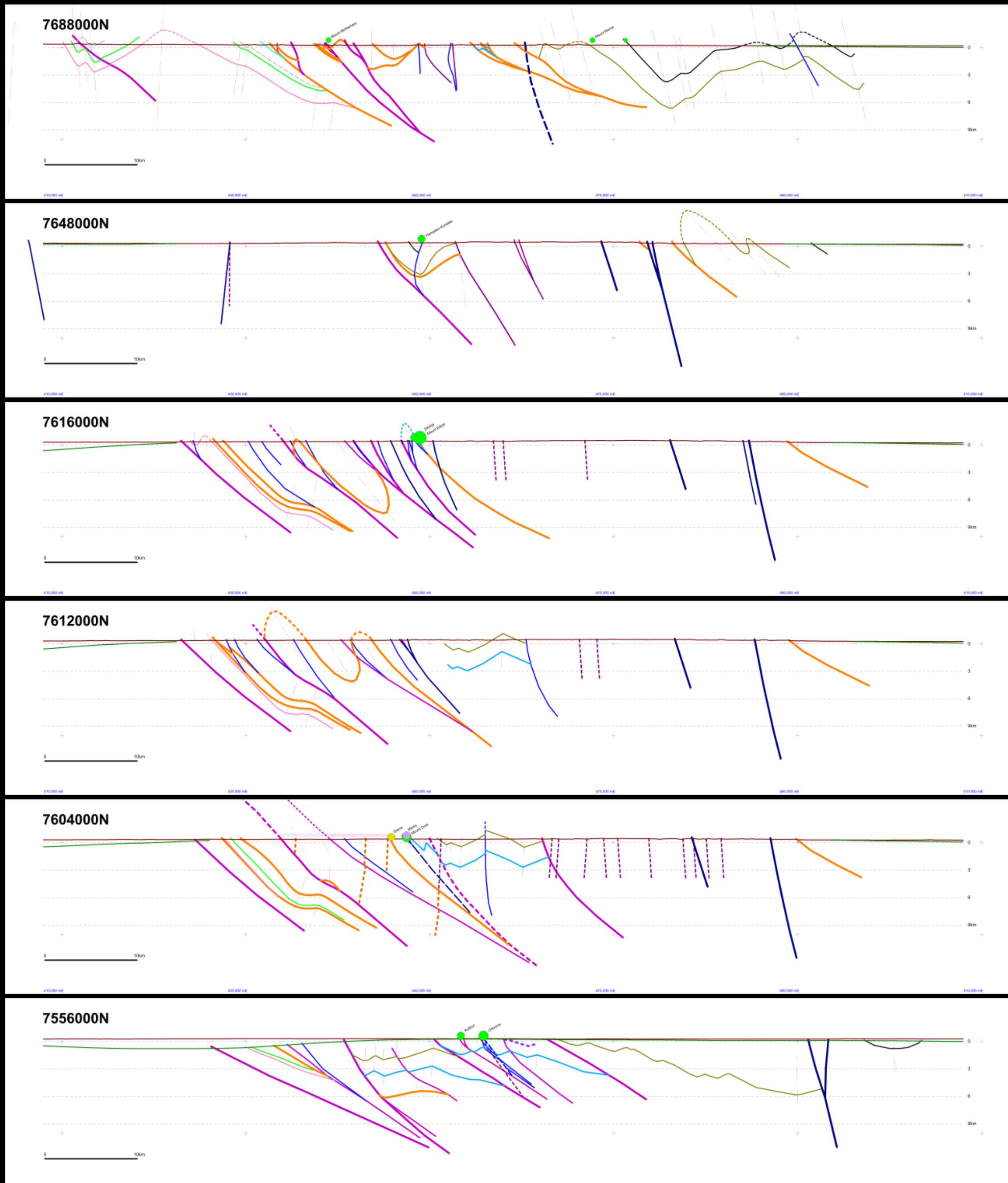
- **D1 Overhang Thrust** (pink) traced to depth **shows angular discordance** with **hangingwall STAVELEY**
- **D1 thrusts are gently D2-folded** and **dismembered by D2 Faults**
- All important **redox Top-STAVELEY** grossly deepens to east … **D2 upthrust block with OSB-KUL-PEG**
- STAVELEY again shallow east of Cloncurry Fault …. D1(!) Fault window
- **Southern Squirrel Hills WILLIAMS granite flange … base of larger eroded intrusive body**
- Houdini granite limited depth extent on section
- **Cloncurry Fault not well imaged** … juxtaposes opposite dipping packages
- Again Overhang Thrust (pink on section) soles at depth
- **Timeslice contacts …. All FORM SURFACES!**





