SMI BRC

WH Bryan Mining & Geology Research Centre

FUTORES II Townsville, June 2017

‘Deep Mining Queensland: A new view of Structural-Stratigraphic-Magmatic, Cu-Au-Mo Prospectivity in the southern Cloncurry Belt’

Mark Hinman

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

HiSeis

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.

Brief overview of Results & Products TODAY

DMQ Project Team

Dr Travis Murphy (Exploration & Mine Geology)
Dr Mark Hinman (Exploration & Mine Geology)
Dr Mark Pirlo (Exploration Geochemistry)
John Donohue (Exploration Geophysics)
Rick Valenta (*new* BRC Program Leader)
Mark Jones (Software Engineering)
Adrian Pratt (Mining Engineer)

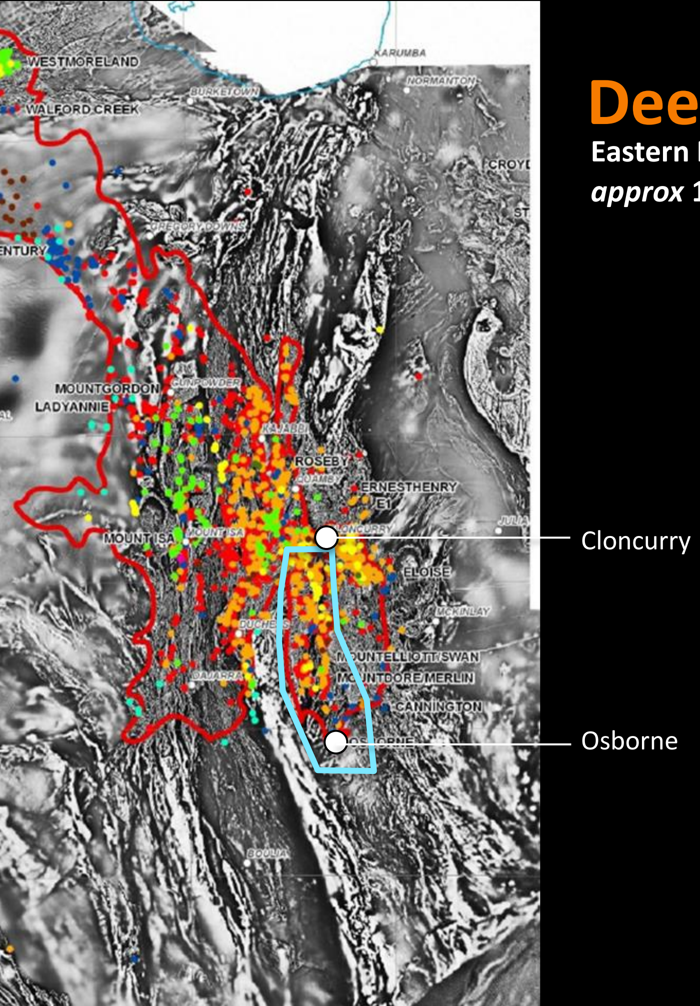
Acknowledgements

Chinova … data including detailed geophysics, detailed prospect mapping & historic project databases
GSQ … **Future Resources Program**; pre-release 100K mapping, geochron database
Historic Work… Leishman, 1970s-80s; Searl, 1952; … *& many others; many companies*

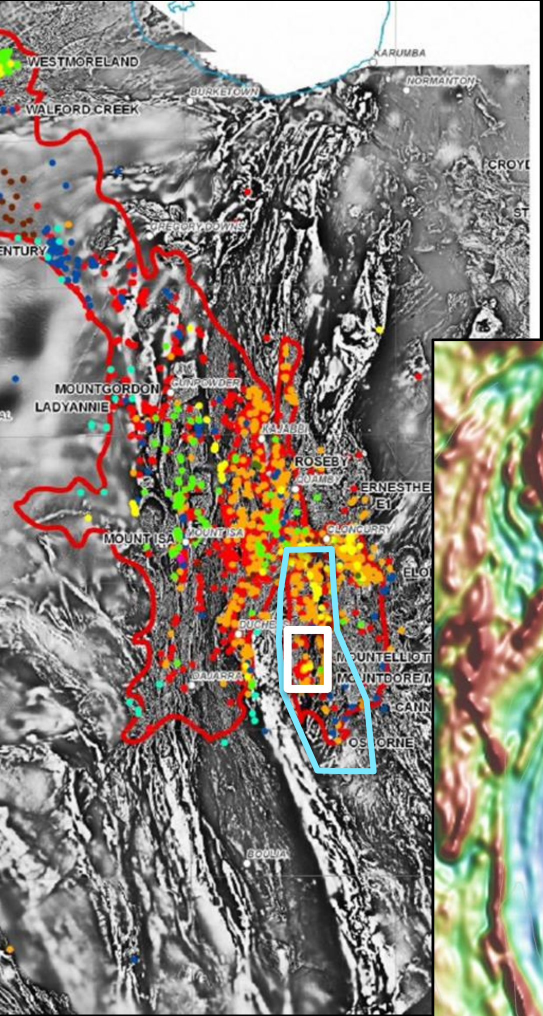
Deep Mining Queensland Project Location

Eastern Fold Belt between Cloncurry & Osborne

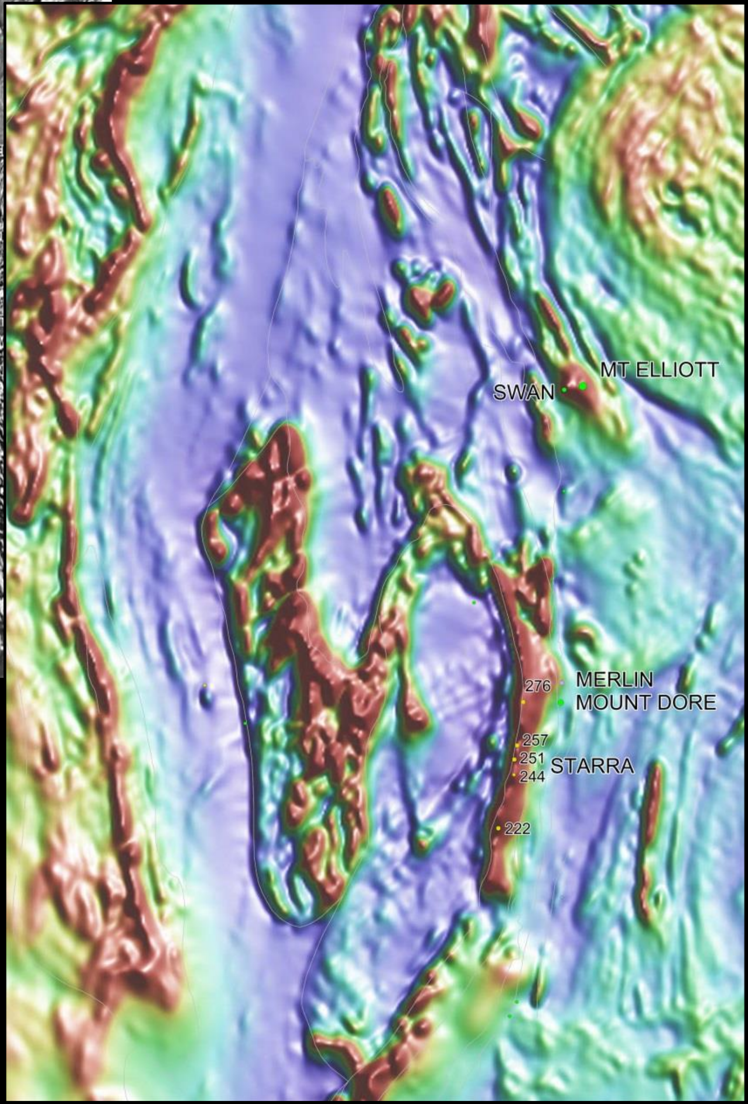
***approx* 180x50km**



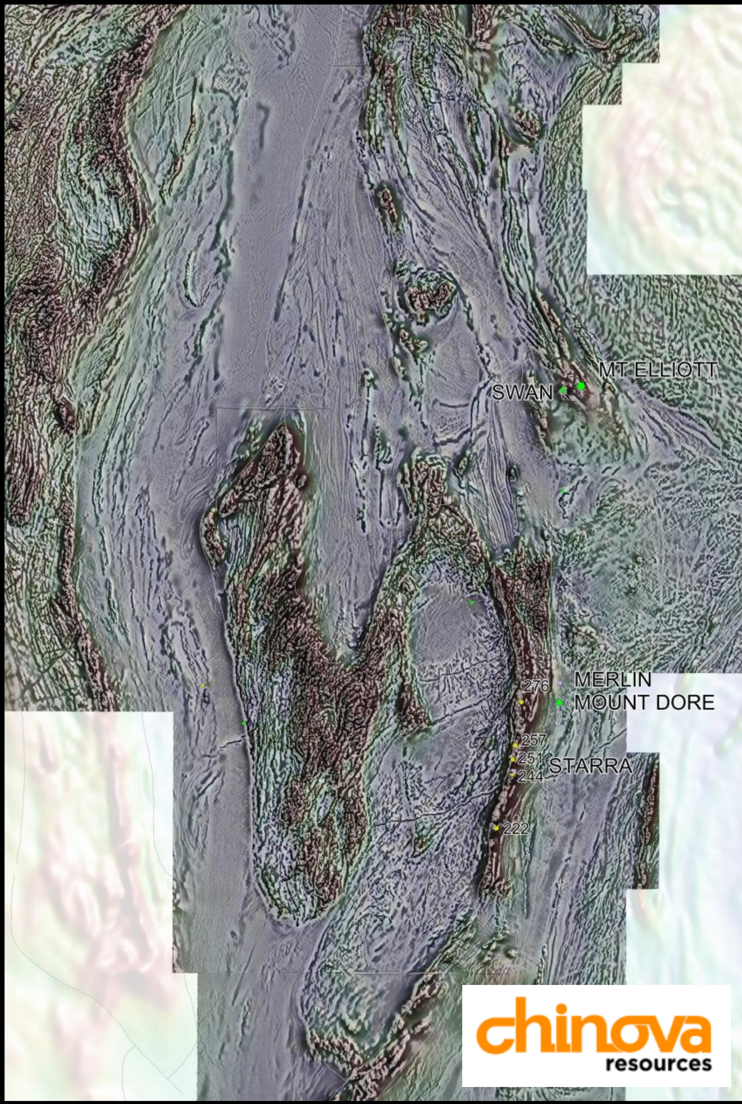
DMQ Geological Re-interpretation
Regional *vs* Detailed Magnetics



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**

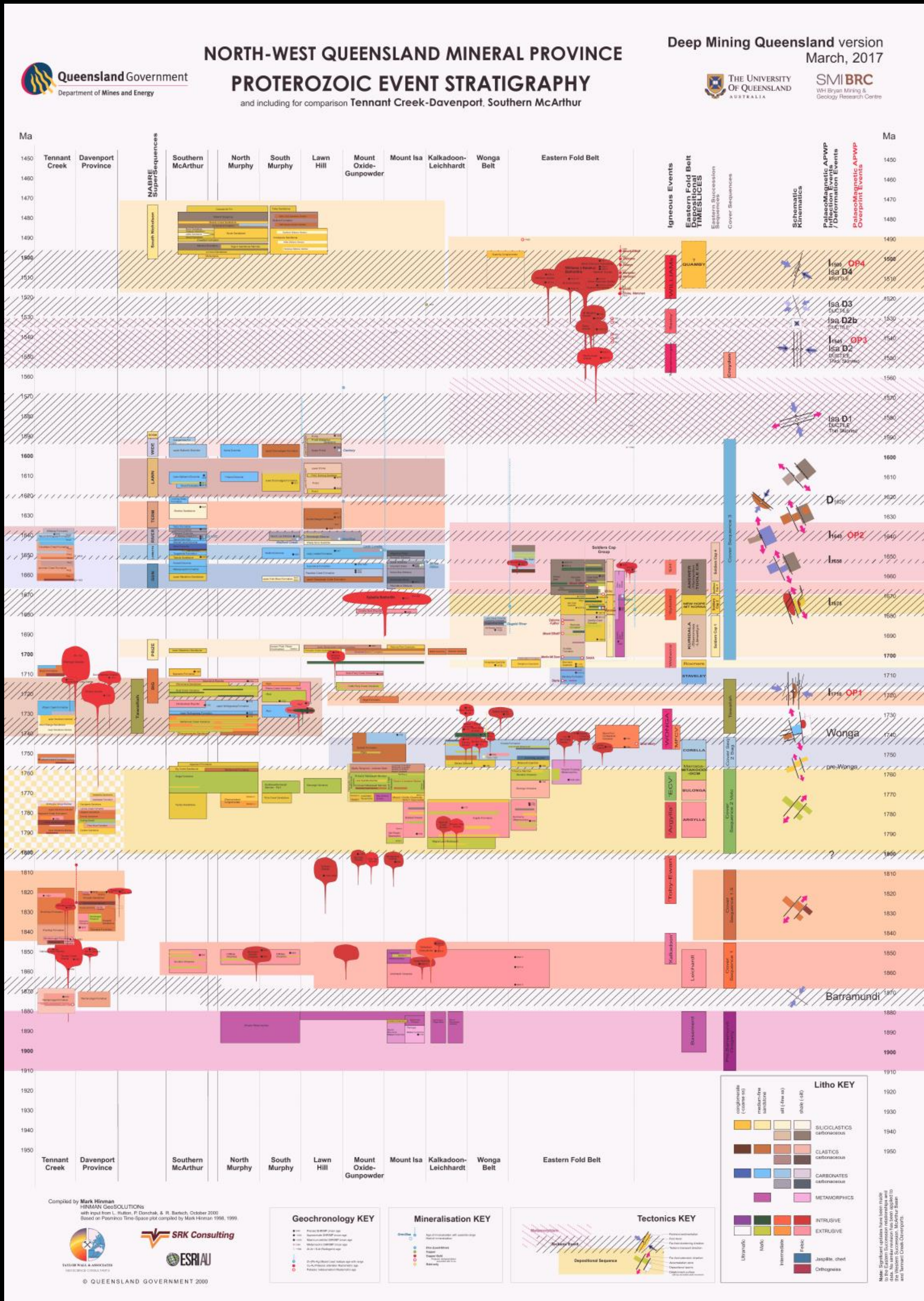
> package continuity

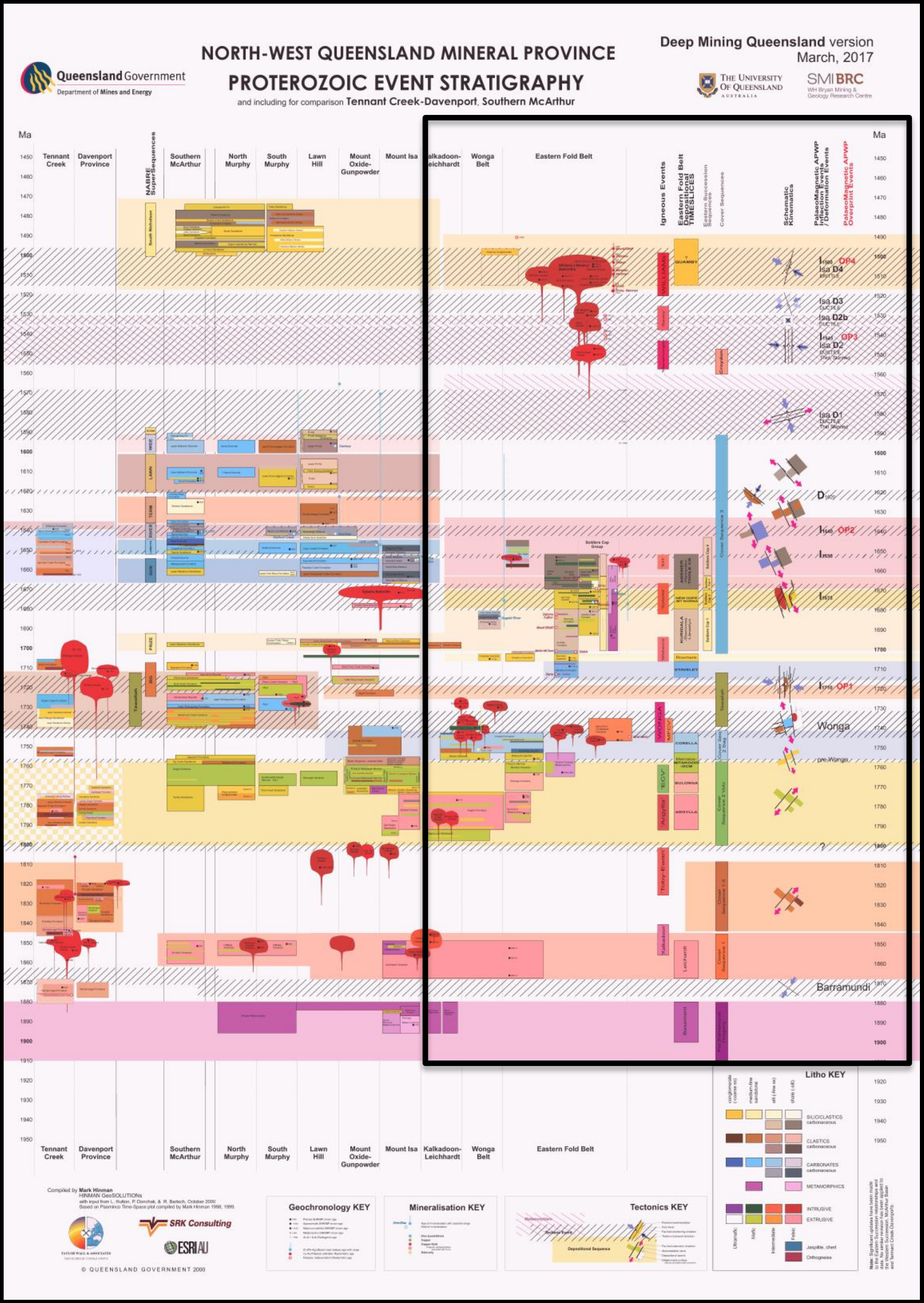
> package architecture

> fine faulting architecture

chinova resources

Updated DMQ 2017 version
of 2000 NWQMP T-x Chart



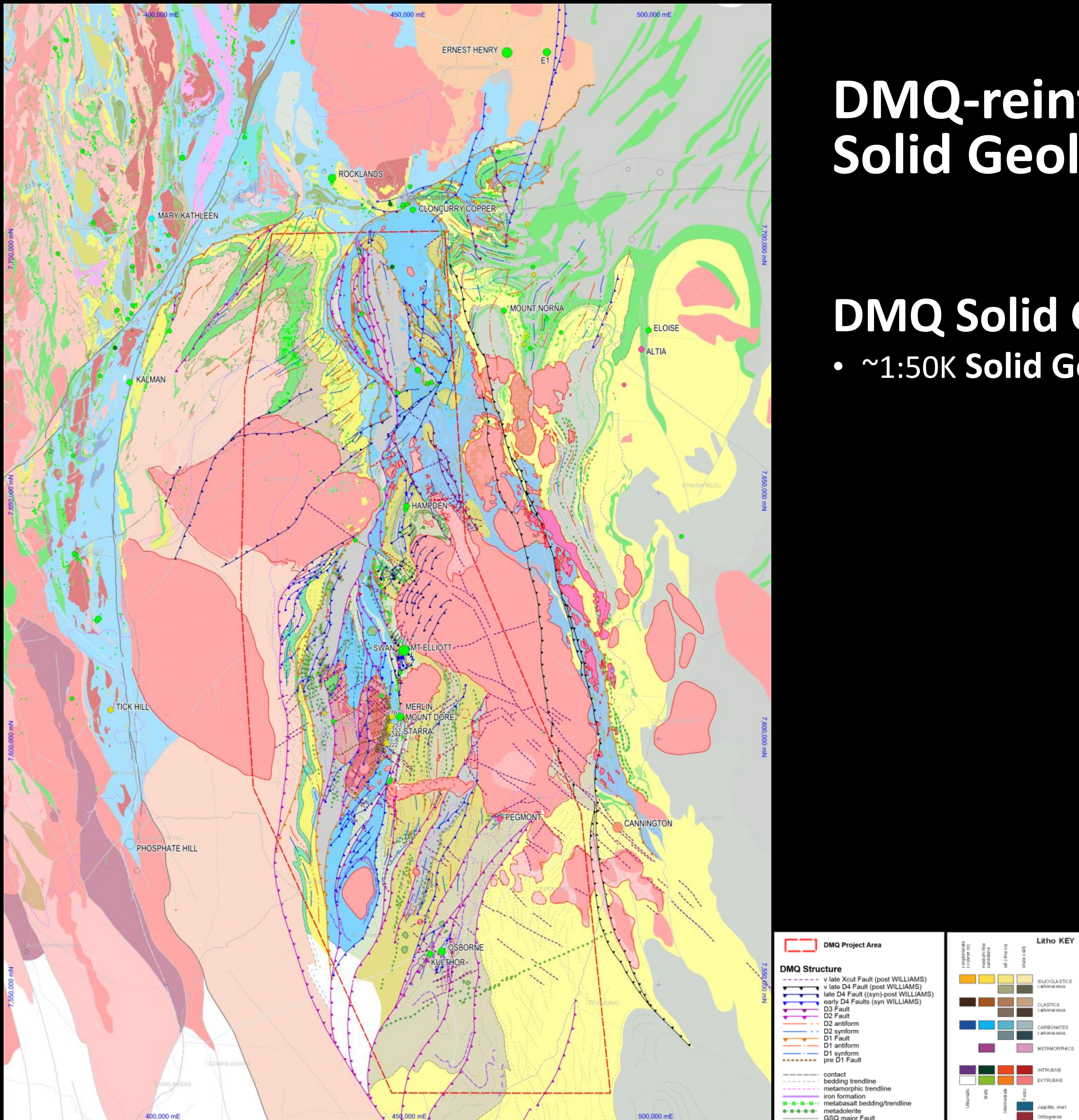


Updated DMQ 2017 version

of 2000 NWQMP T-x Chart

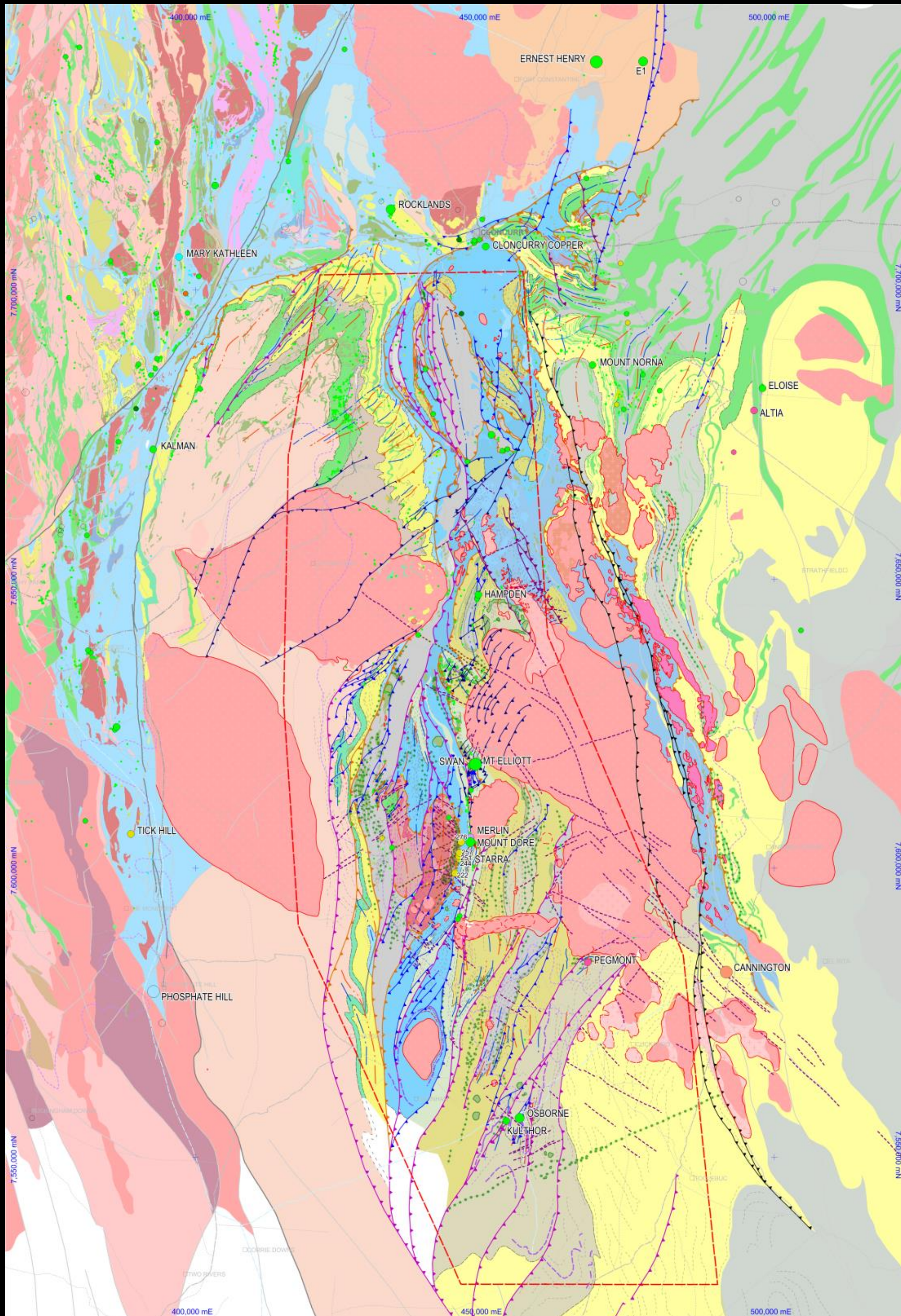
- Reflects current understanding of **EFB package relationships** gleaned from the **DMQ interpretation** & **latest geochronology** (Withnall-Parsons, 2007-2009; NWQMEP, 2011; GSQ geochron database, Withnall, 2016)
- Updated Isan Deformation Events to reflect **D1, D2, D2b, D3 & D4** in common usage.
- **TIMESLICES** reflecting **DMQ re-packaging** of mapped Formations, Members & units.

DMQ-reinterpreted Solid Geology



DMQ Solid Geology PRODUCTS

- ~1:50K **Solid Geology Interpretation**



DMQ-reinterpreted Solid Geology

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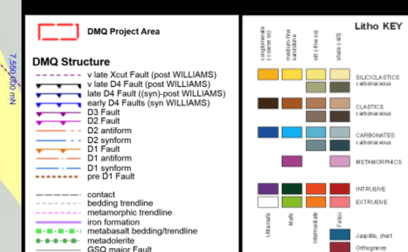
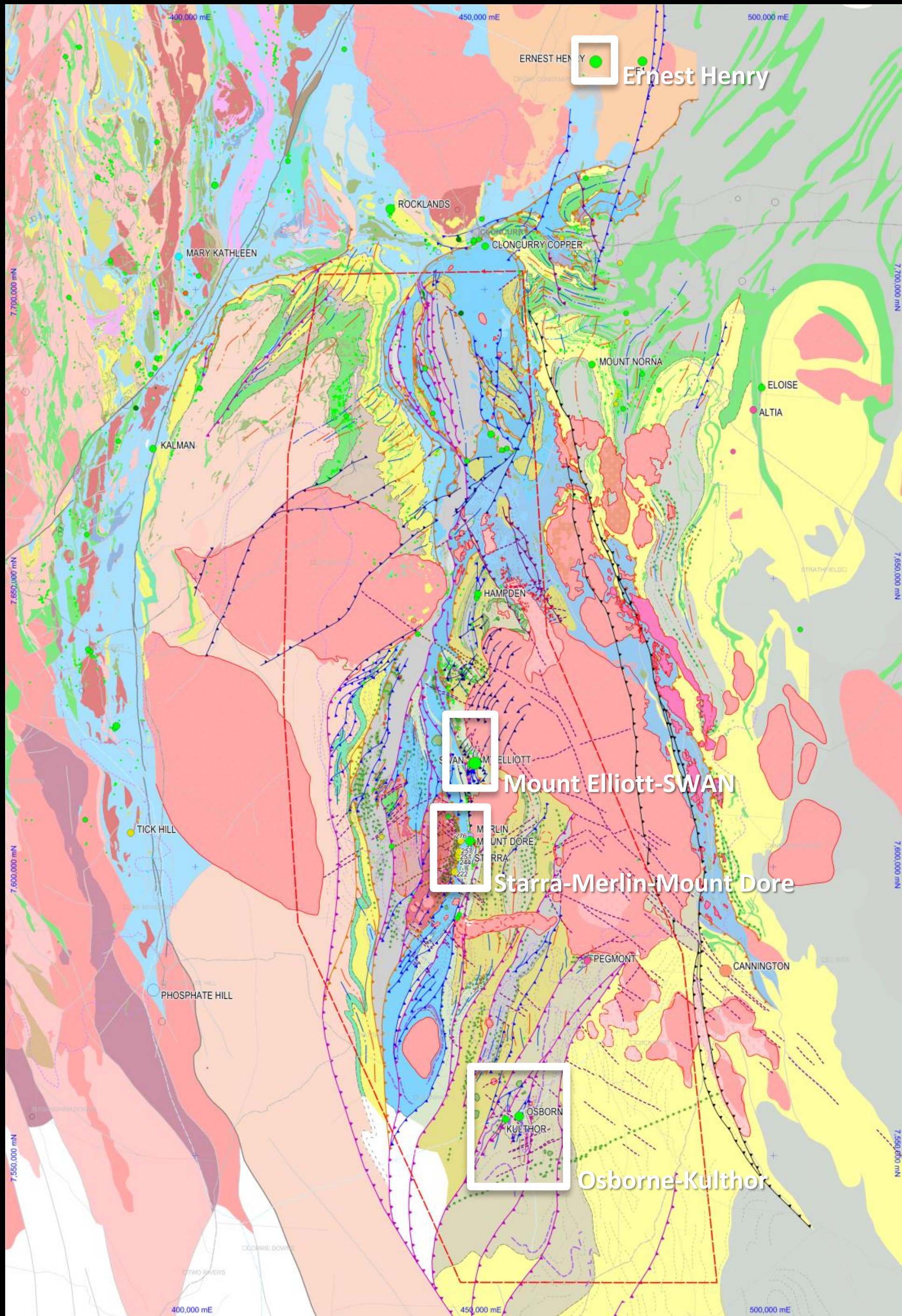
- **GIS Package of TIMESLICED Geology**
- **GIS Event-attributed Structures**





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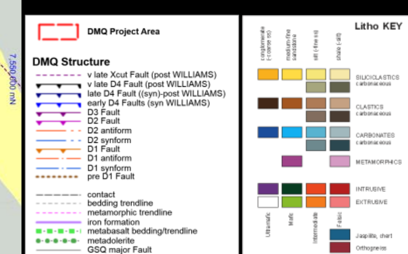
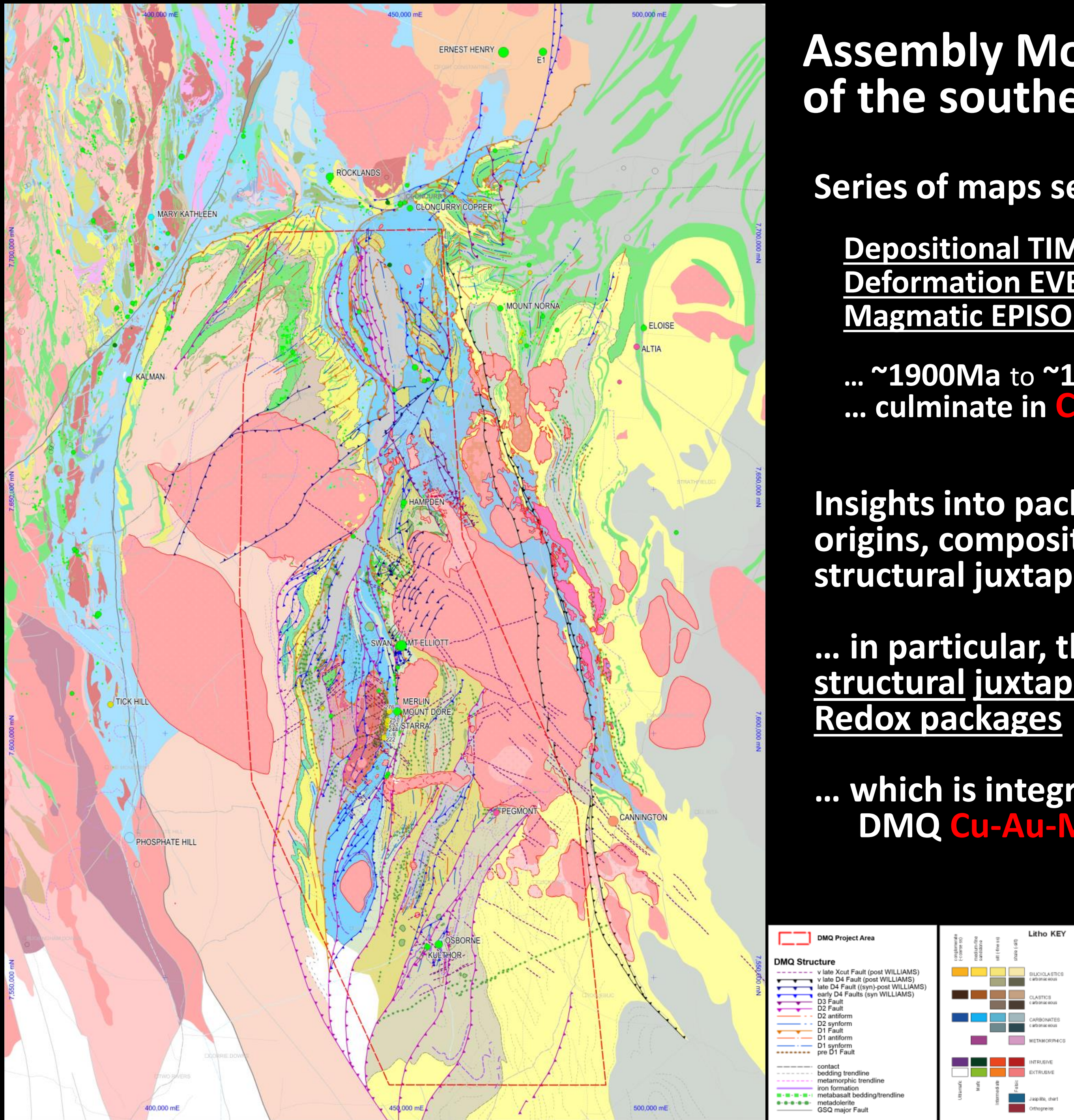
DMQ Solid Geology PRODUCTS

- ~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 Model of the southern Cloncurry Belt

Series of maps sequentially highlighting ….

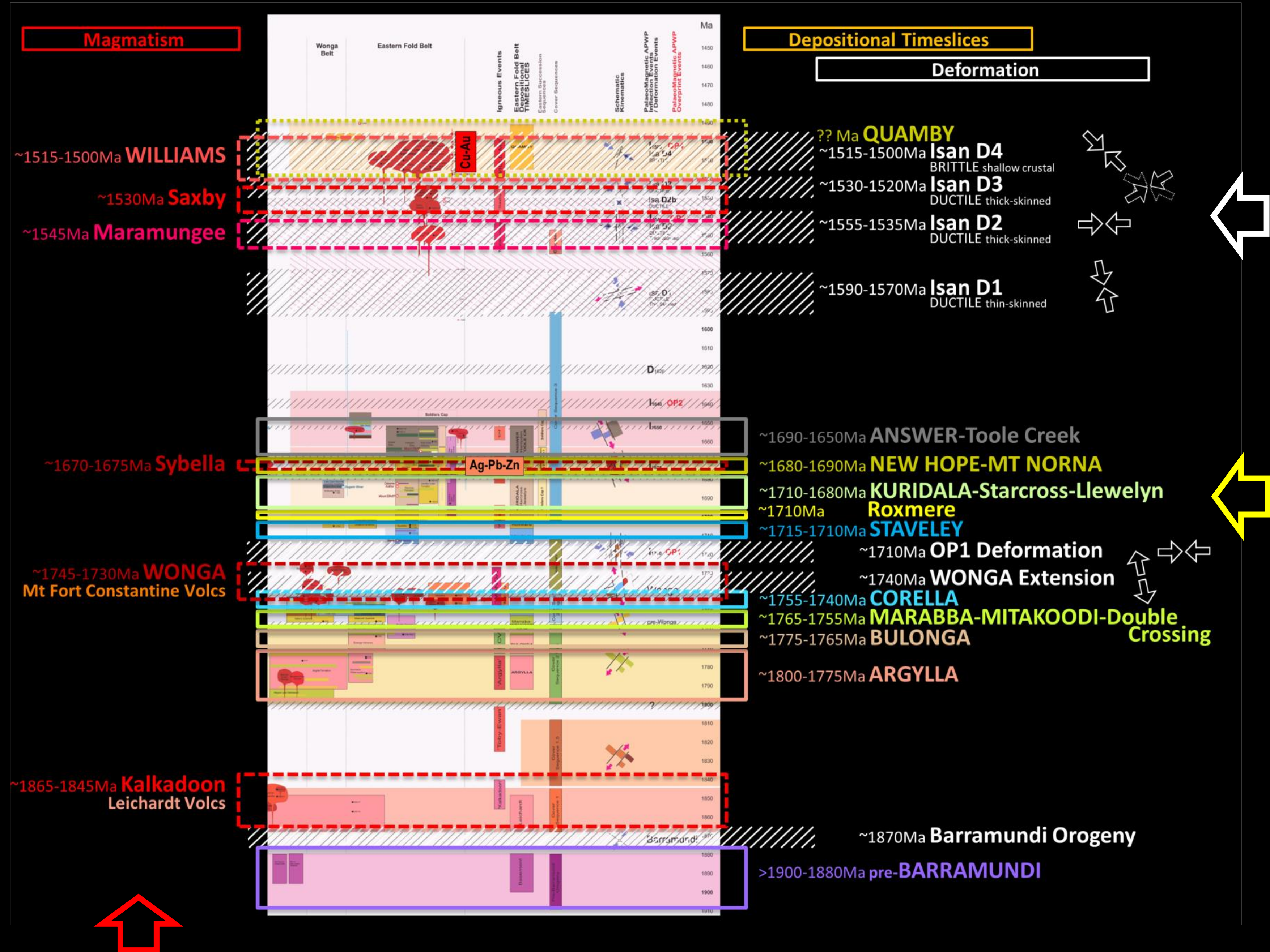
<u>Depositional TIMESLICES</u>, <u>Deformation EVENTS</u>, and <u>Magmatic EPISODES</u>

… ~1900Ma to **~1400Ma**
… culminate in Cu-Au-Mo mineralisation

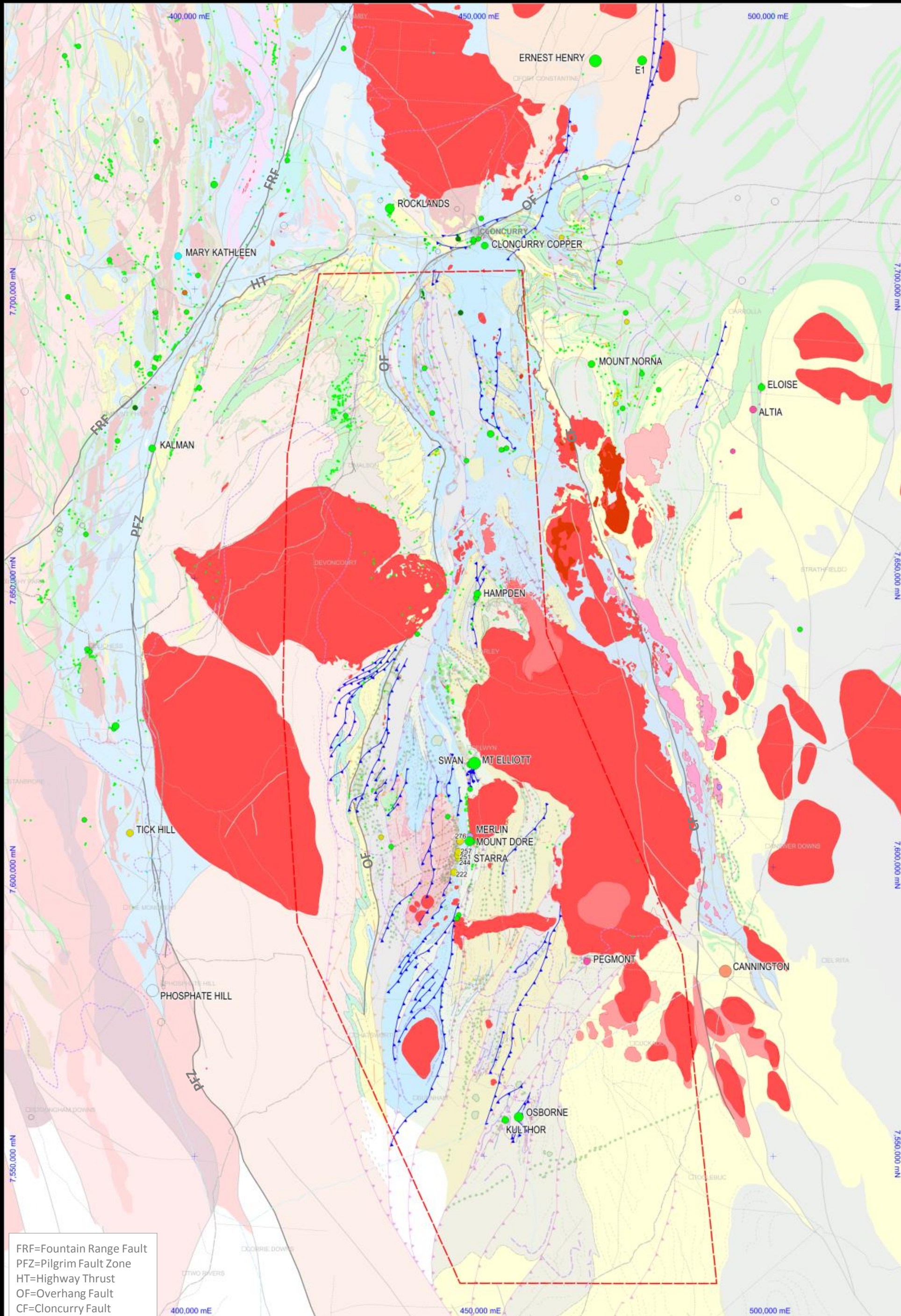
Insights into package relationships, their origins, compositions & nature of their structural juxtapositioning …

… in particular, the <u>stratigraphic</u> and <u>structural</u> <u>juxtapositioning of contrasting Redox packages</u>

… which is integral to DMQ Cu-Au-Mo Propsectivity Analysis



Highlights 29 phases of **Accumulation** in TIMESLICES, **Deformation** EVENTS and Episodes of **Magmatism** in relation to Mineralisation …. *but time short!*

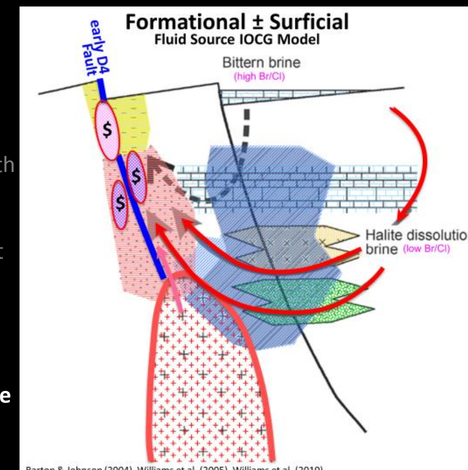


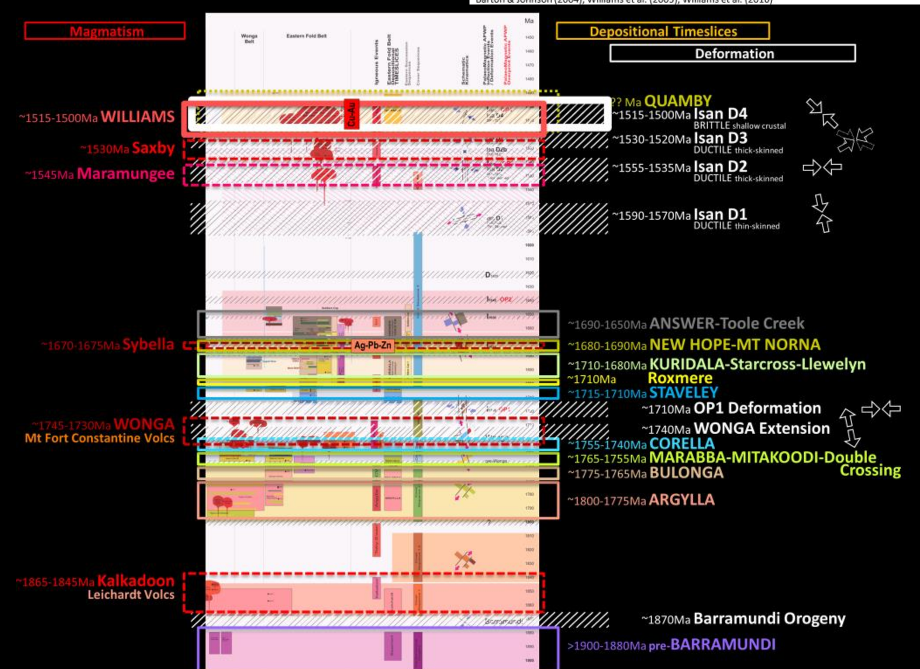
~1515-1500Ma
early **D4 Faulting/re-Activation**

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

Post-peak meta-times, at shallower crustal levels, **NW-directed shortening** results in early **D4 Faulting/re-Activation** of older structures .. focuses **Cu-Au-Mo minz**

- **D4 Faults** (cf D1-D2-D3) are **small scale** with **small displacements**; many so small that **not mapped**.
- 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 deposition site and **P-T-x conditions** en route & at site of deposition.