- **D1 Overhang Thrust of ANSWER** .... & MITAKOODI **D2-folded at depth**
- D2 folds of metadolerite in ANSWER in Overhang HW
- **D2 reverse faulting of DCM-GCG block over ANSWER** … **D2 Faults steeper than D1 Thrusts** in section
- **Possible bland granites zones** at base and east of section … indistinct due to merge with zone of seismic Fold-failure test (due to east-dipping reflectors)
- **Planar block faults in DCM-GCG block** … potentially important for Starra Cu-Au localisation

DMQ 4D Geological Model
selected Sections from the forty-seven, 4km-spaced Sections



- **Interpreted to ~9km**
- **Honoring surface DMQ Solid Geology**
- **FAULTS attributed by Event** (of initiation)
- **Stratigraphic surfaces: Top-of-TIMESLICE**

…. but NO granites!

LEGEND

- surface
- base of cover

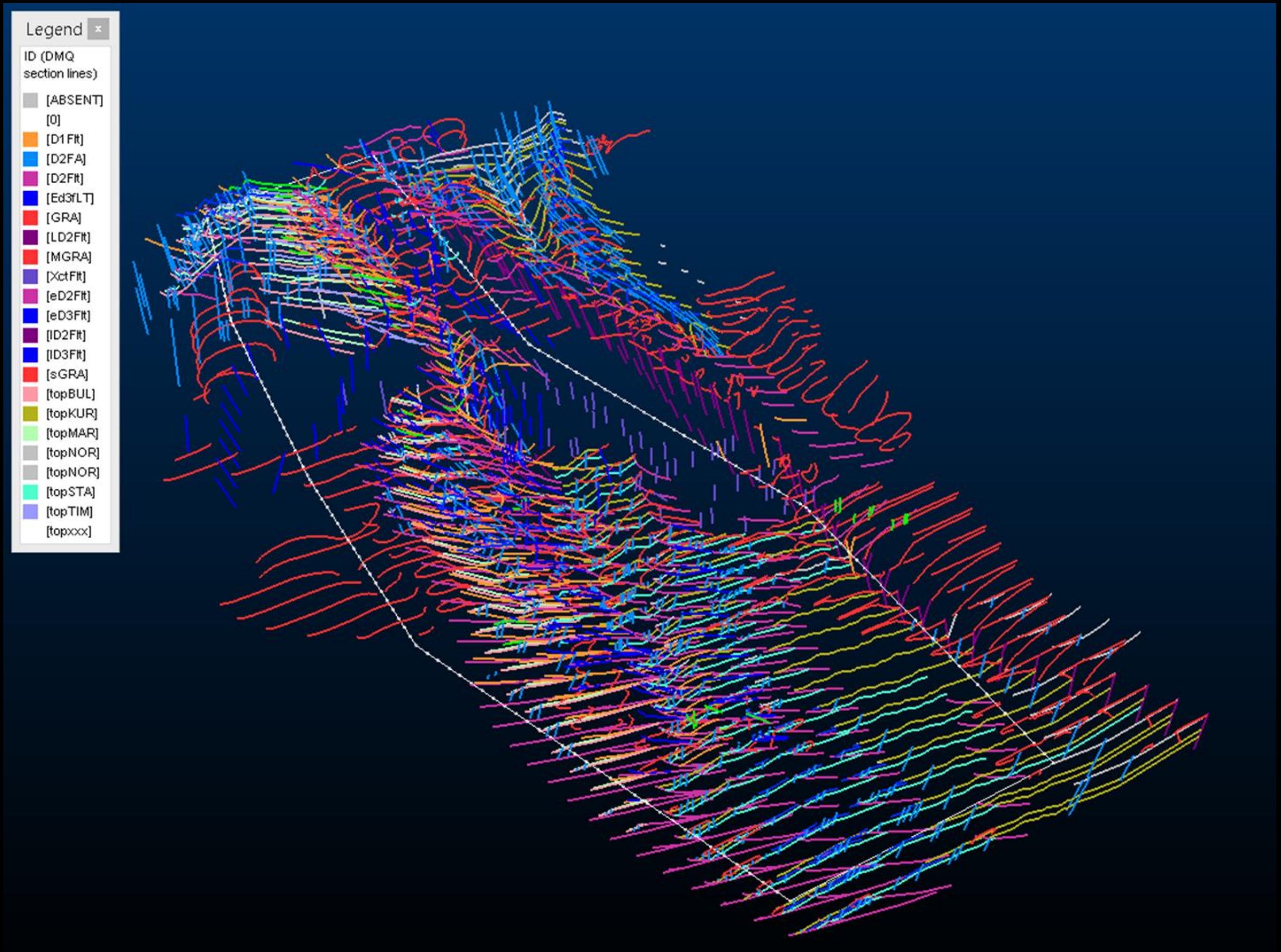
Structure

- v late D4 Fault (post WILLIAMs)
- late D4 Fault ((syn)-post WILLIAMs)
- early D4 Fault (syn WILLIAMs)
- D3 Fault
- D2 Fault
- D2 Fault (major)
- D2 synform
- D2 antiform
- D1 Fault