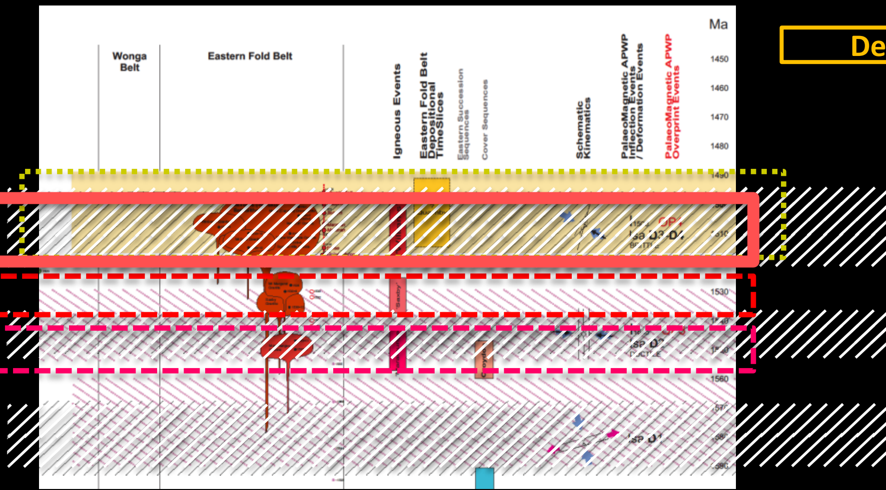




Magmatism

Depositional Timeslices

Deformation



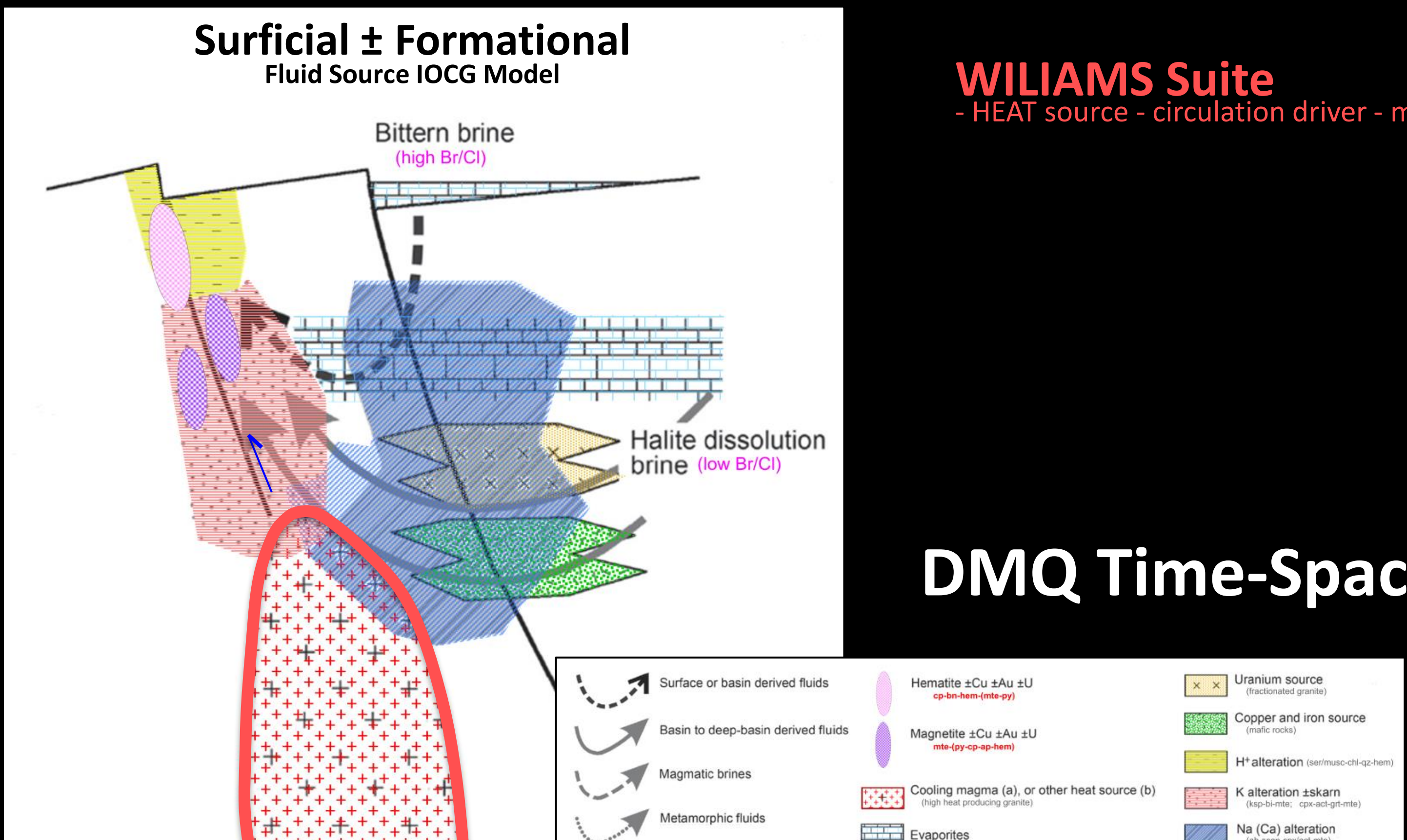
~1515-1500Ma **Williams**

~1530Ma **Saxby**

~1545Ma **Maramungee**

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

At ~1515-1500Ma …



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

WILIAMS Suite
- HEAT source - circulation driver - metal contribution

DMQ Time-Space Control

Magmatism

Depositional Timeslices

Deformation

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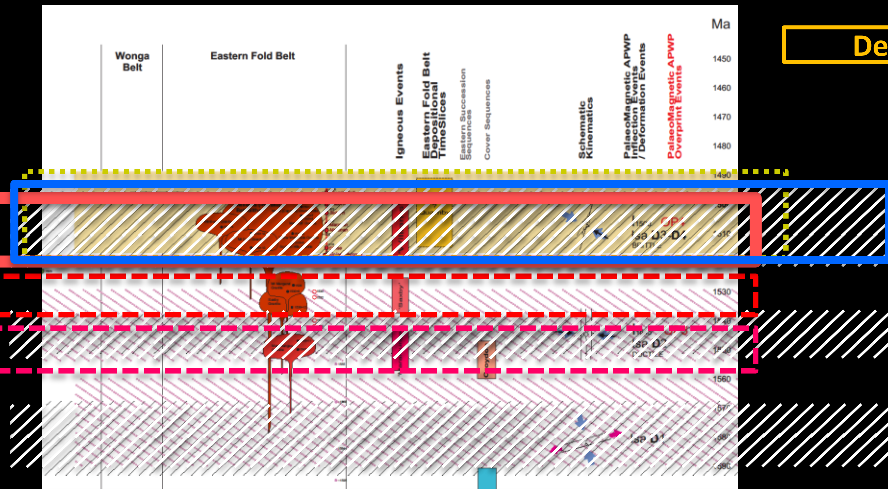

~1520-1490Ma Isan D4
BRITTLE shallow crustal

~1590-1570Ma Isan D2
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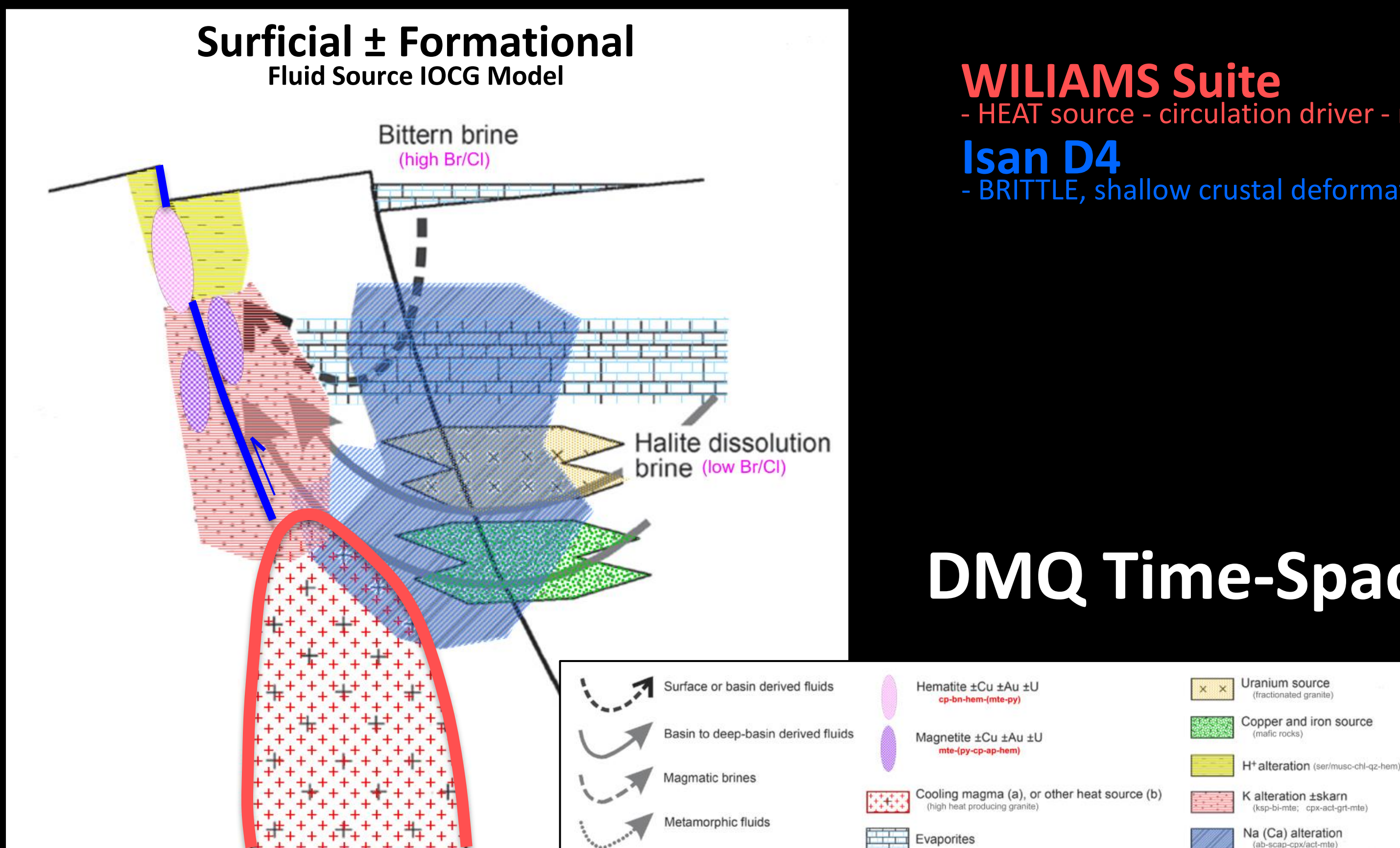
At ~1515-1500Ma ...



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WILIAMS Suite
- HEAT source - circulation driver - metal contribution

Isan D4
- BRITTLE, shallow crustal deformation > permeability

DMQ Time-Space Control

Magmatism

Depositional Timeslices

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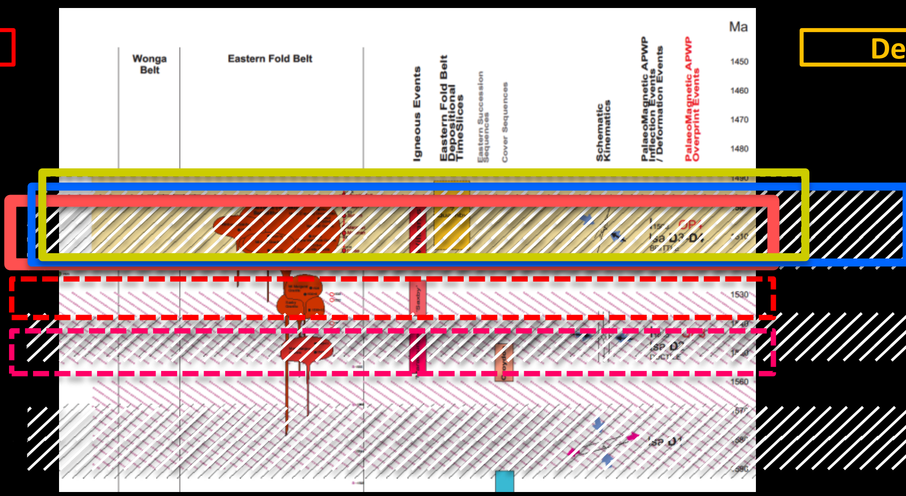

?? Ma **Quamby**

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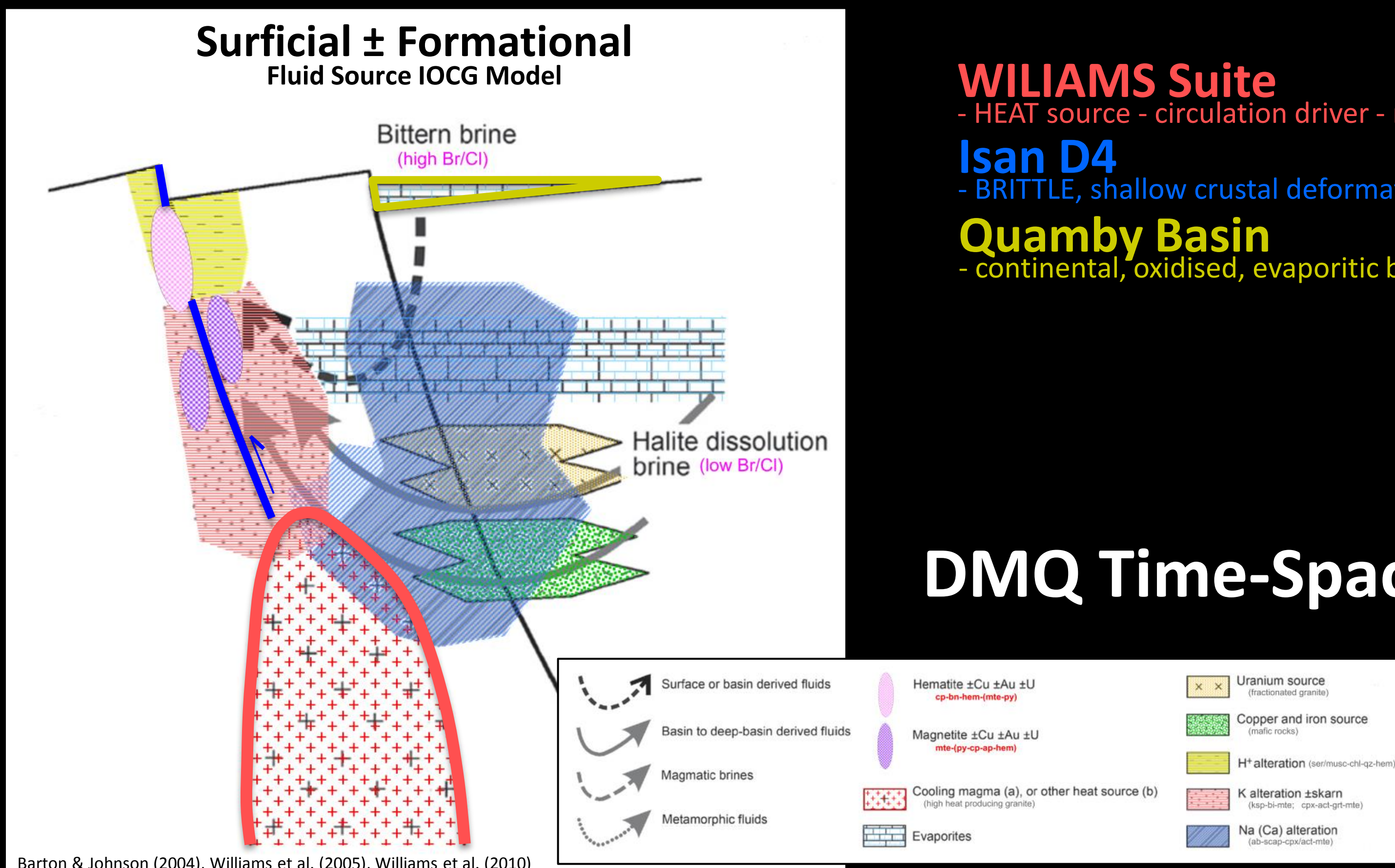
At ~1515-1500Ma …



WILIAMS Suite
- HEAT source - circulation driver - metal contribution

Isan D4
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Quamby Basin
- continental, oxidised, evaporitic brine source

DMQ Time-Space Control

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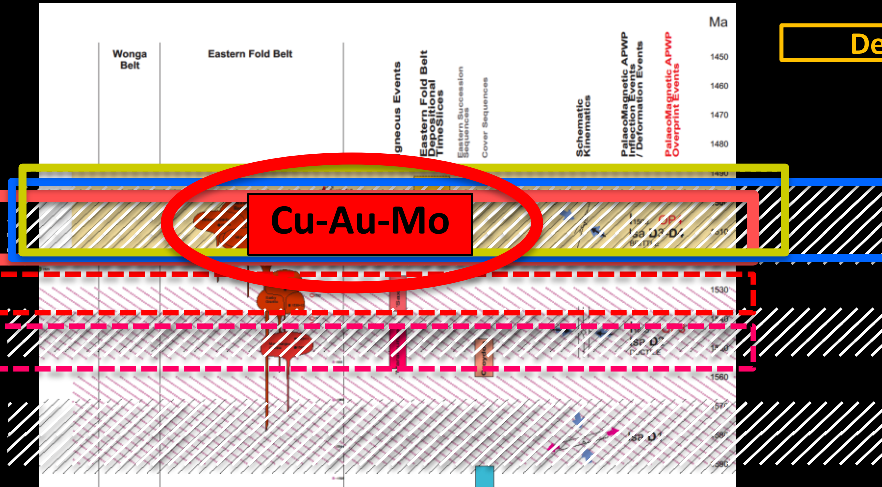

Depositional Timeslices

Deformation

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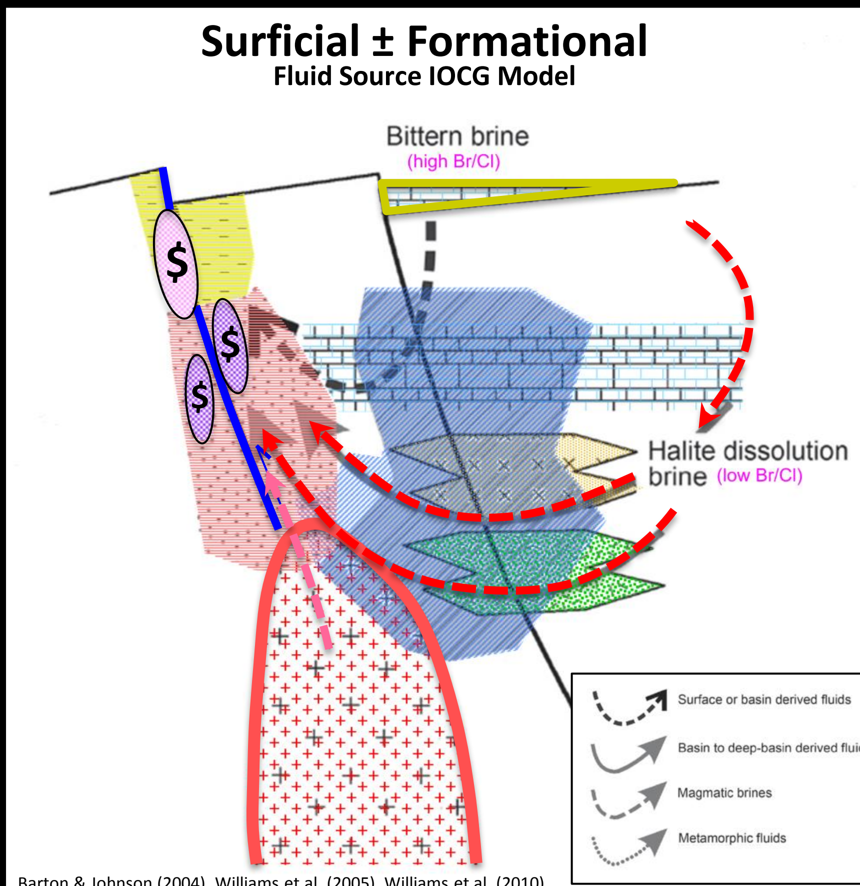

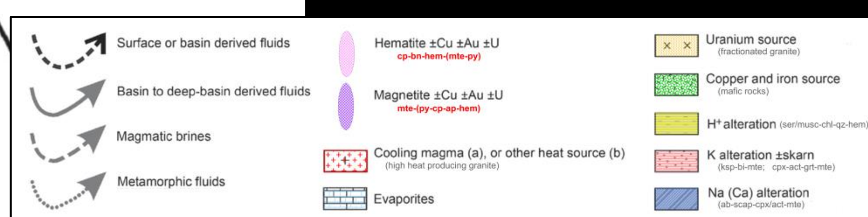

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Quamby Basin
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>> Cu-Au-Mo *IOCG/ISCG* Mineralisation

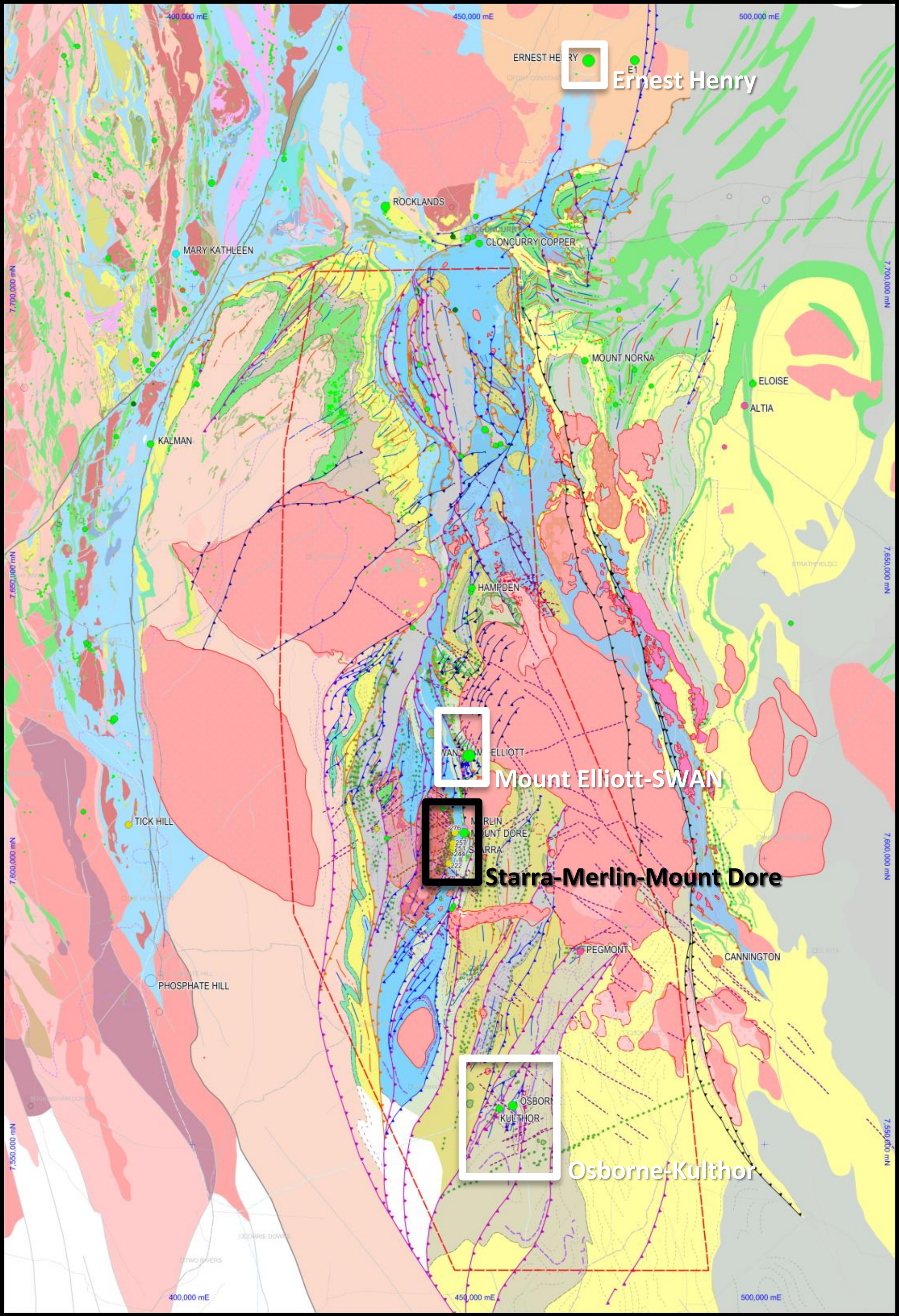
DMQ Time-Space Control

DMQ District to Local: Deposit Controls

detailed geological compilations

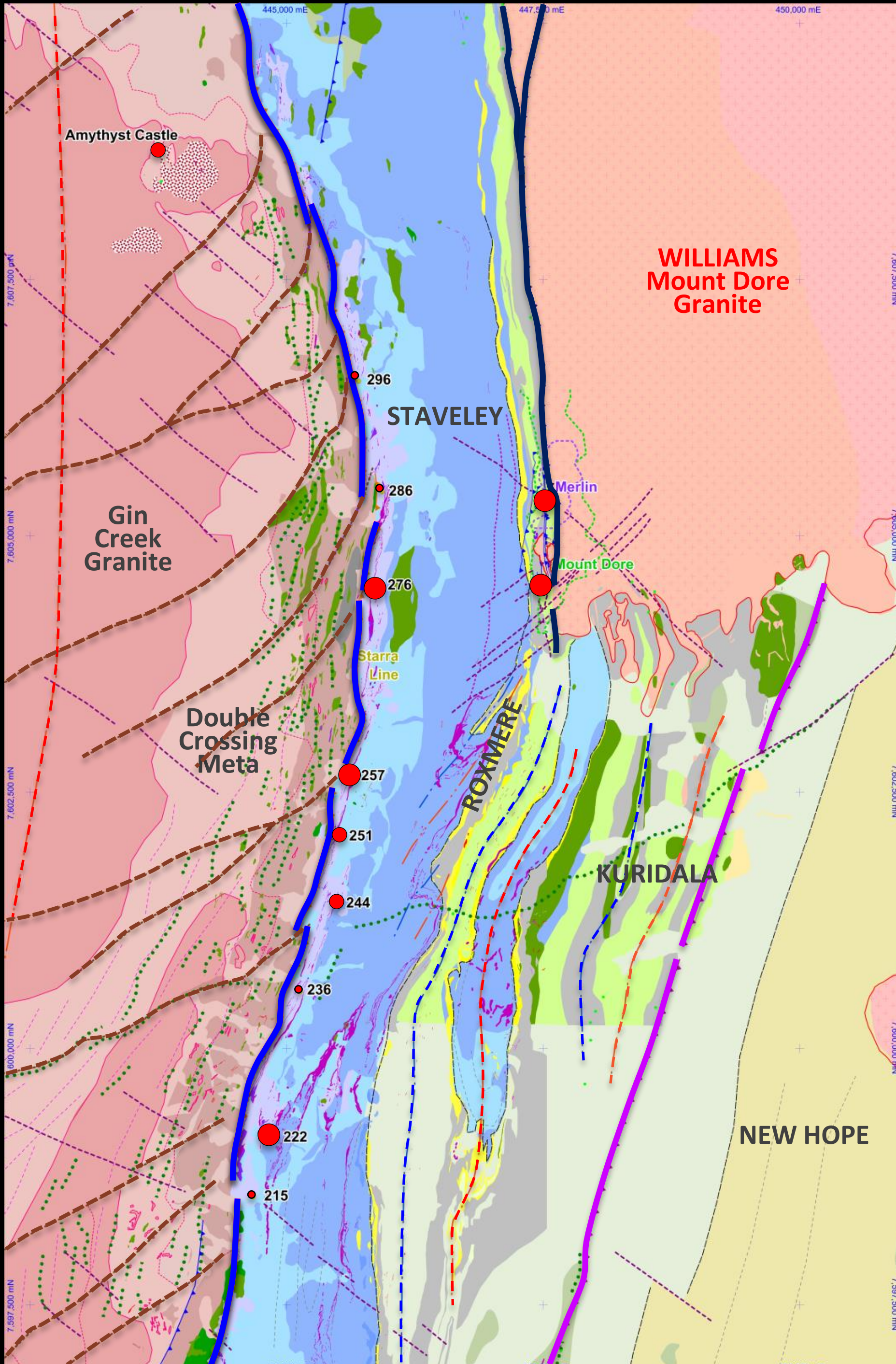
& interpretations of geodynamic mineralisation control

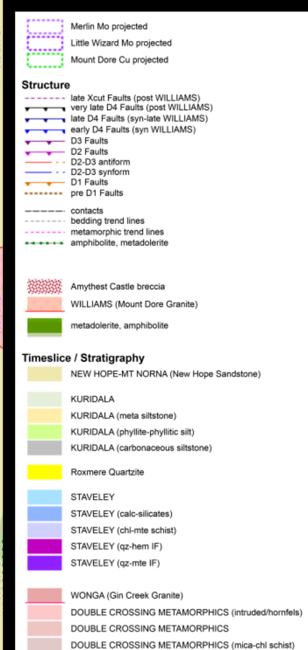
Starra-Merlin-Mount Dore
Mount Elliott-SWAN
Osborne-Kulthor
Ernest Henry

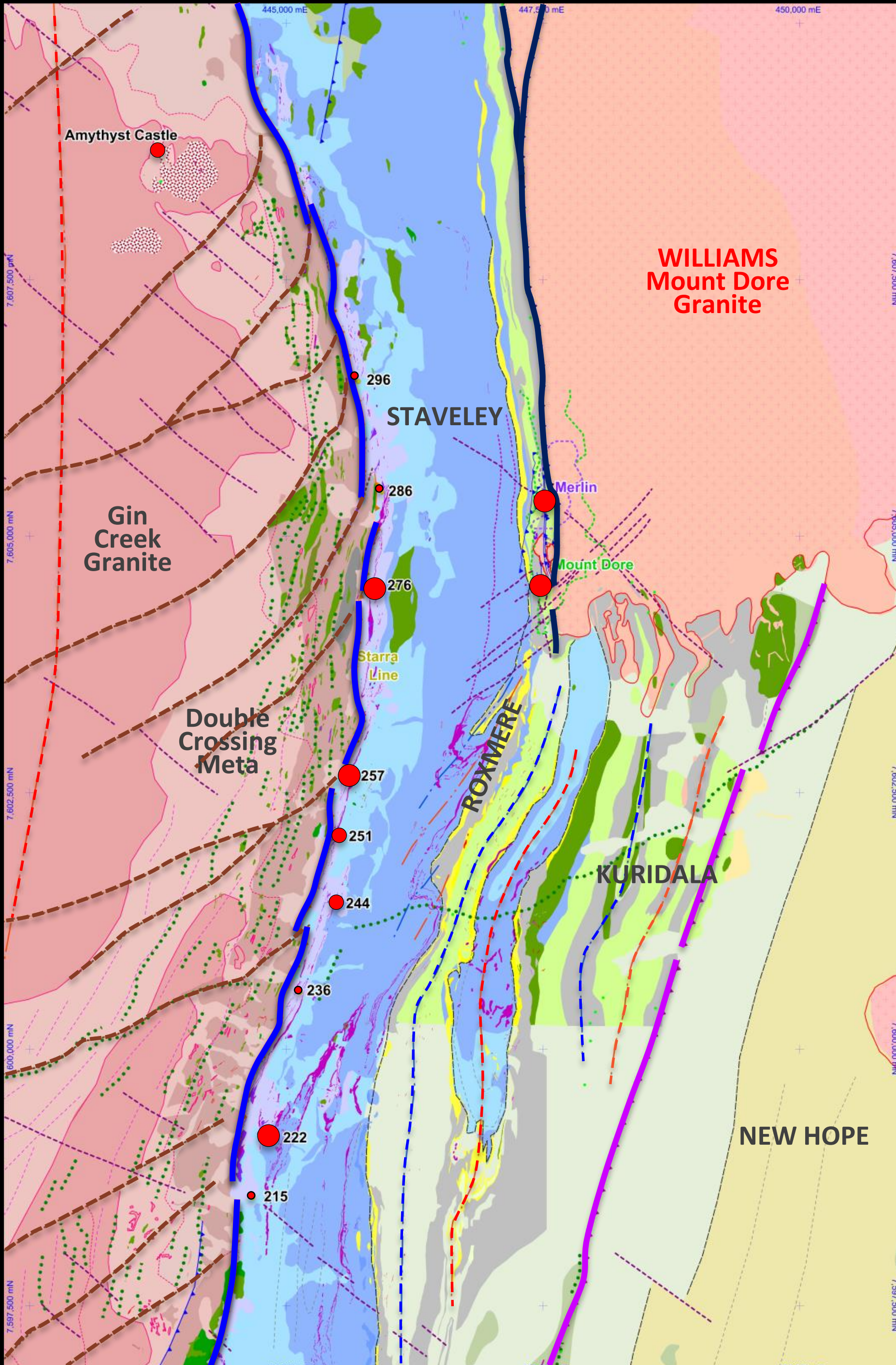


Starra-Merlin-Mount Dore

5K-10K Leishman Geology (1970s-1980s)
Ivanhoe-Chinova Mapping (2000s)
DMQ Geophysical Interpretation (2016)







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MARRABA-MITAKOODI-Double Crossing Metamorphics

syn-deformational WONGA Gin Creek Granite

OP1 Exhumation of DCM-GCG … Block Faulting
Significant offsets of GCG-DCM

STAVELEY
ROXMERE
KURIDALA
NEW HOPE … deposited somewhere to the south(-east)

D1 thin-skinned, sub-horizontal, NNW-overthrust of STAVELEY-ROXMERE-KURIDALA-NEW HOPE over DCM-GCG
(Starra Shear)
E-W Folds; highly attenuated/folded MIF-HIF; over FW architecture

D2 EW-shortening Folding
D1 *Starra Shear* folded to sub-vertical; F1 folds steep in *Starra Shear* cf sub-horizontal F2 Folds >> steep ribbons & rootless folds of MIF

D2 EW-shortening Reverse Faulting/re-Activation
Re-activated D1 *Starra Shear*; new F2 Folds

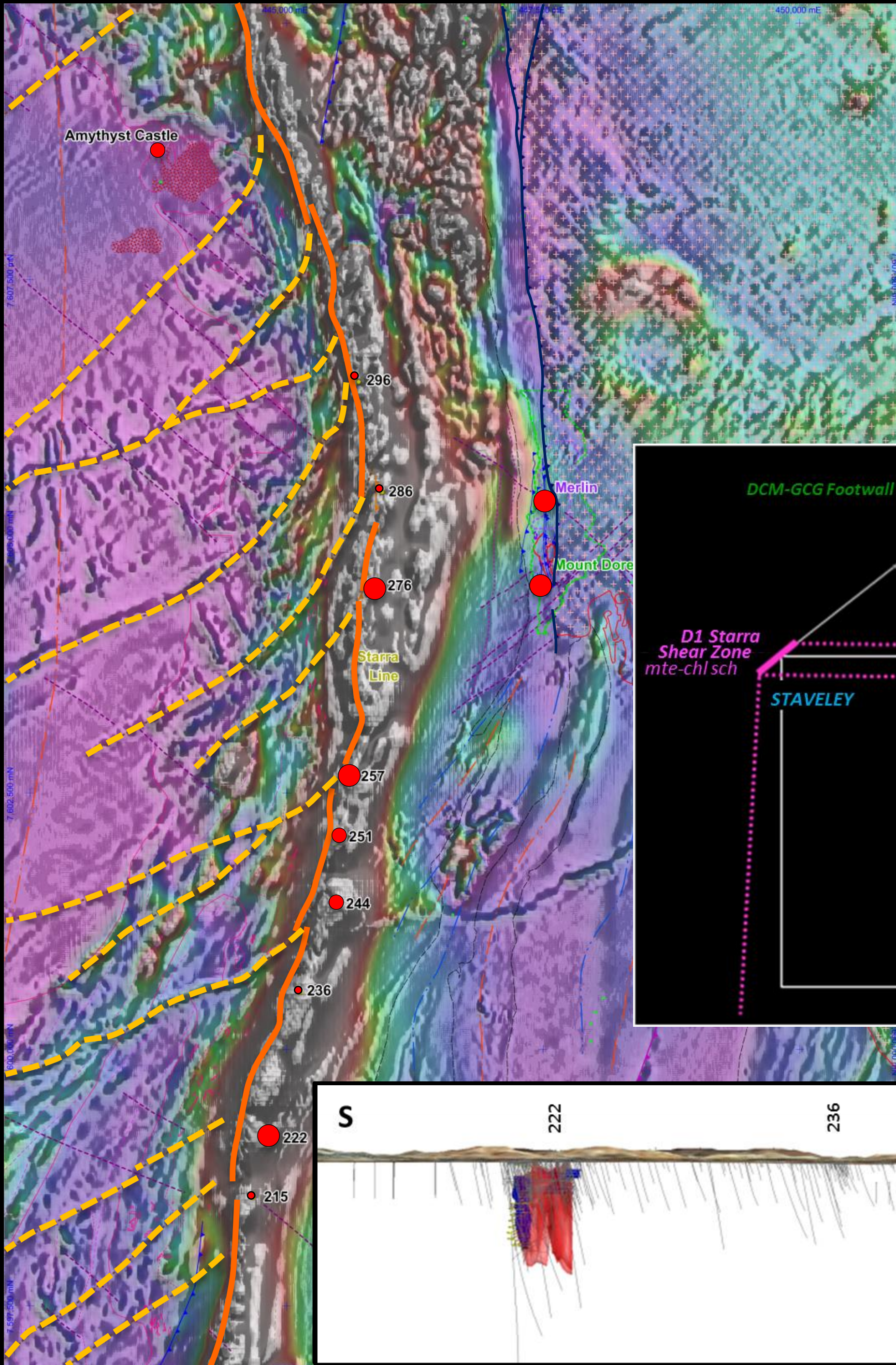
D4 NW-directed, BRITTLE Transpressive Re-activation; WILLIAMS Mount Dore Granite intrusion;
Mineralisation
Along *Starra Line*: FW block architecture contribution to Fr-Bx where remnant MIF coincident with FW Faults
At *Merlin-Mount Dore*: strain intensification; small-scale D4 Faulting

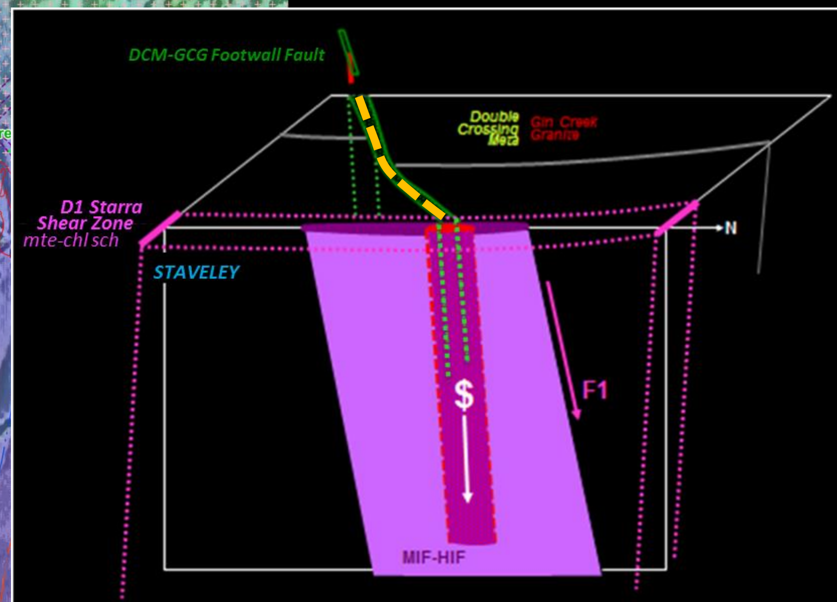
Late D4, post-mineral Faulting
Mount Dore Granite over *Merlin-Mount Dore* *Cu-Au-Mo*

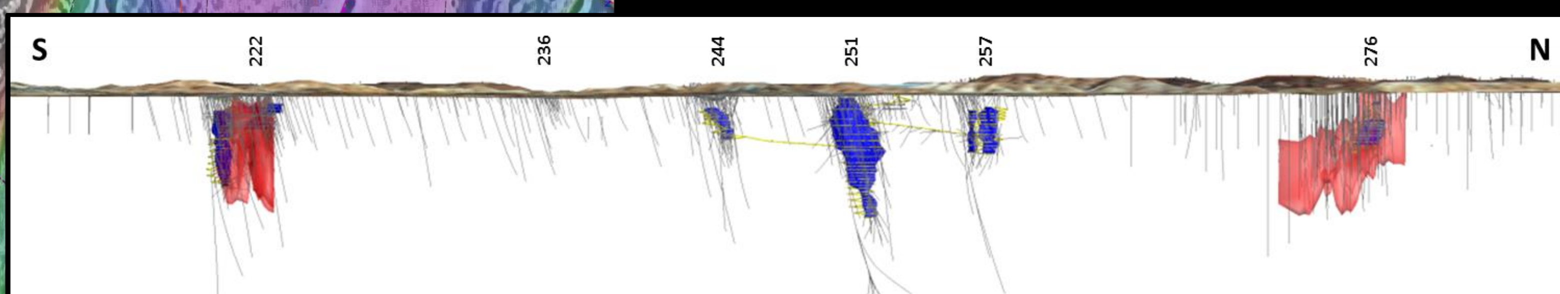
Starra Mineralisation Model

Cu-Au Mineralisation forms during ..
D4 sinistral transpressive re-activation of D1 *Starra Shear*

FOCUS requires the coincidence of …
(1) a D1 remnant BRITTLE ribbon of <u>massive IF</u> with
(2) pre-D1 <u>FW Fault</u> that contributes to the focused BRITTLE deformation … **Permeability > Cu-Au**







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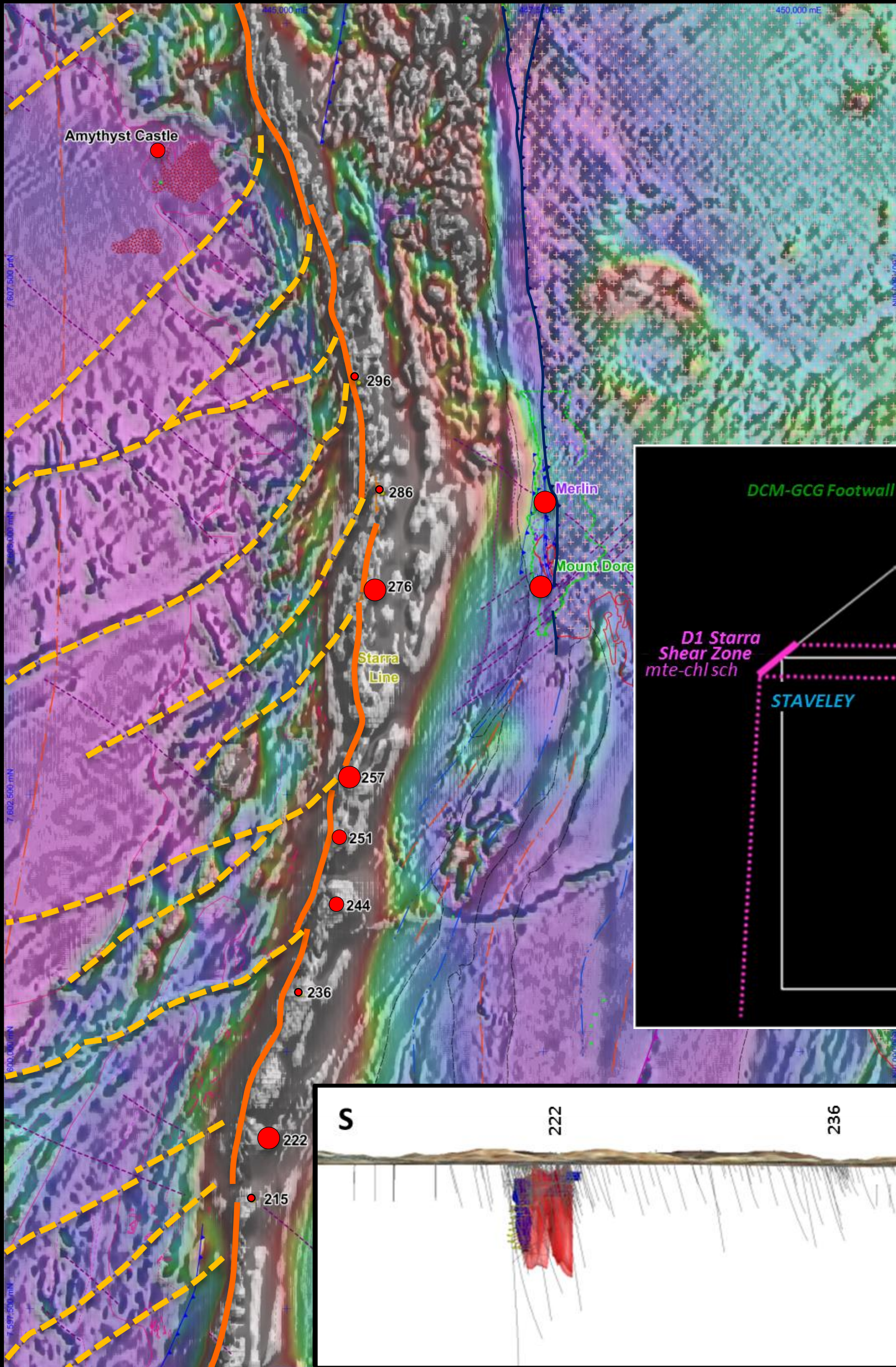

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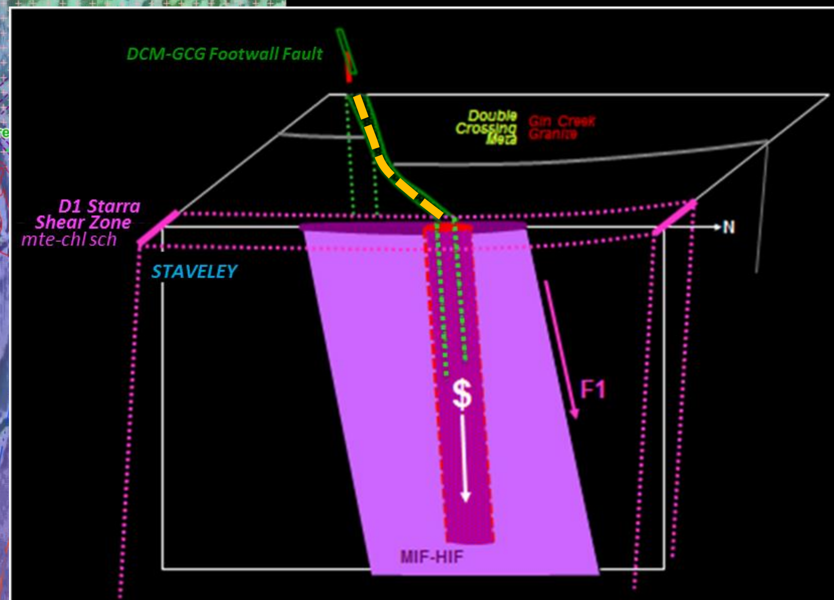
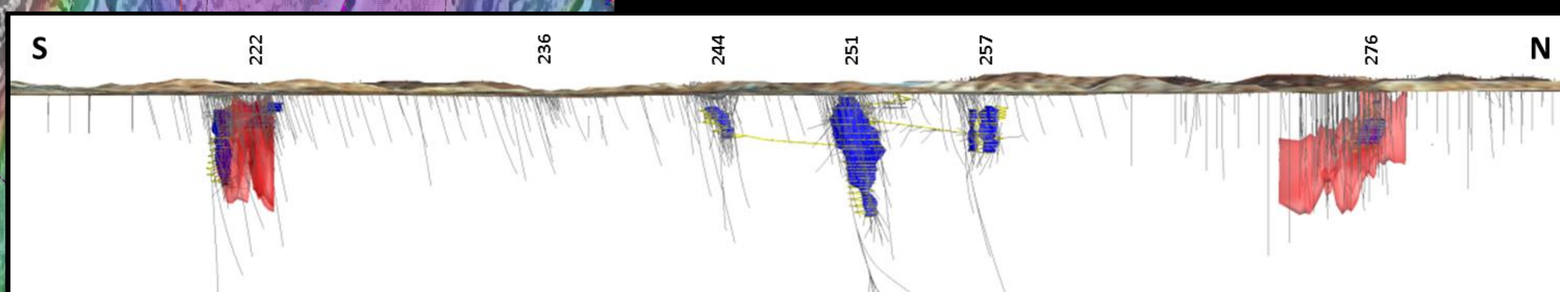


Orebody plunge reflects intersection of the pre-D1 FW Faults with the *Starra Shear*, <u>NOT</u> the plunge of the rotated IF D1 ribbons & folds

Strong magnetic signature >
Large volumes of *chl-magnetite schist* accommodates the D4 re-activation by slip on existing fabrics … NO Permeability



SUMMARY CONCLUSIONS **DMQ Deposit Control Insights**

In D4 time … Need **BRITTLE** lithology in a **D4 structural setting** that compels it to **BRECCIATE**

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MOST COMMONLY NOT Major Structures ….