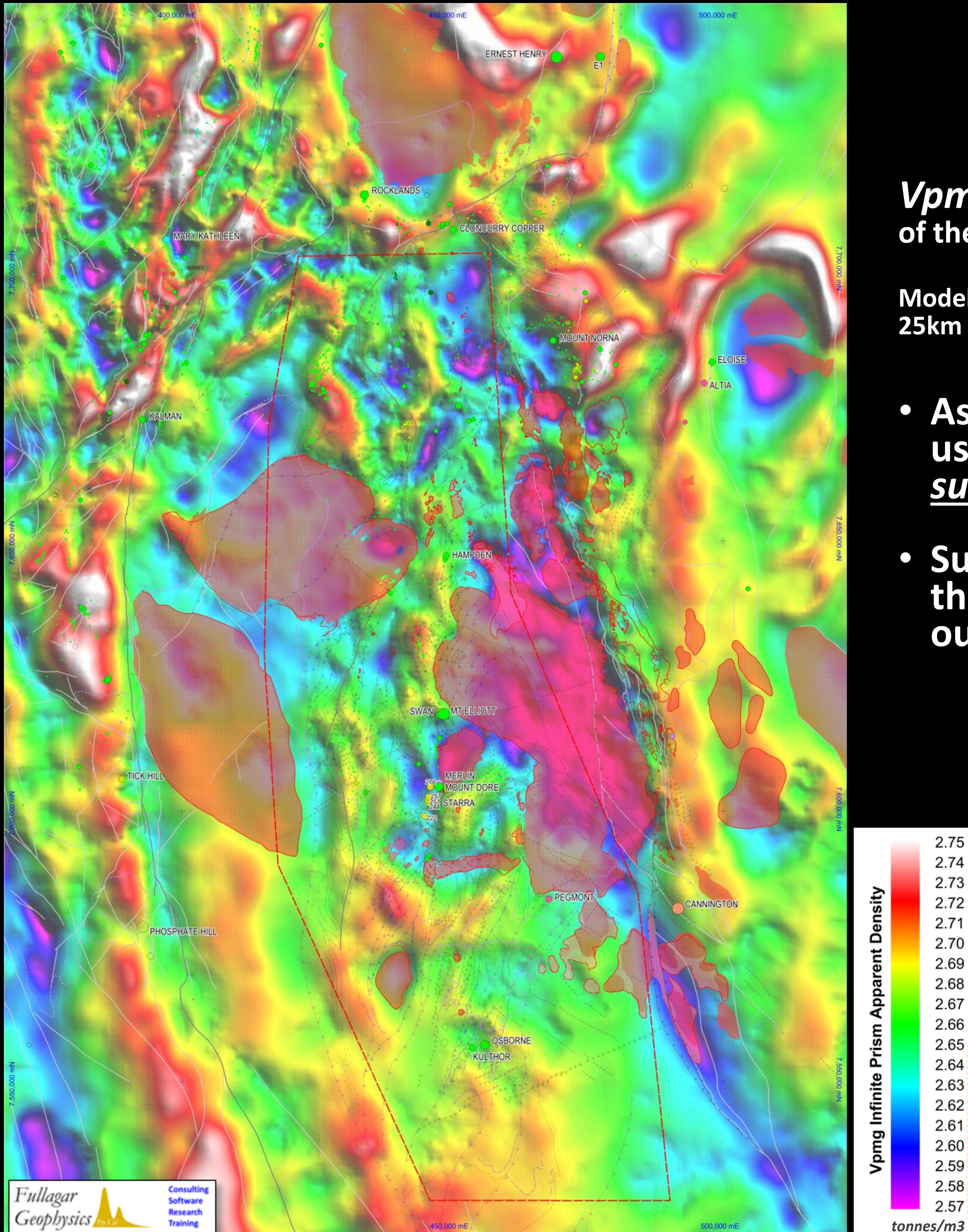
Stratigraphy

- top NEW HOPE-MT NORNA (base ANSWER-TOOLE CREEK)
- top KURIDALA-STARCROSS (base NEW HOPE-MT NORNA)
- top STAVELEY (base KURIDALA-STARCROSS)
- top MITAKOODI (base CORELLA)
- top MARRABA (base MITAKOODI)
- top TIMBEROO (base MITAKOODI)
- top BULONGA (base MARRABA)

DMQ 3D Geological Model
4km-spaced Serial Sections



colour-coded strings pre-wireframing



What about the Granites?