….. often **insignificant Faults** (not mappable) & **insignificant re-Activations** of older structures

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But **NEED BRITTLE** Host that **survives** into **POST-PEAK META** times …
… BRECCIATES > **PERMEABILITY >** **Mineralisation**

Vast volumes mod-high grade schists (-gneisses) in **POST-PEAK META** times …
accommodate D4 shortening by slip on existing peak-metamorphic fabrics
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Structural abutting of BRITTLE lithology against D4 re-activating D2-structures … **KULTHOR**
BRITTLE lithologies against small-displacement D4 Faults …. **MERLIN-Mt DORE**
BRITTLE D1-remnants of IF coincident high angle FW weakness …. **STARRA**
BRITTLE lithologies within D4 strain partitioning domains … **Mt ELLIOTT-SWAN, EH**

Different Geodynamic Games in Different Camps
NO D4 Structural Silver Bullets

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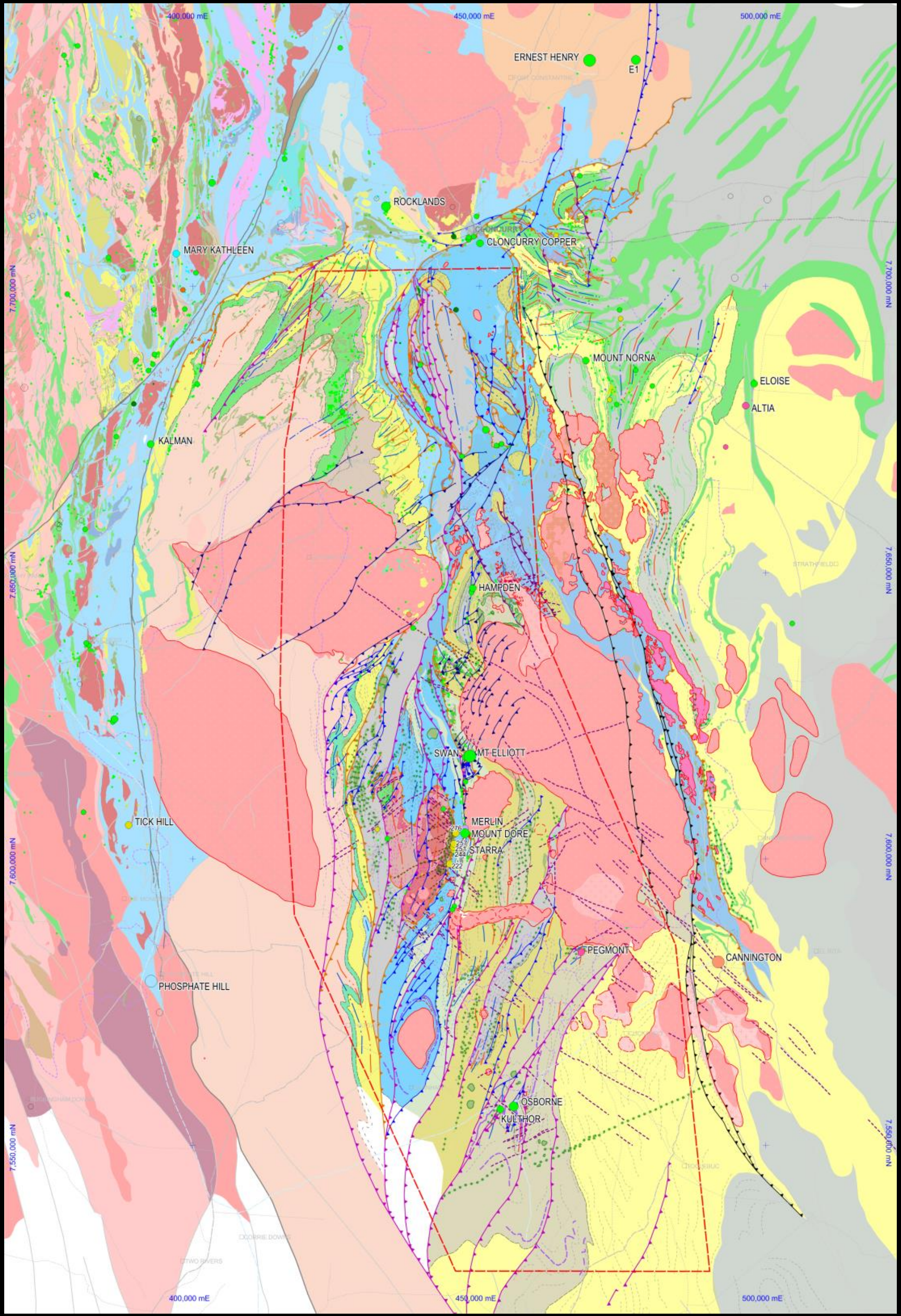
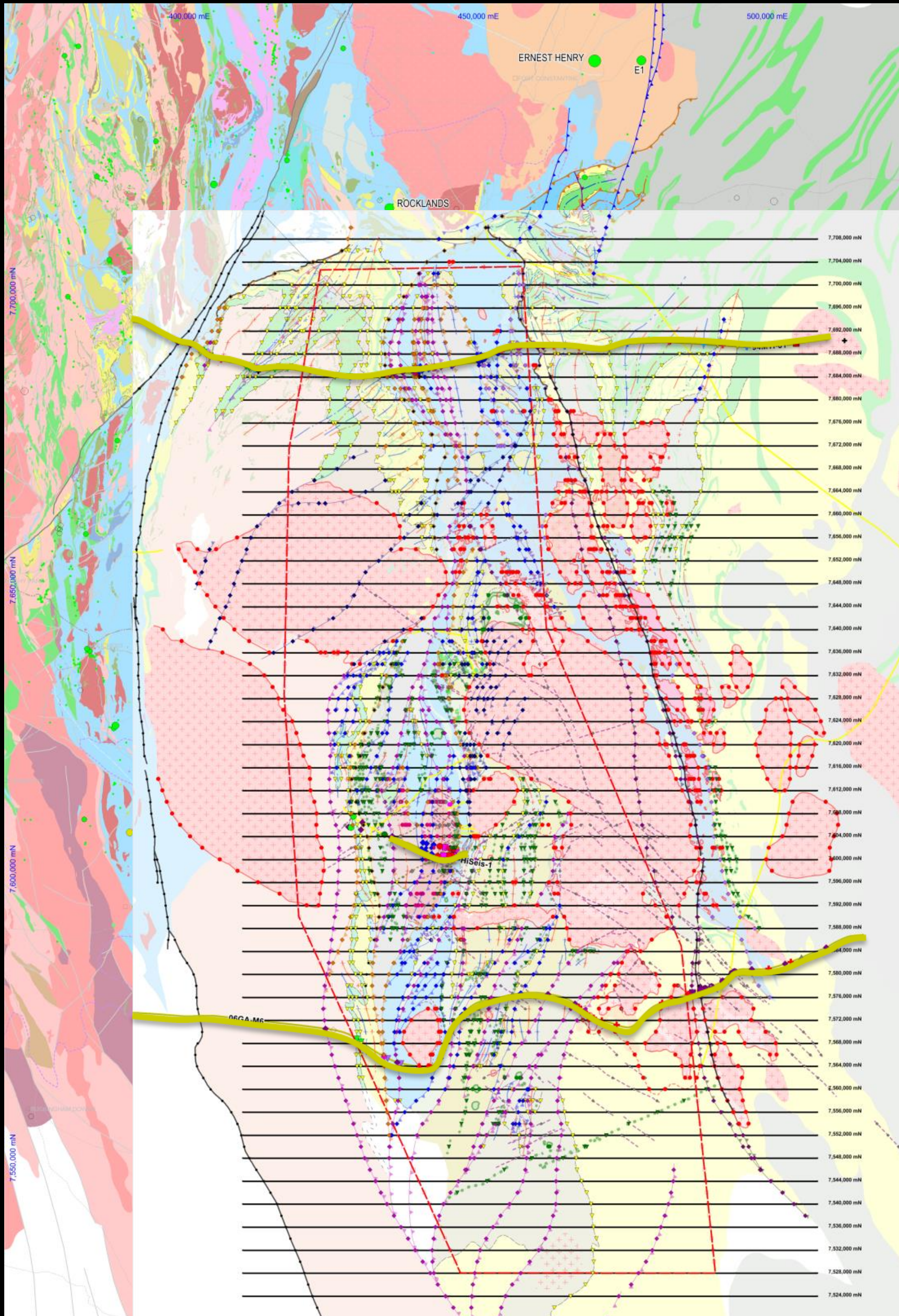
Different Geodynamic Games in Different Camps
NO D4 Structural Silver Bullets
ALL in proximity to juxtapositoning of **Redox-contrasting** packages!
But **ALL** synchronous with **WILLIAMS** intrusion!



DMQ 3D Geological Model

Particular Focus on …

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



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DMQ produced …

<u>Forty-seven, 4km-spaced SECTIONS</u>

… heavily leveraged Solid Geology
… and 3 Seismic Lines

… acknowledge

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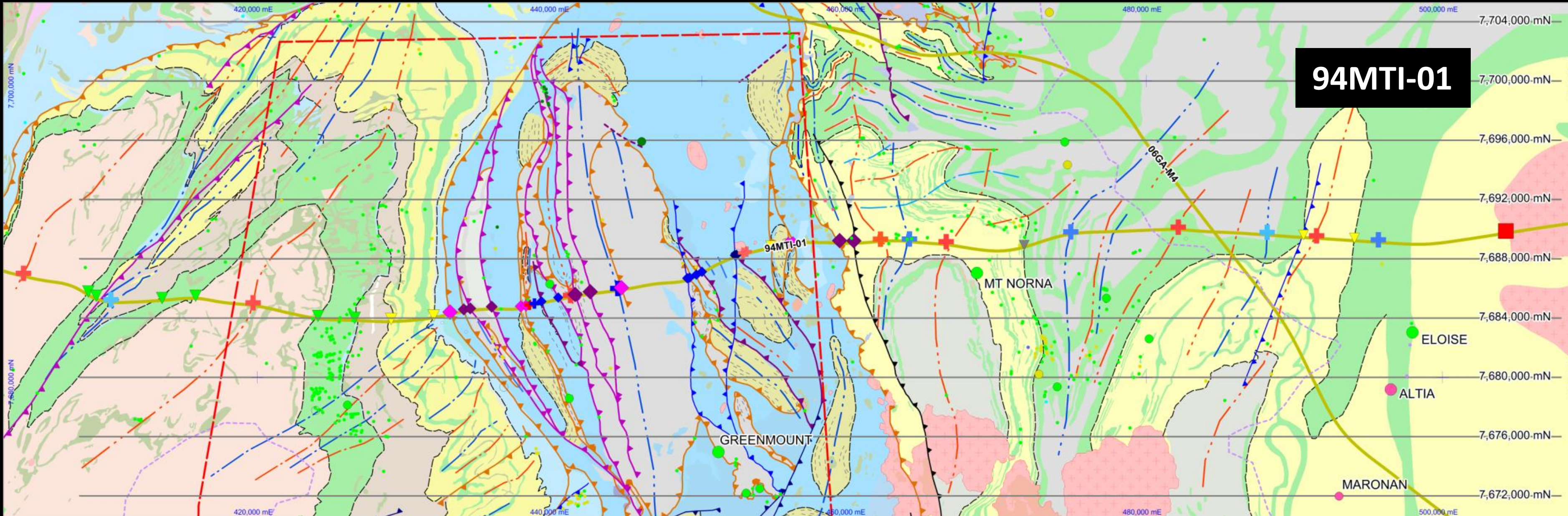
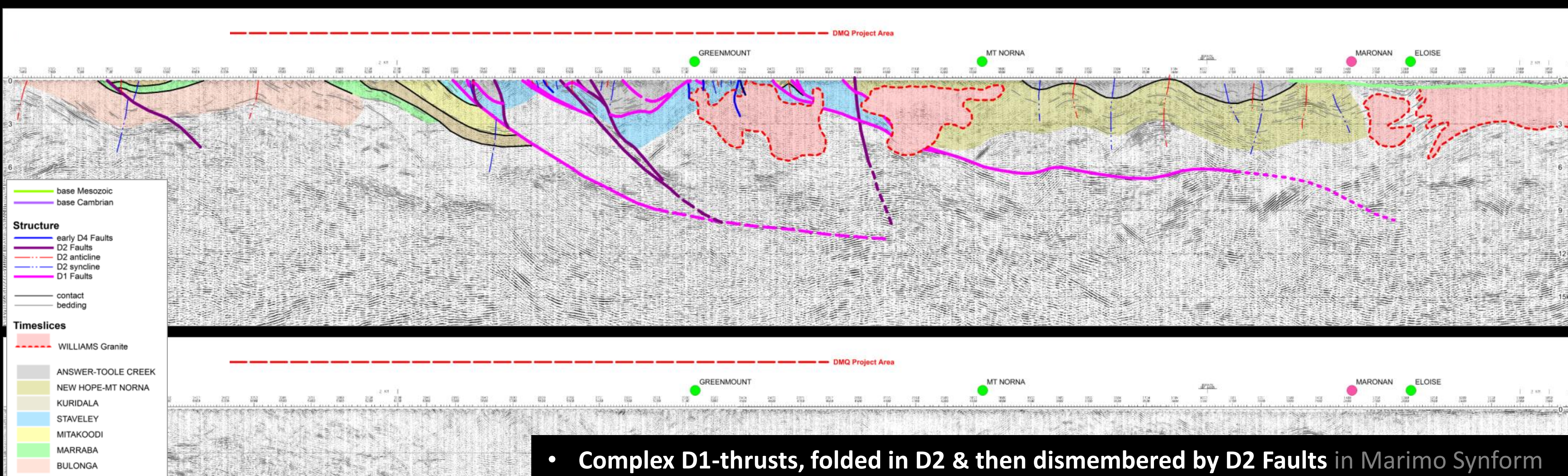
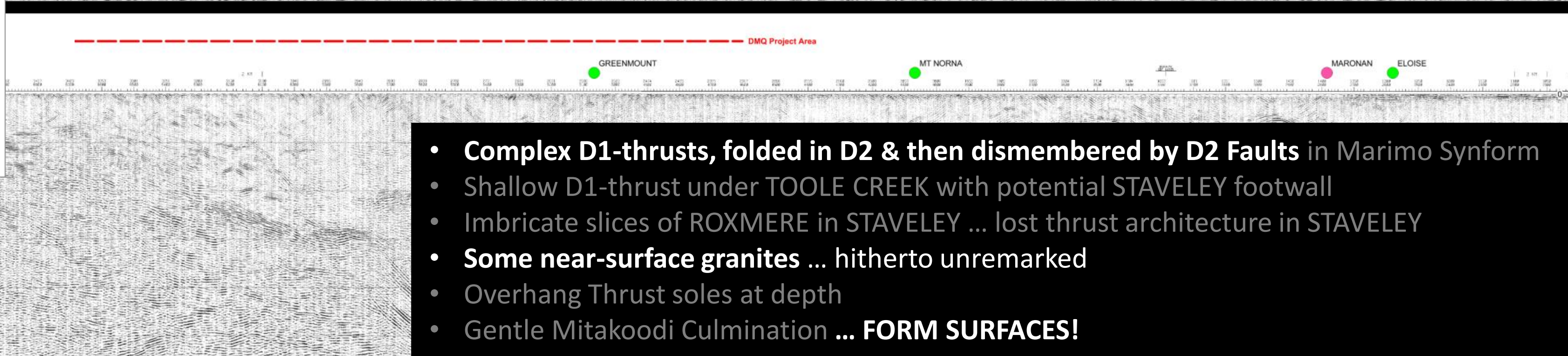


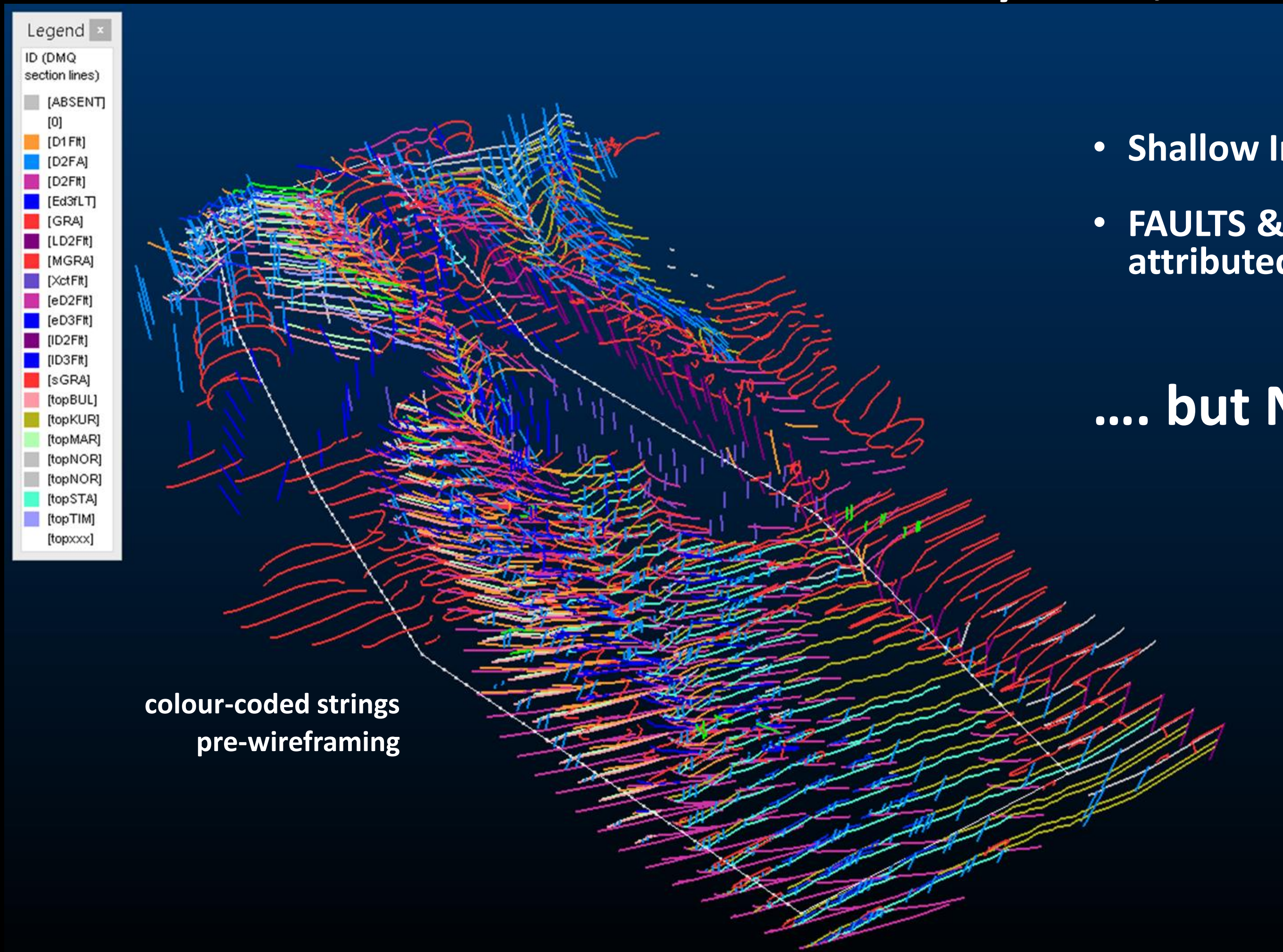




- **Complex D1-thrusts, folded in D2 & then dismembered by D2 Faults** in Marimo Synform
- Shallow D1-thrust under TOOLE CREEK with potential STAVELEY footwall
- Imbricate slices of ROXMERE in STAVELEY … lost thrust architecture in STAVELEY
- **Some near-surface granites** … hitherto unremarked
- Overhang Thrust soles at depth
- Gentle Mitakoodi Culmination **… FORM SURFACES!**

DMQ 3D Geological Model

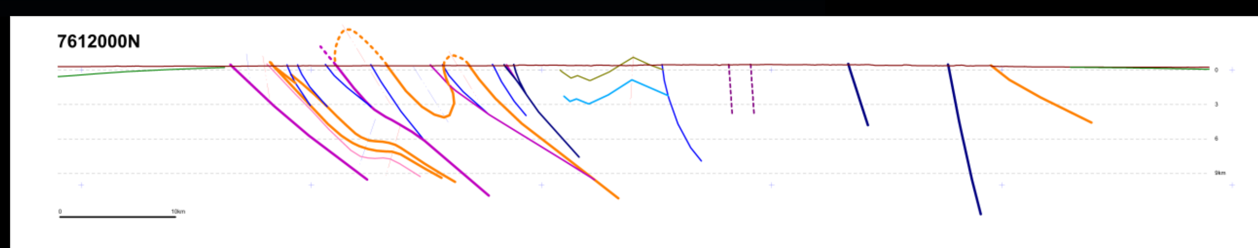
built on **forty-seven, 4km-spaced Sections**



colour-coded strings pre-wireframing

- **Shallow Interpretation to ~9km**
- **FAULTS & TIMESLICE surfaces fully attributed**

…. but NO granites!

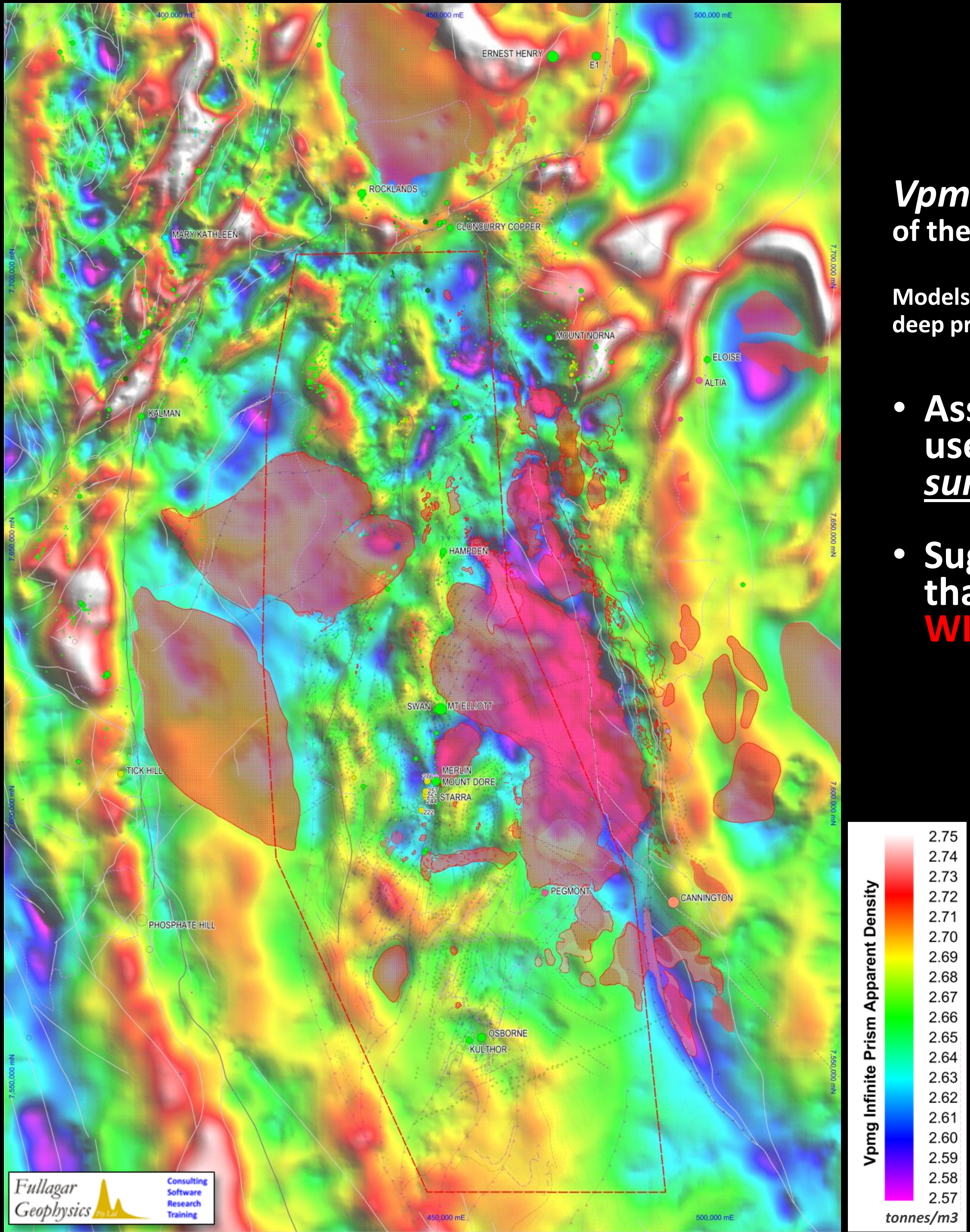


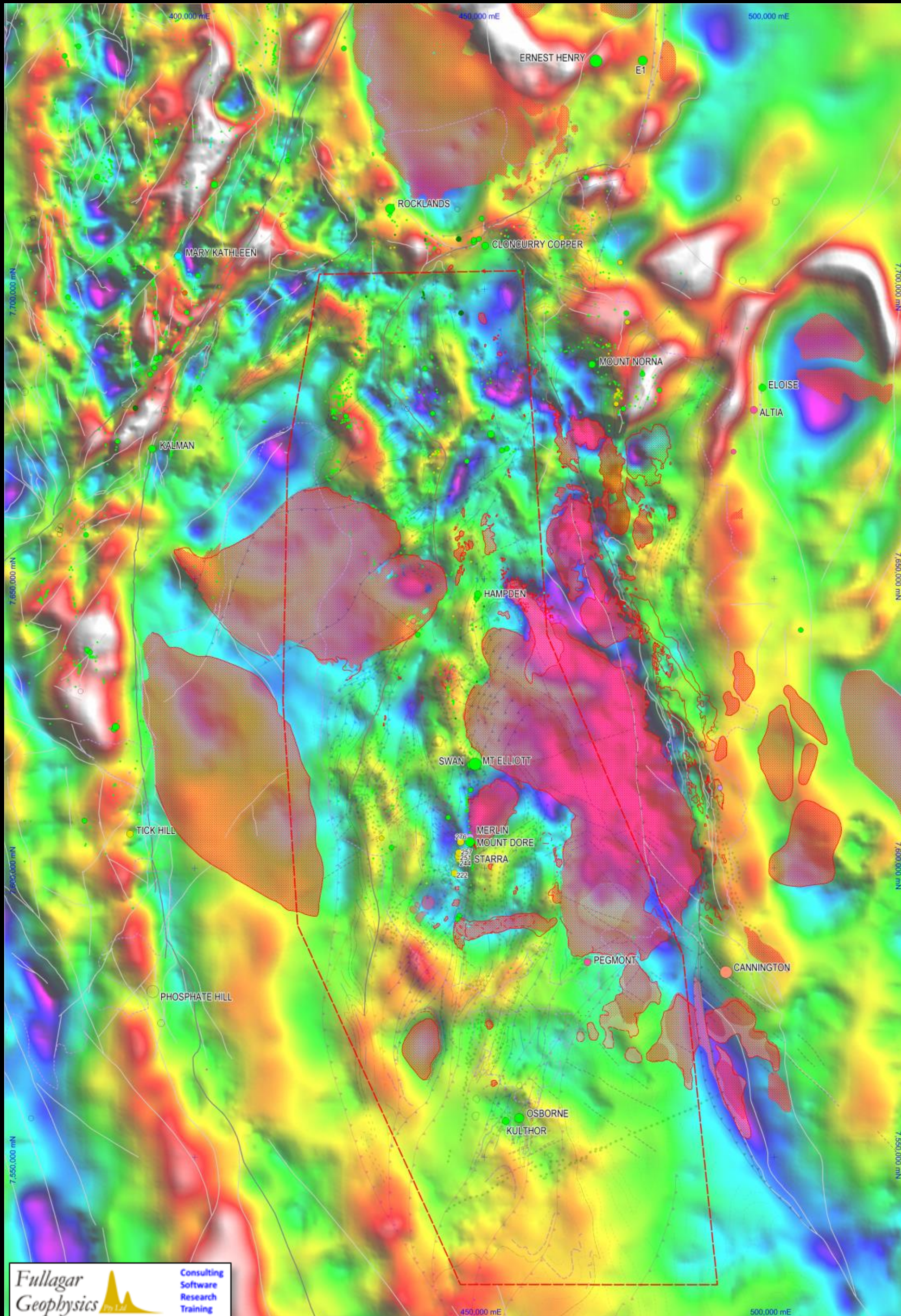
What about the Granites?

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 ...

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





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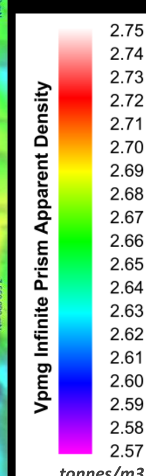
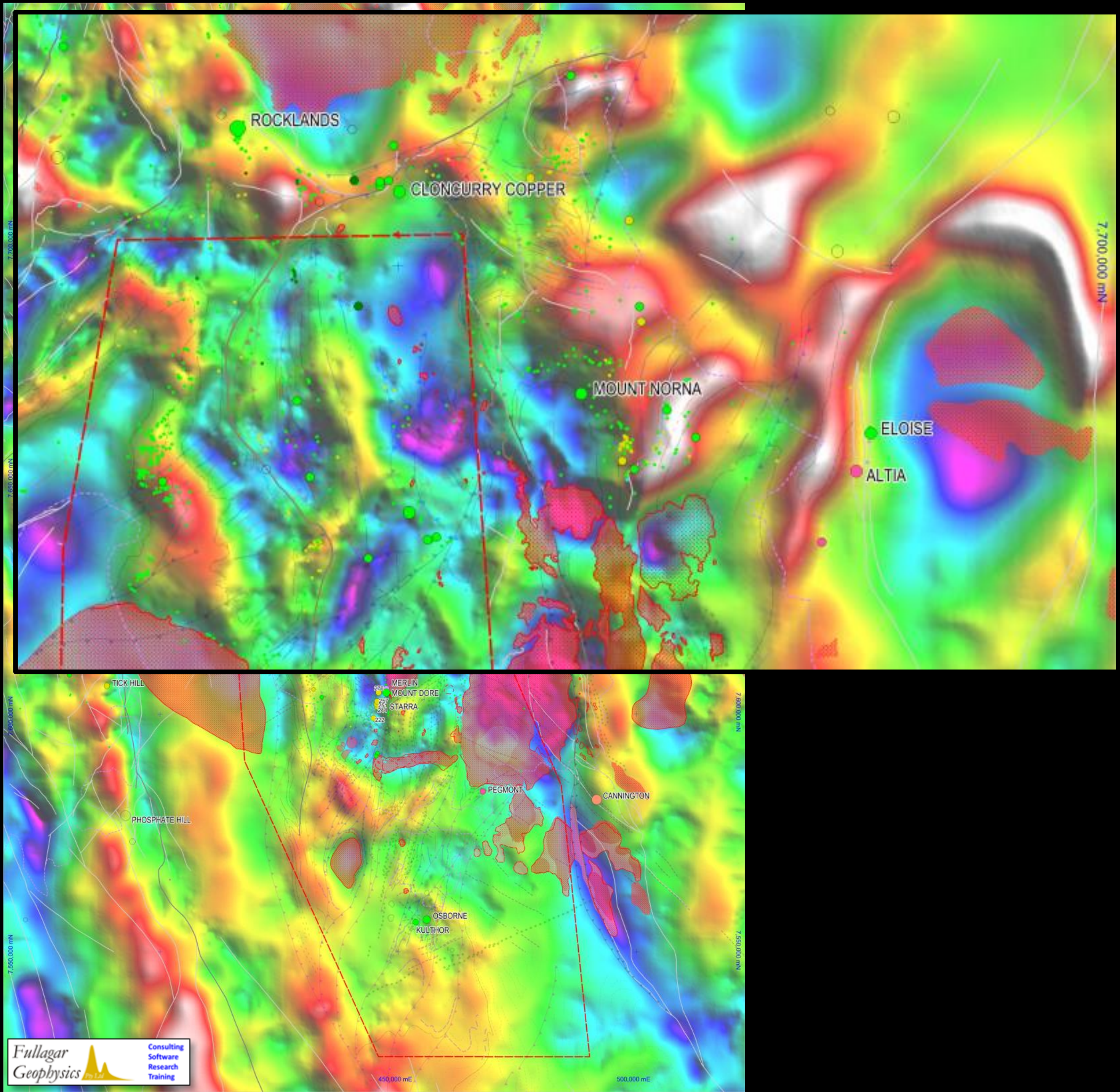
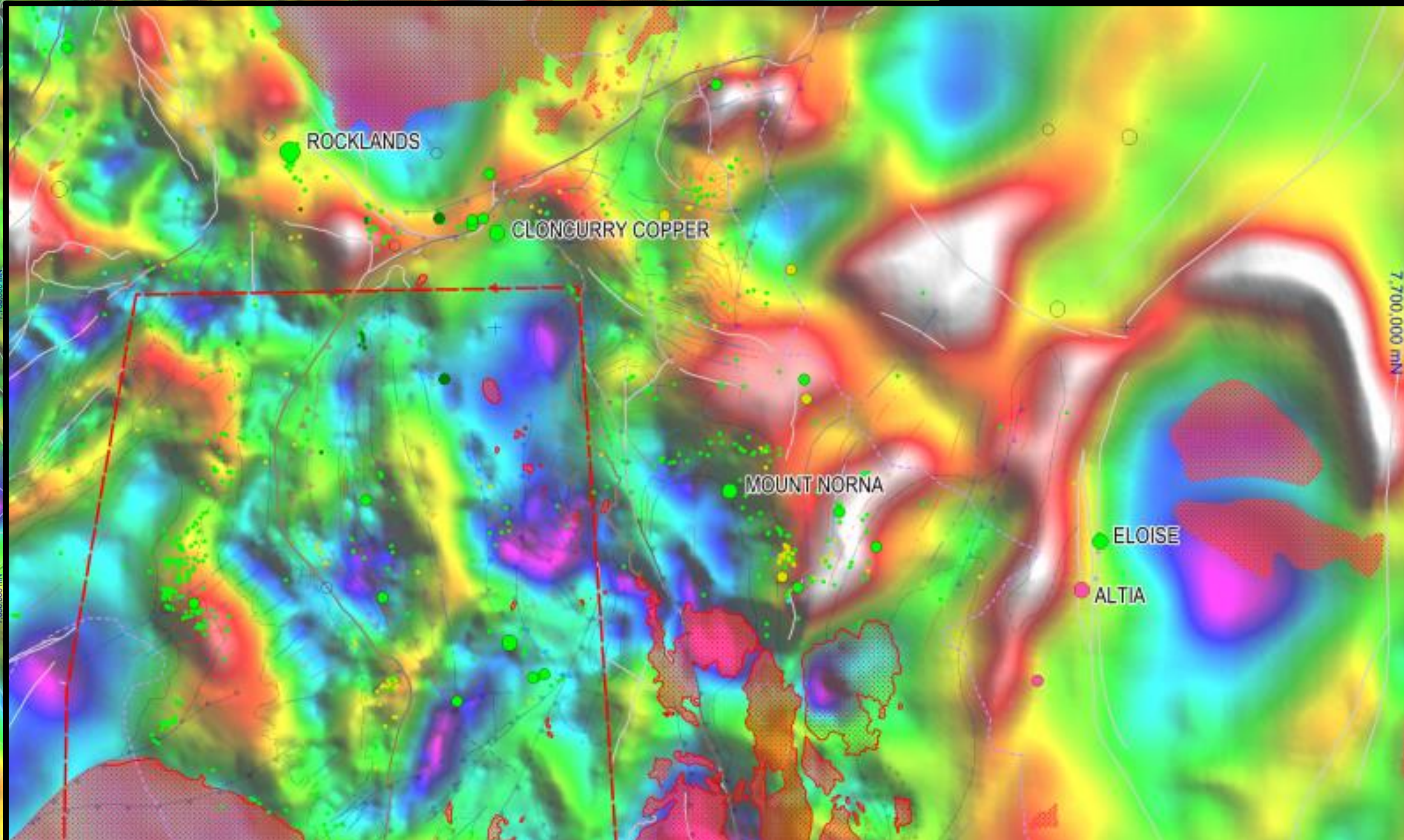


This image drove DMQ into geologically-constrained Gravity Inversion Modelling!

… but more importantly!



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



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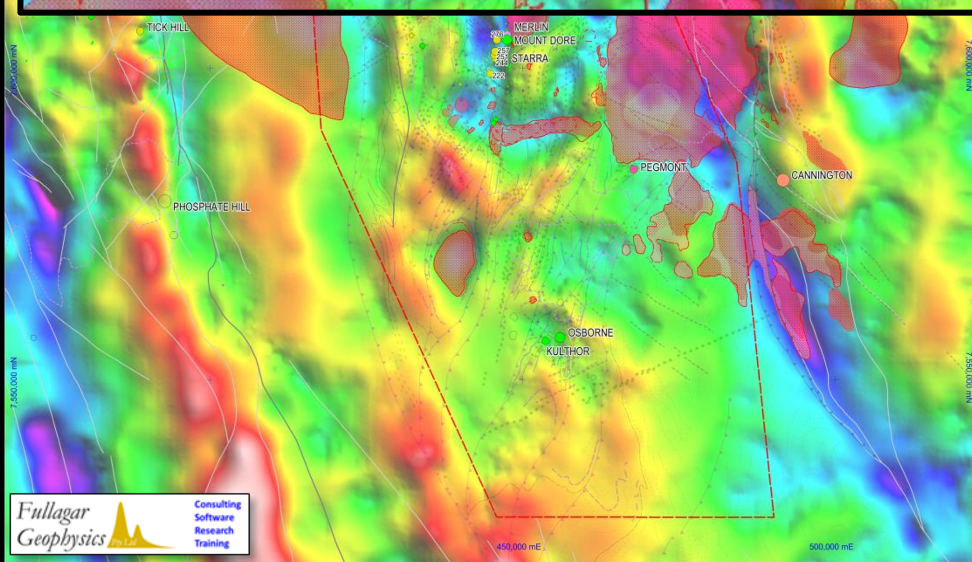
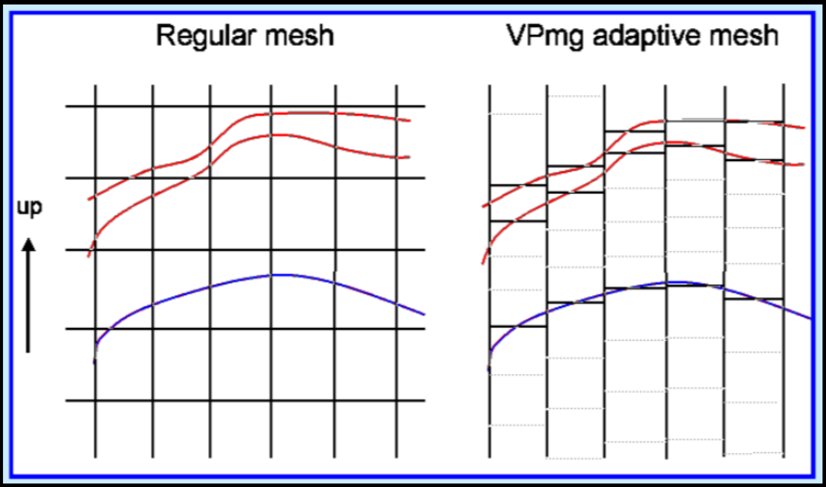


Highlights a LACK of deposits & occurrences in the roof zones of those intrusives …

.. which suggests that fertile Cu-Au mineralising fluids FLOW UP the margins and <u>NOT</u> out of the roofs of the intrusives …

… implies that fluid circulation, <u>NOT</u> simple magmatic exhalation, is IMPORTANT

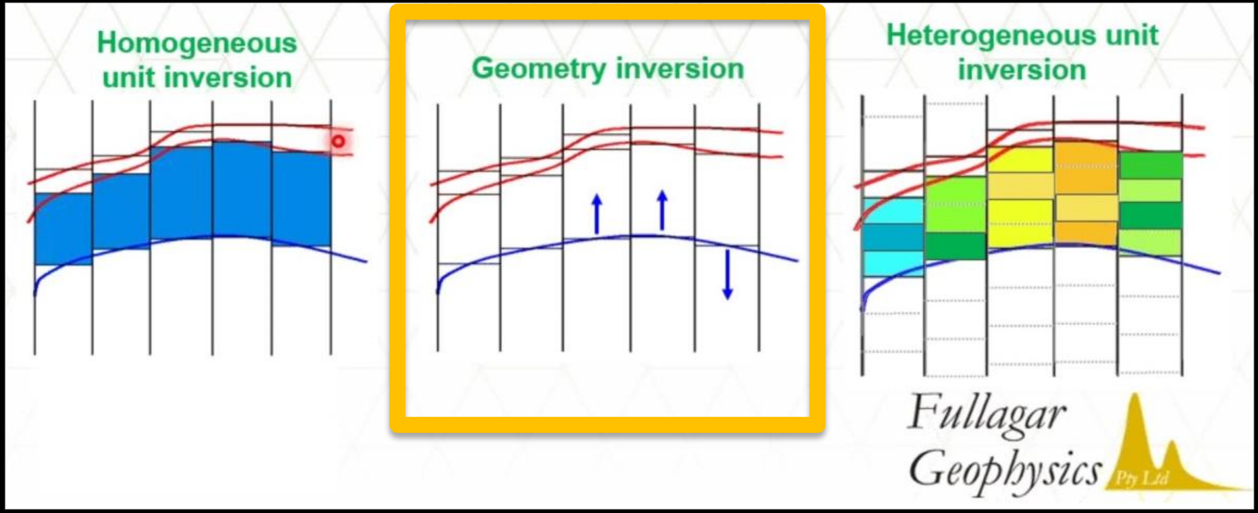
Geologically-constrained *Vpmg* Gravity Inversion



Fullagar Geophysics Pty Ltd
Consulting
Software
Research
Training

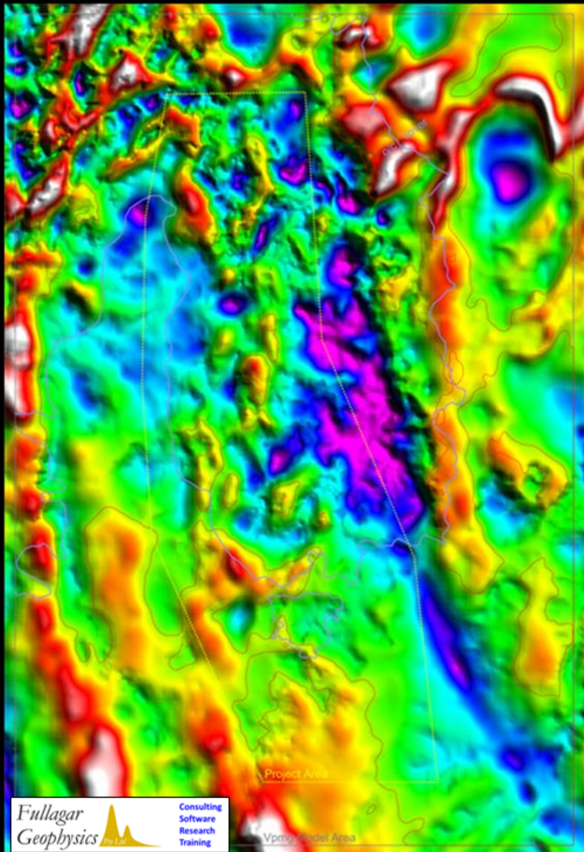
Fullagar Geophysics *VPmg* advantages …
- **Adaptive mesh better fits known geometries**
- **3 modes of inversion available**
- **DMQ made use of all of them …**