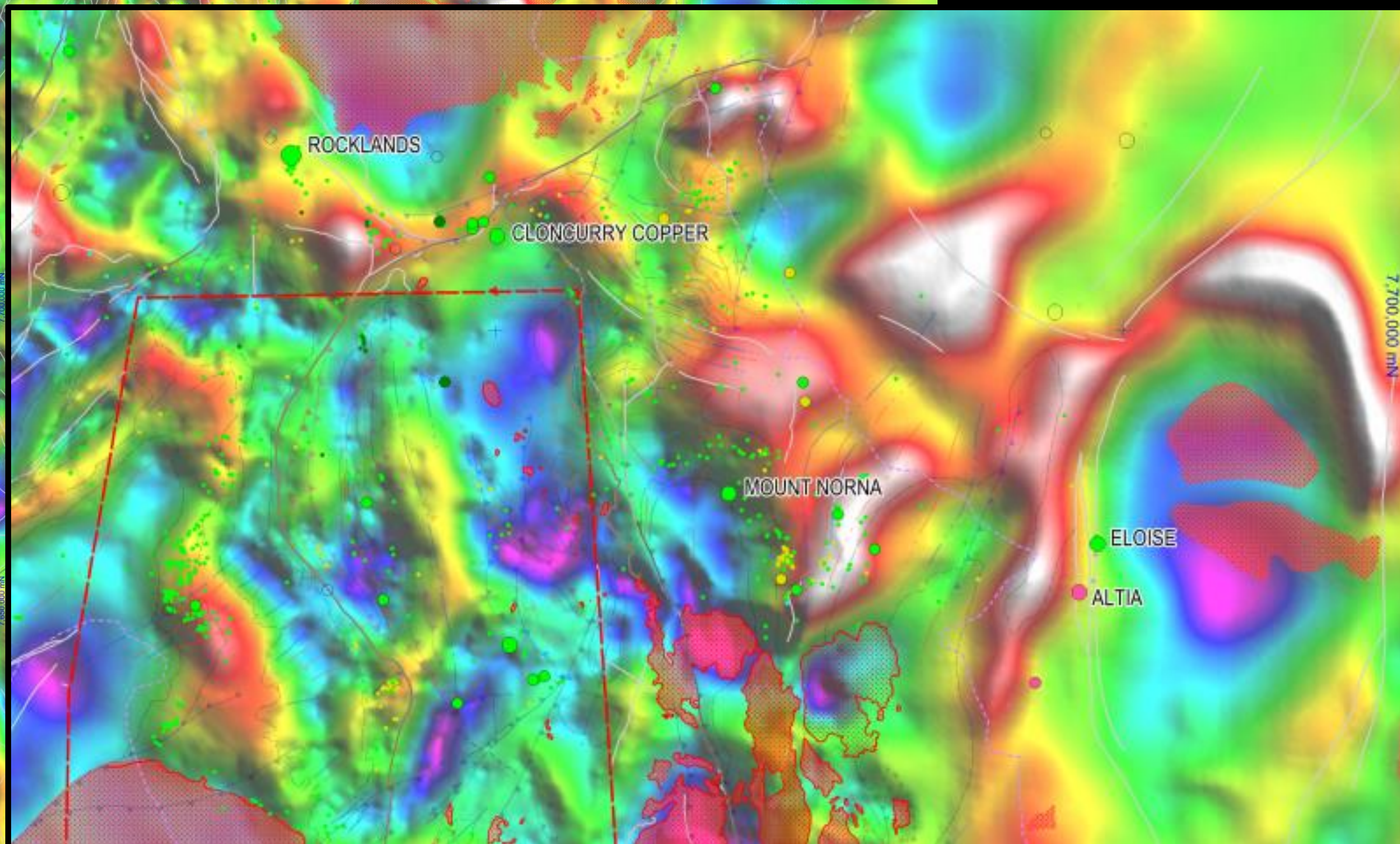
Vpmg Apparent Density Inversion Model

of the GA 2011 Gravity Data

Models a single density to each of a mesh of 900m x 900m x 25km deep prisms to match the gravity data *... JD to elaborate*

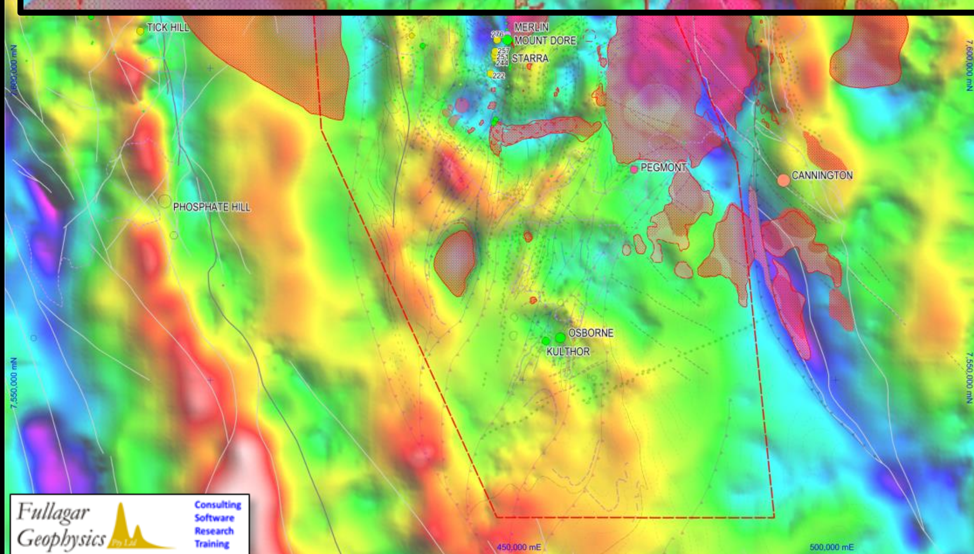
- **Assumes no crustal architecture but usefully highlights density *deficits* & *surpluses***
- **Suggests granite is far more extensive than the mapped/interpreted WILLIAMS outcrop extent**

This image drove DMQ into the intricacies of constrained-Gravity Inversion Modelling



… but much more importantly!