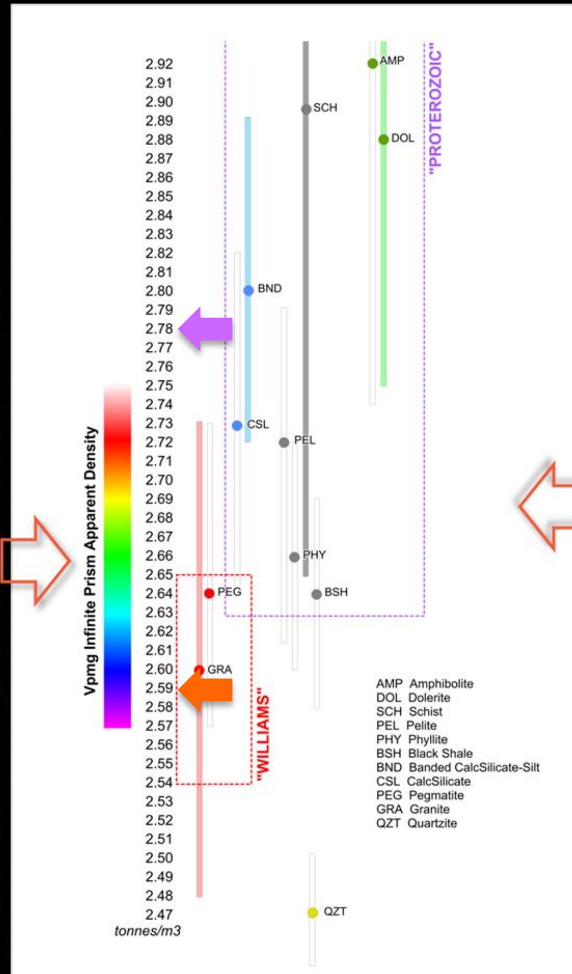
… but heavy use of GEOMETRY INVERSION

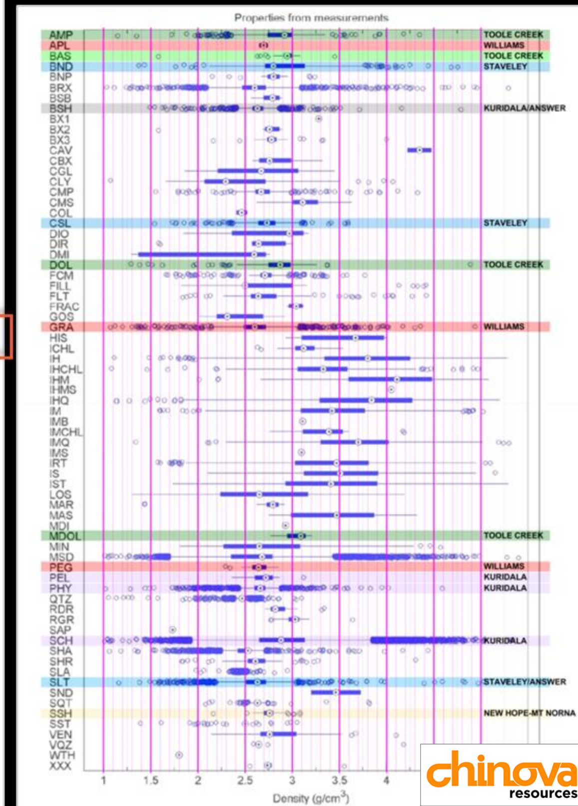


Density Constraints

Vpmg Apparent Density Model





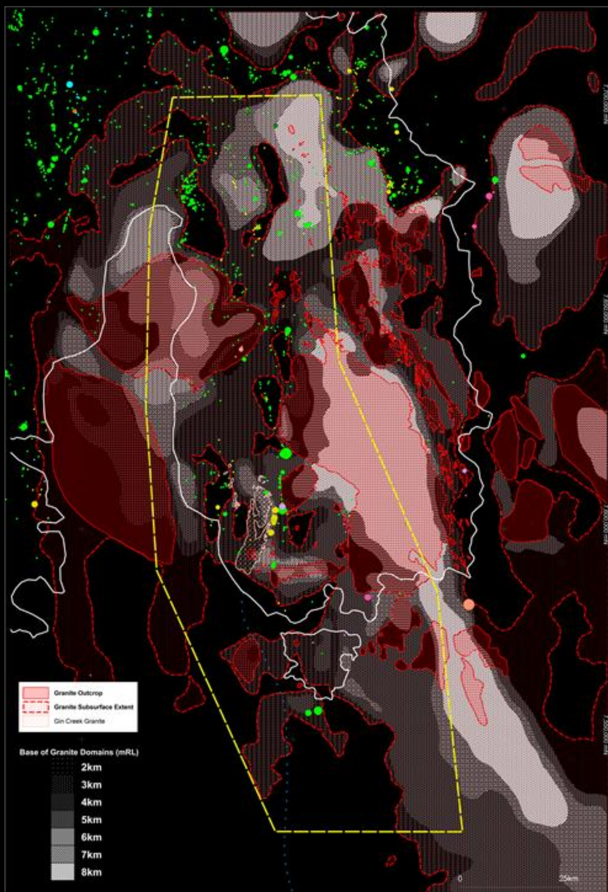


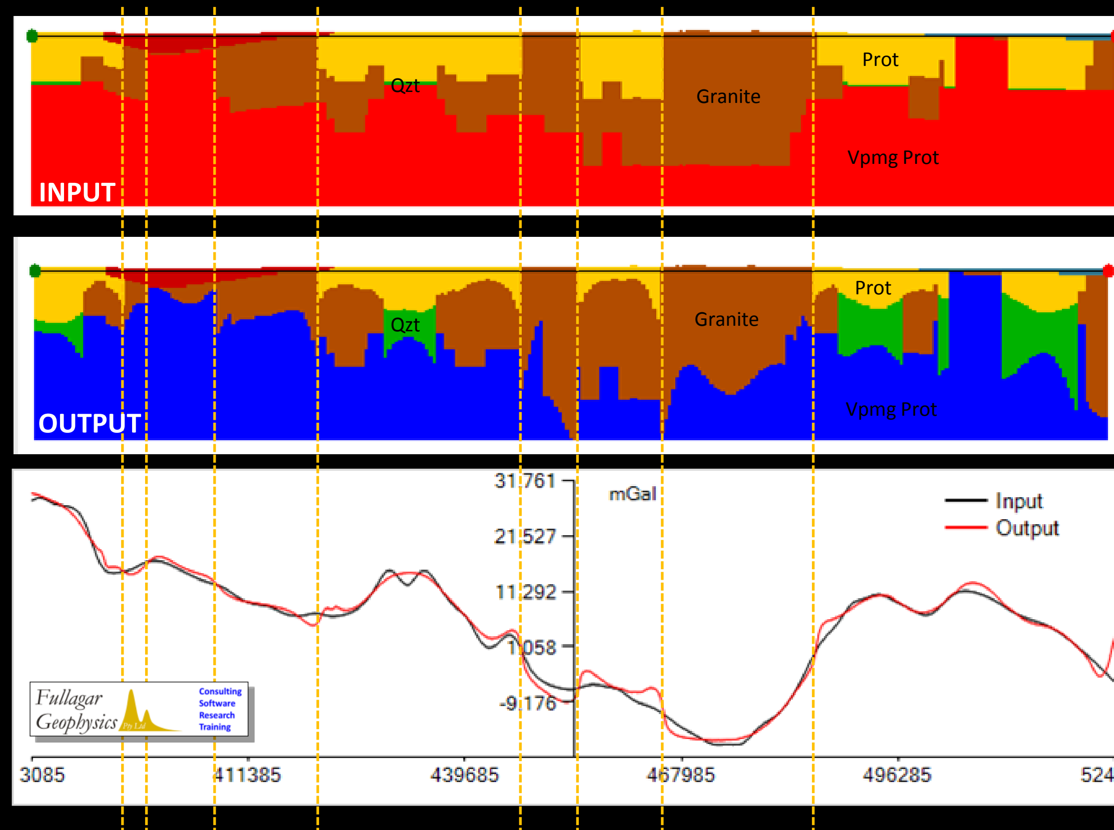
Chinova DDH density data

	LOW		MEDIUM		HIGH	
b/g	2.67	contrast	2.67	contrast	2.67	contrast
'Cover'	2.45	-0.22	2.45	-0.22	2.45	-0.22
'Cover LST'					2.54	-0.13
'Granite'	2.61	-0.06	2.61	-0.06	2.59	-0.08
'Proterozoic'	2.73	+0.06	2.79	+0.12	2.78	+0.11

Geologically-constrained *Vpmg* Gravity Inversion
Domained RL, Base-of-Granite Models

Honoured Granite outcrop
Domained RL Base-of-Granite START depths
Granite free to 'grow' top and/or bottom





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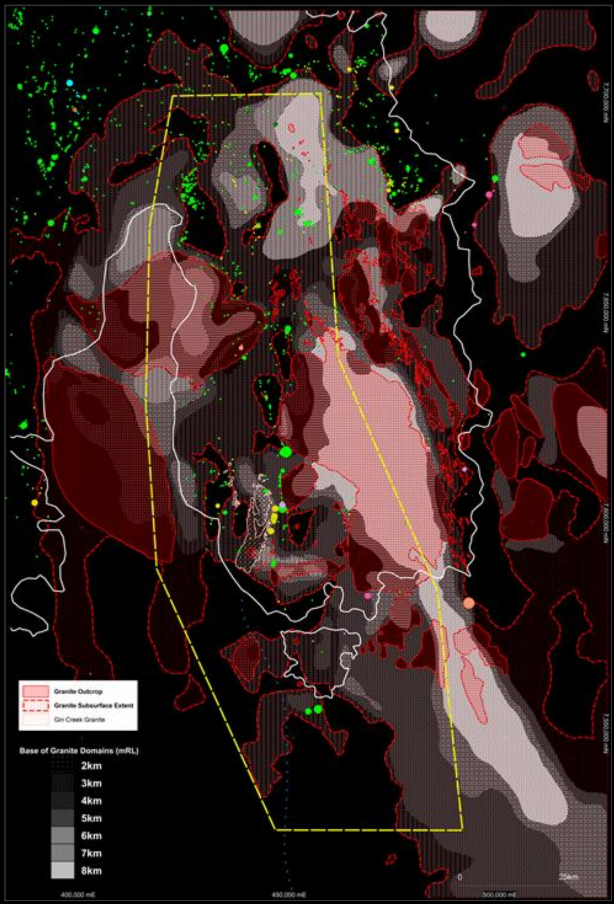
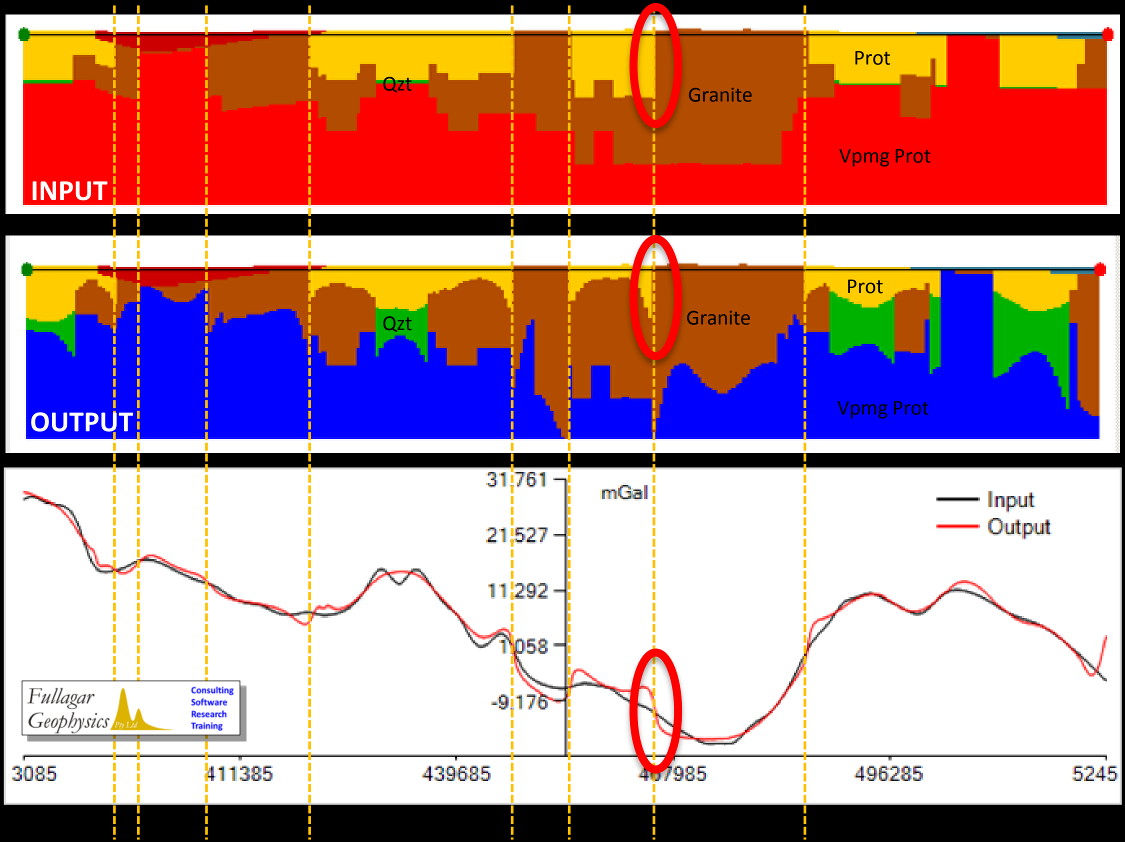




FAILED!

Unable to produce geologically-reasonable & smooth transitions from outcrop into the subsurface; nasty dipoles on contacts

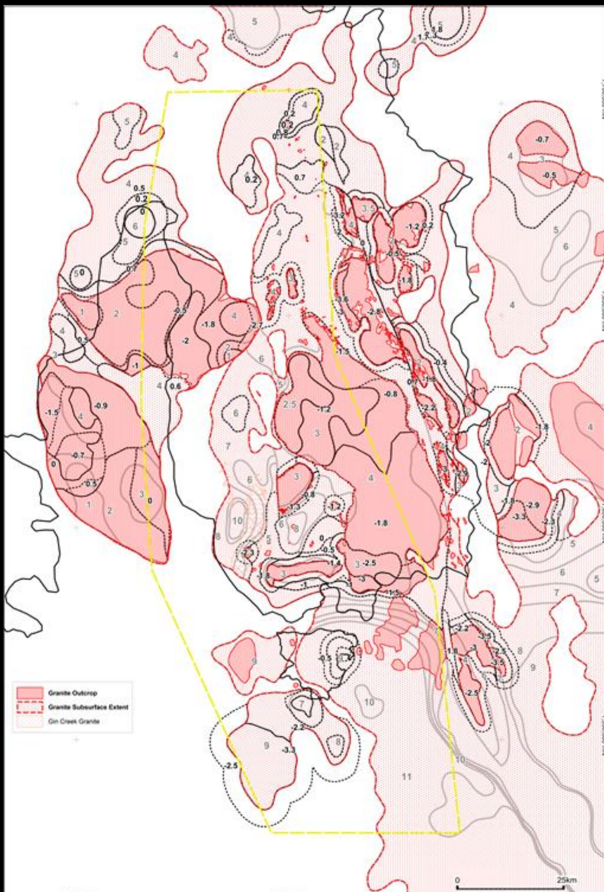
Geologically-constrained *Vpmg* Gravity Inversion

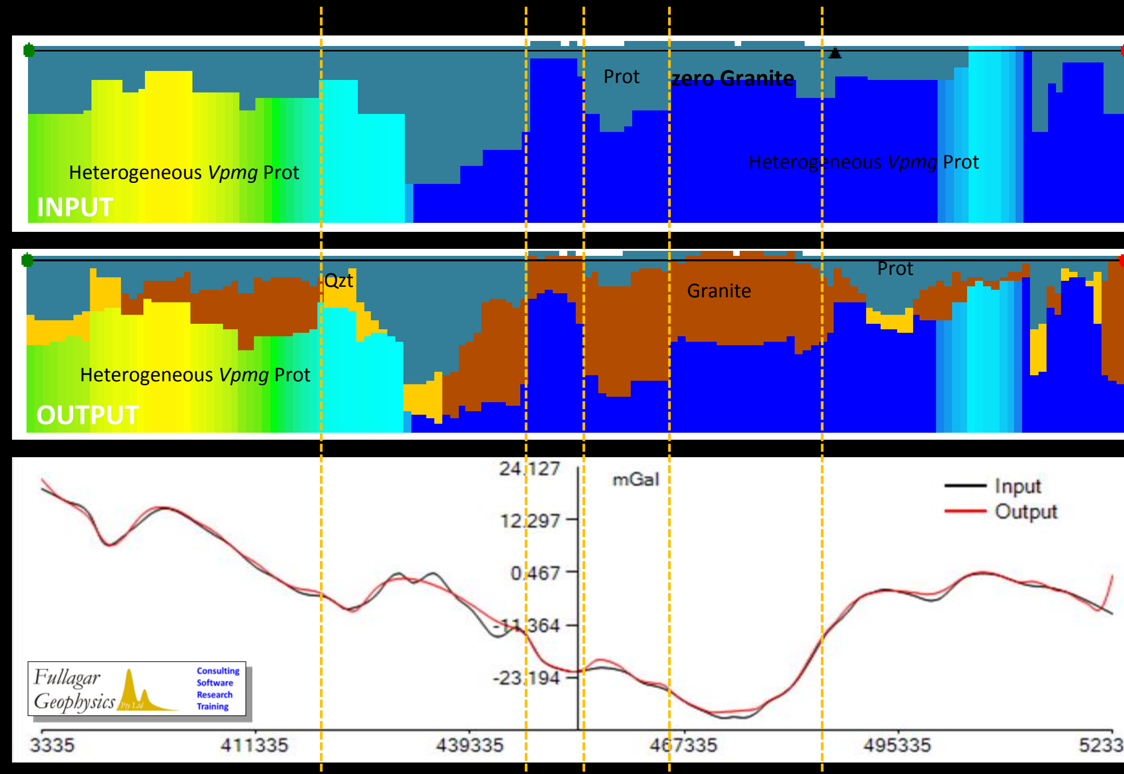
Domained RL, mid-Granite 'PERT' Models

Domained zero-thickness Granite START

… NO Granite outcrop!

High Density *Vpmg* basement fixes 'PERT' *Vpmg* function to drive 'growth' equally up & down from START depth





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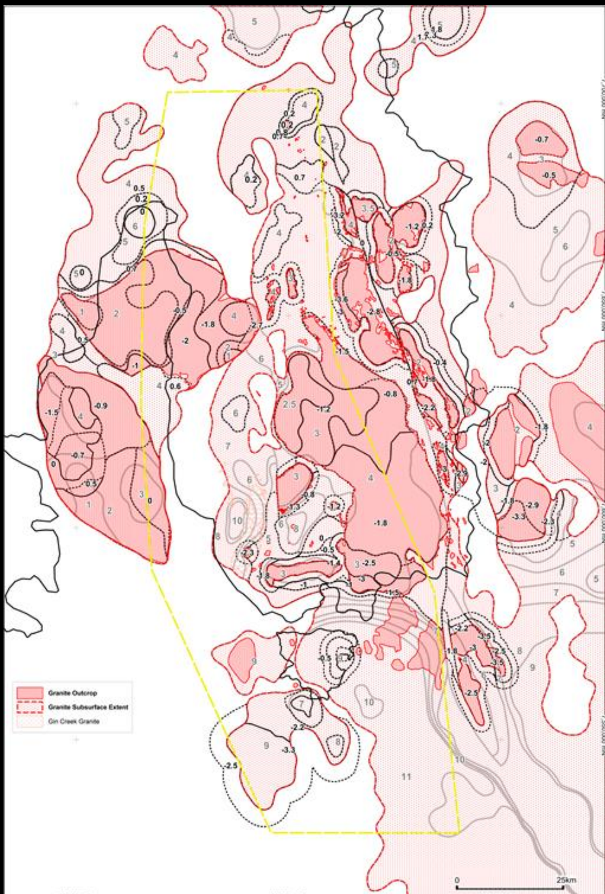
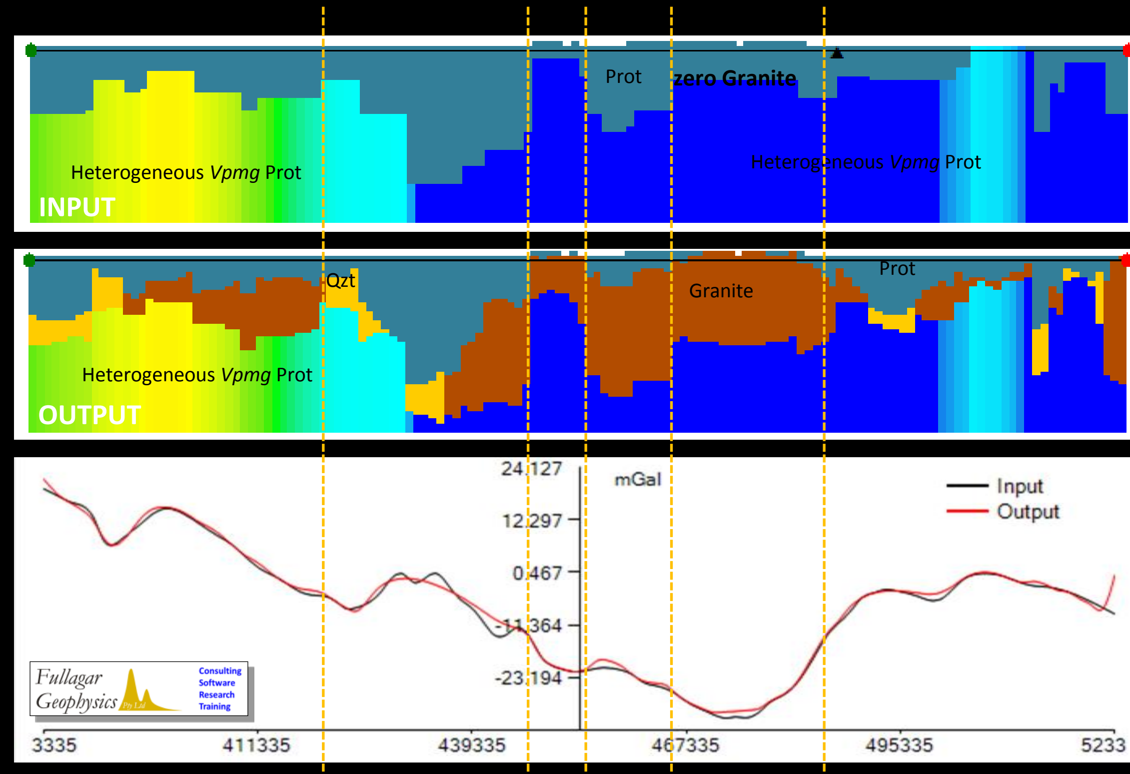
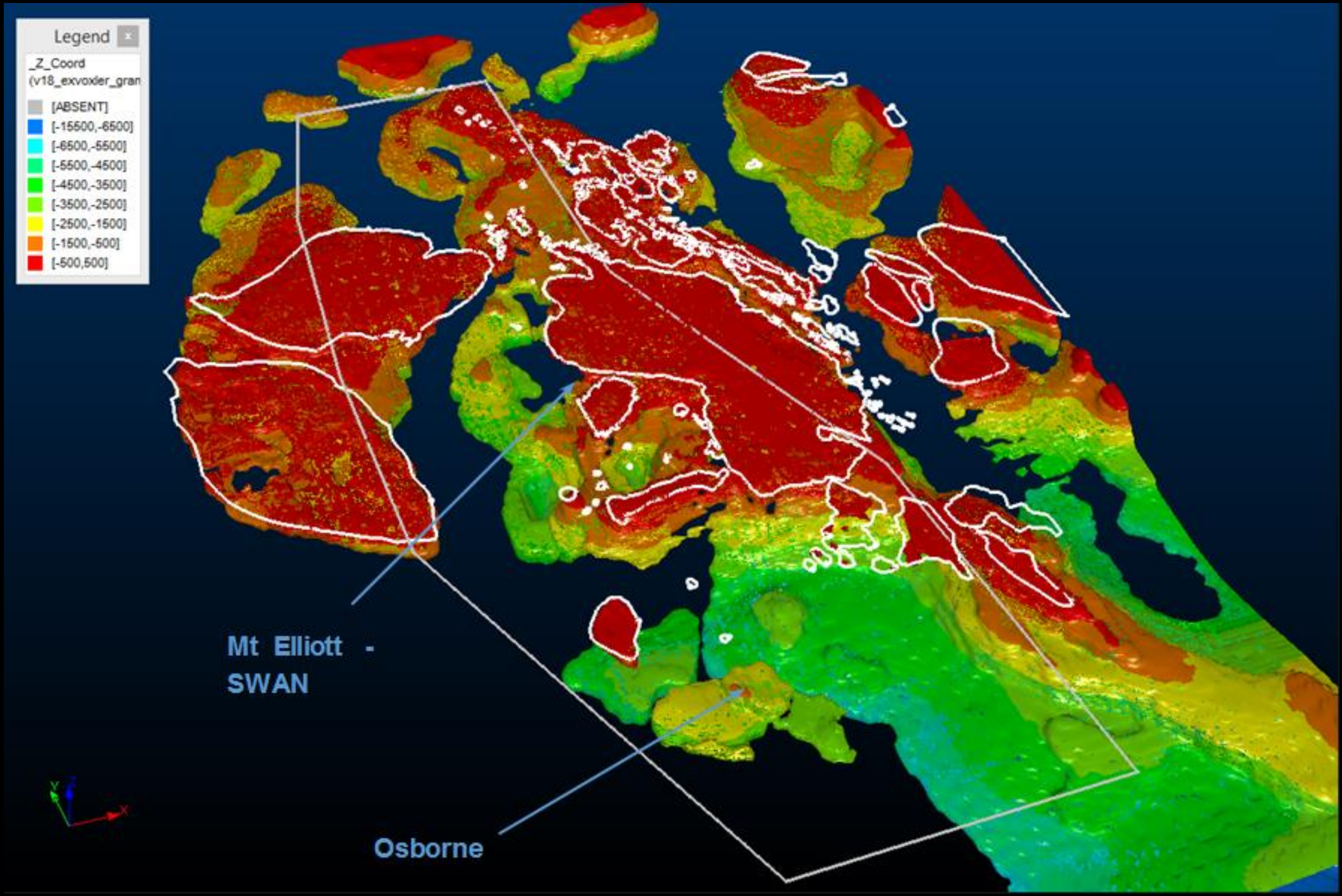




Ultimately SUCCESSFUL!