Locates many **Cu-Au deposits** & **occurrences** OVER margins & shoulders of what DMQ interpret to be WILLIAMS intrusives at depth

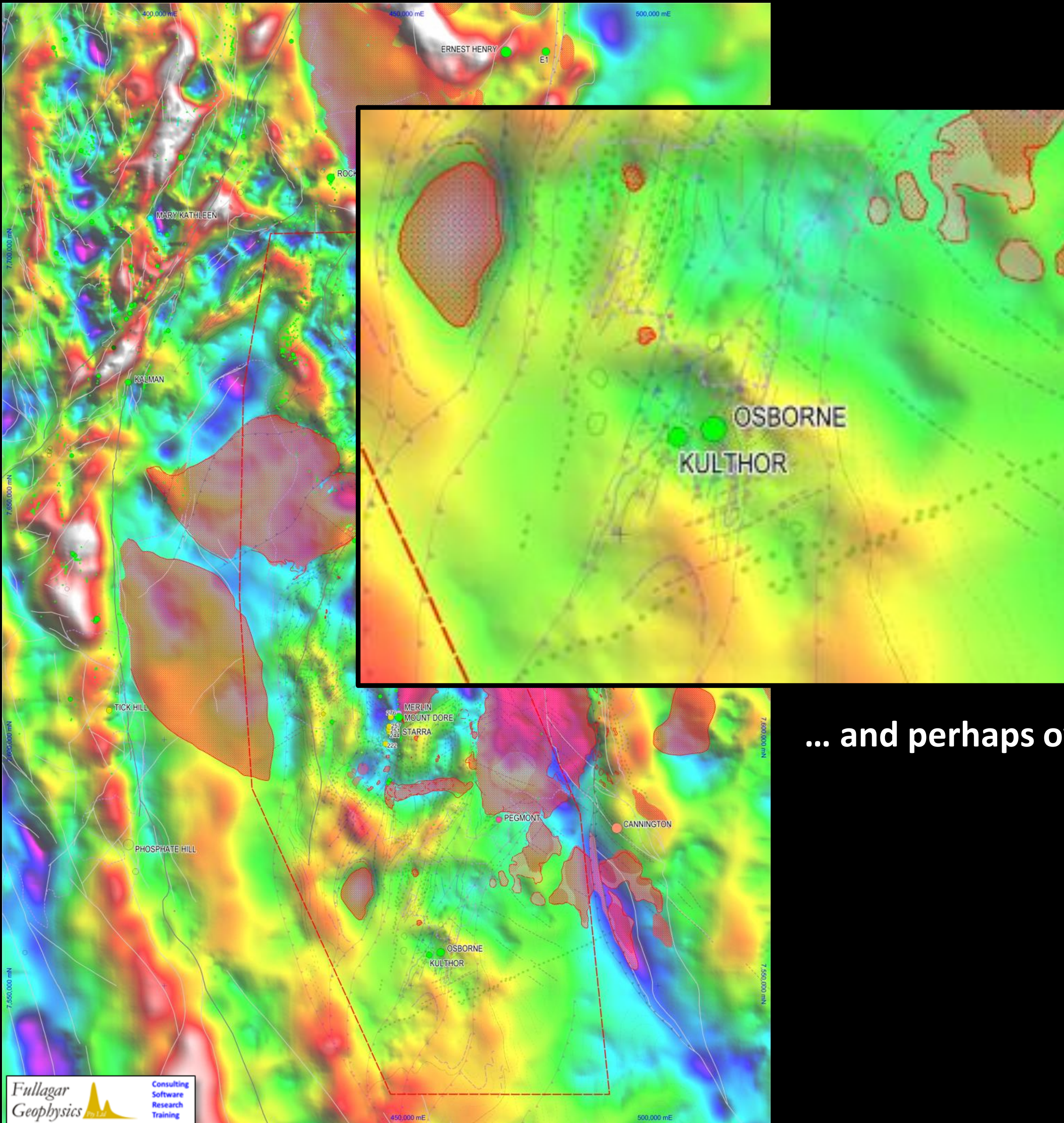


Highlights a LACK of deposits & occurrences in the roof zones of those intrusives …

.. which suggests that fertile Cu-Au mineralising fluid FLOWS UP the margins and NOT out of the roofs of the intrusives …

… implies fluid circulation systems are important; NOT simple magmatic exhalation

Does not diminish the significant metasomatism in the roof zones of sub-surface granites … alone **NOT enough!**



… but much more importantly!

… and perhaps over deeper apophyses