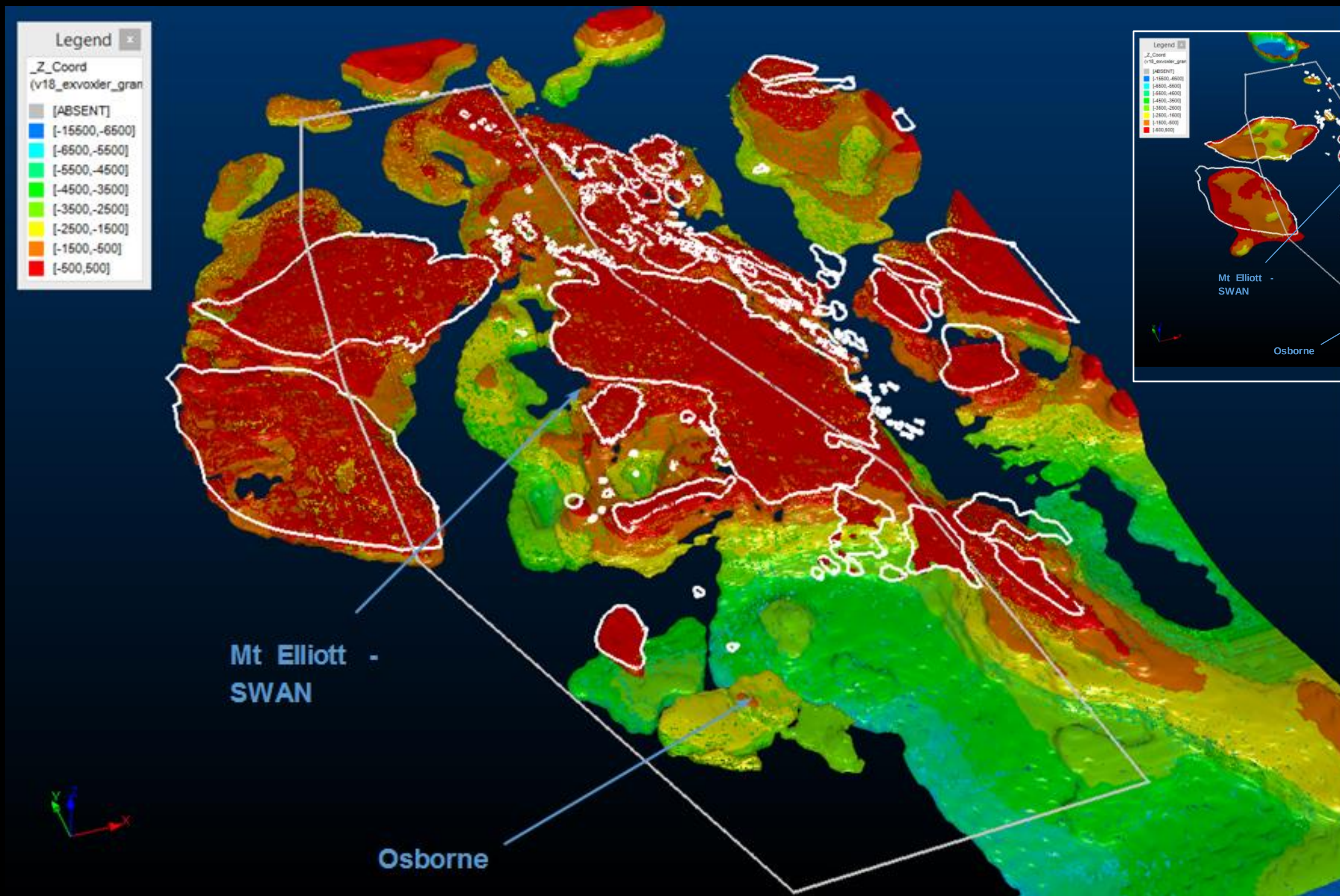
Produce geologically-reasonable granite morphologies; built outcrop where required; matched sub-surface geological constraints & produced smooth transitions from outcrop

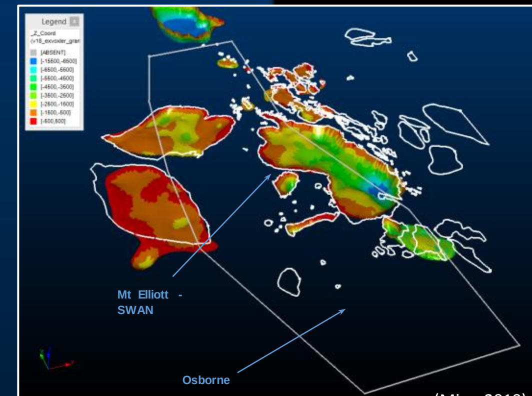
Geologically-Constrained *Vpmg* Gravity Inversion
Domained RL mid-Granite 'PERT' Models



Version 18 DMQ Granite Model
… into 4D geological model & DMQ Prospectivity Analysis

Geologically-Constrained *Vpmg* Gravity Inversion
Domained RL mid-Granite 'PERT' Models



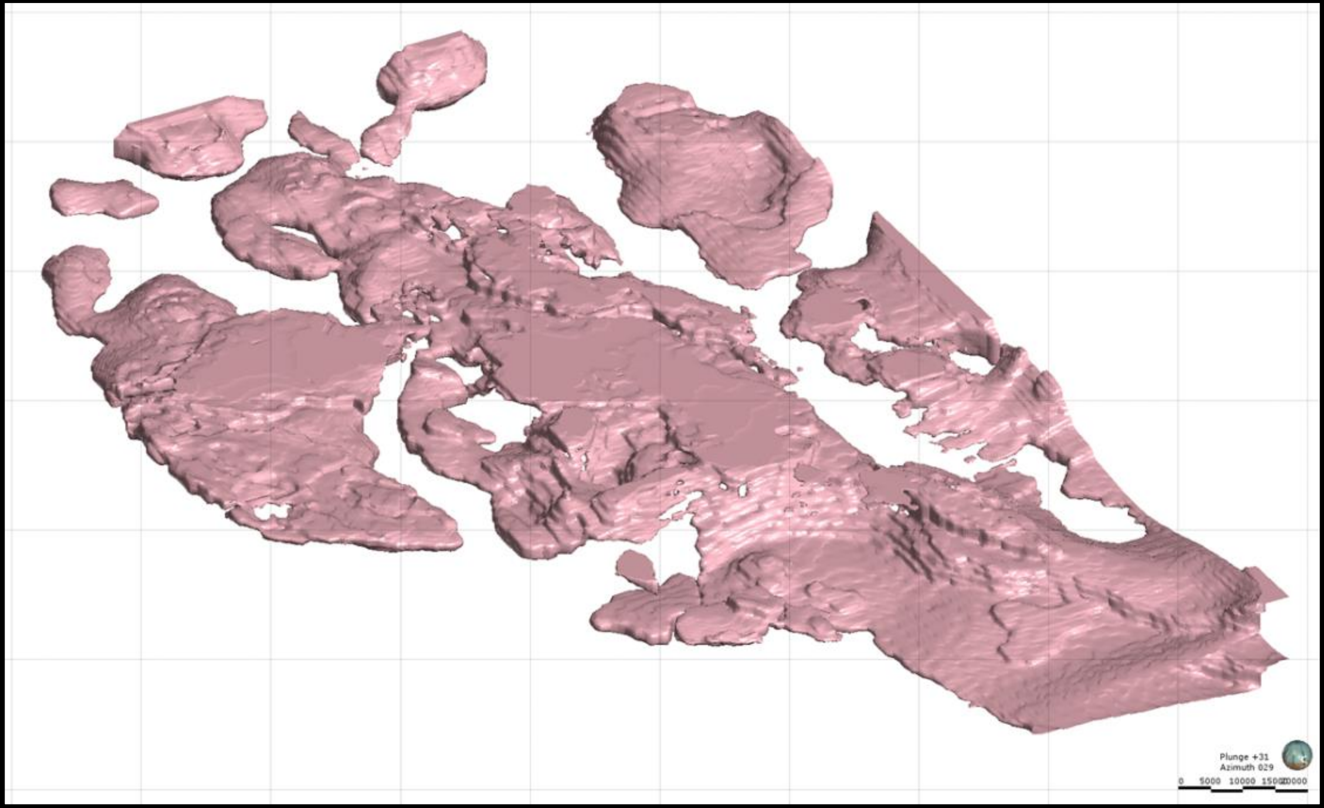


(Mira, 2010)

Version 18 DMQ Granite Model
... into 4D geological model & DMQ Prospectivity Analysis

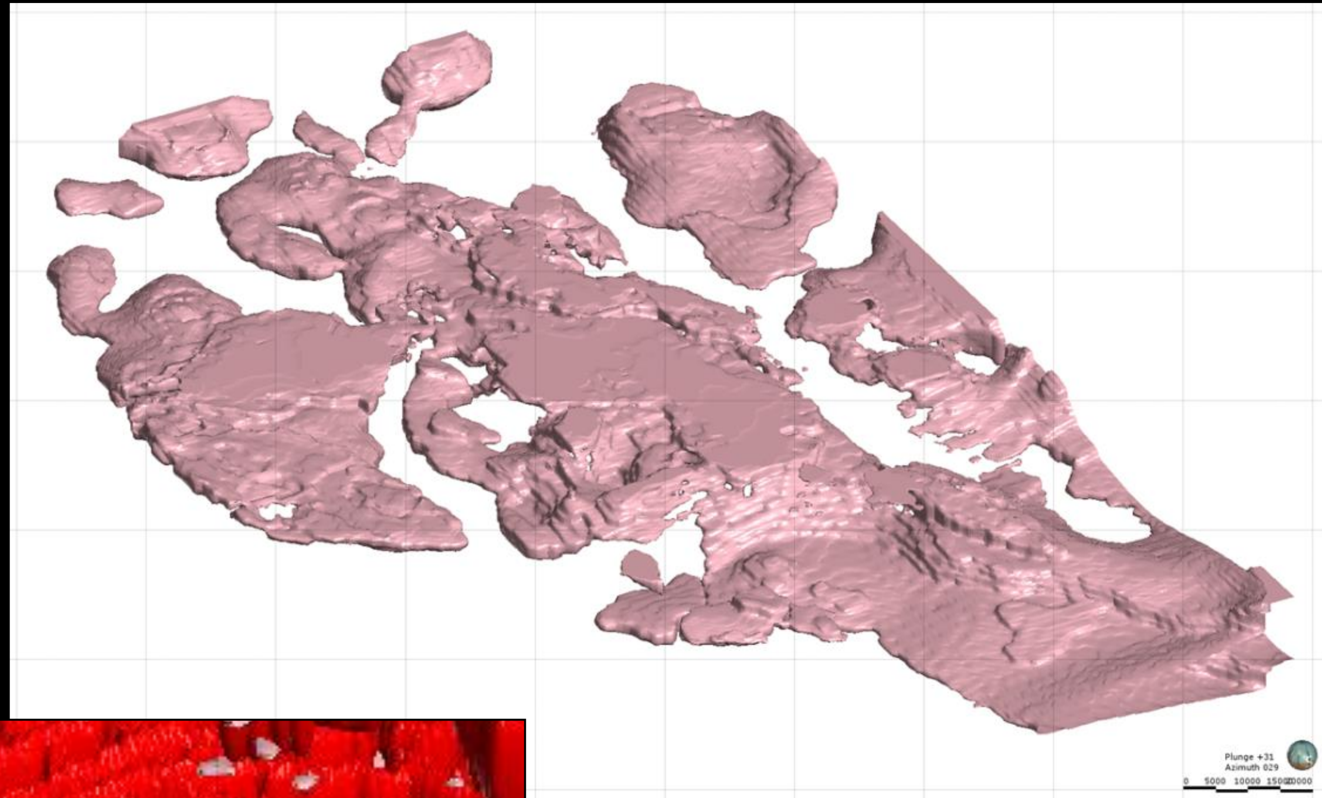
Prospectivity Analysis built on …

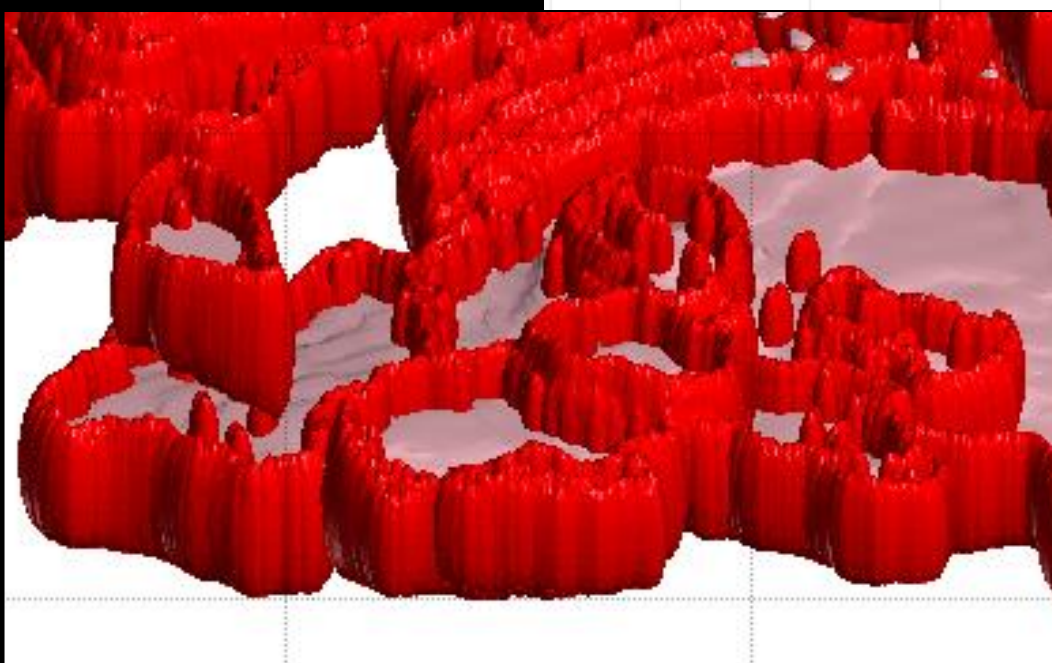
… 3D WILLIAMS Intrusives



Prospectivity Analysis built on …

… 3D WILLIAMS Intrusives



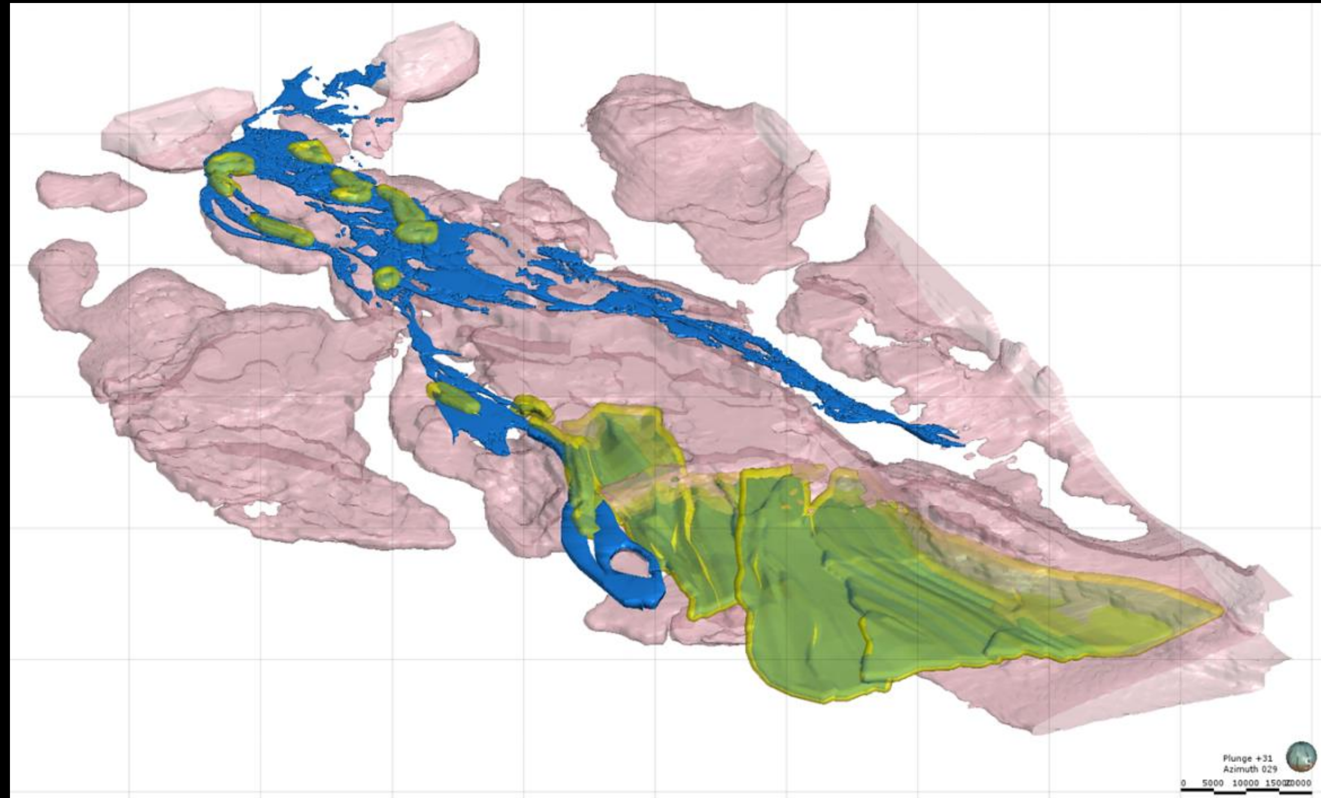


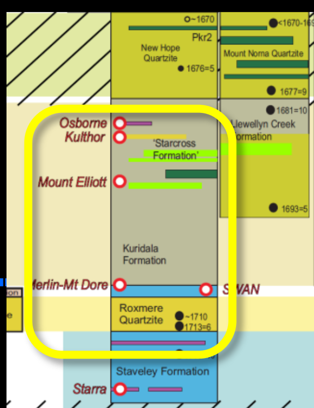
Applied an Anisotropic BUFFER to …

Margins, Shoulders & Apophyses of WILLIAMS Intrusives

Top-of-STAVELEY Stratigraphic Redox Contact

BUFFER





+1500m

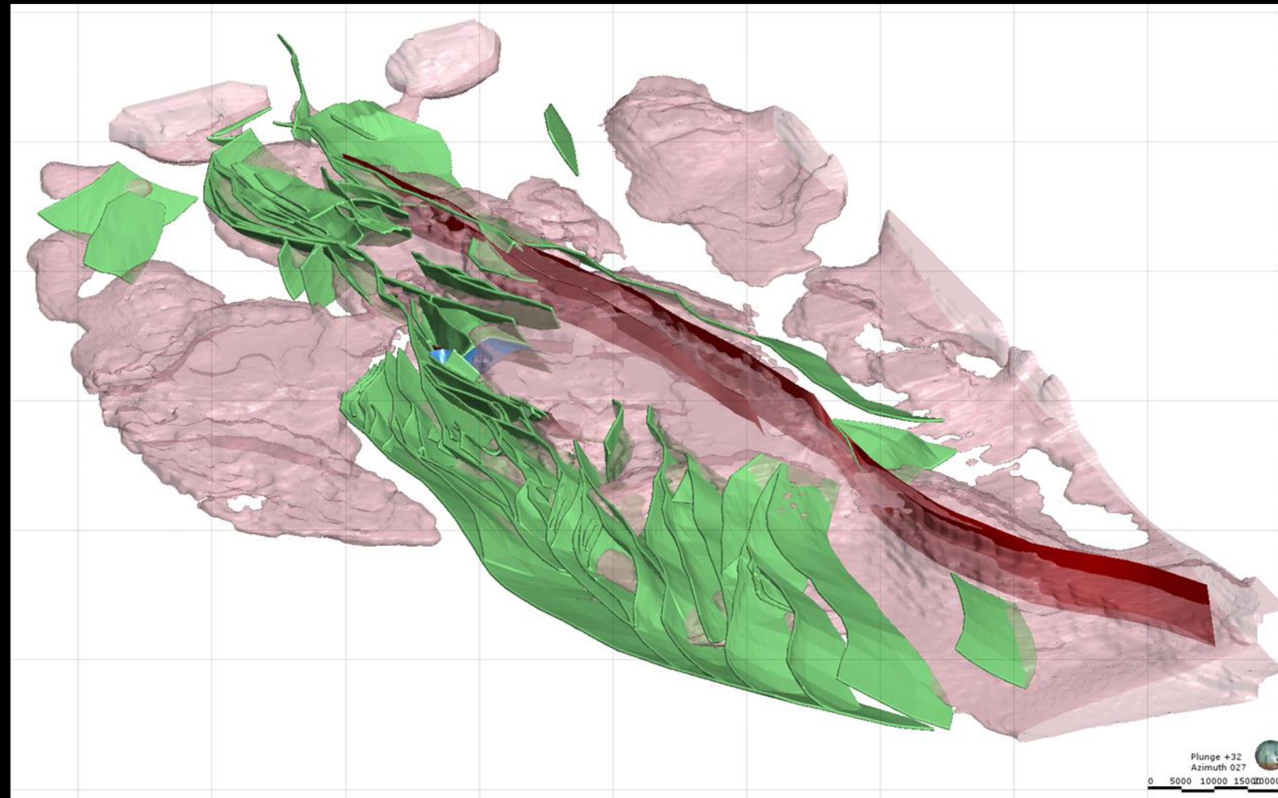
-300m

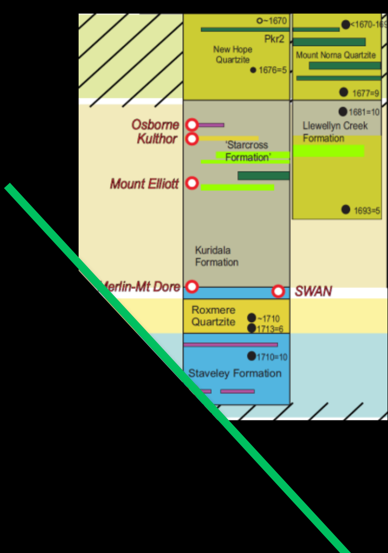
KURIDALA

STAVELEY

Asymmmetric BUFFER
applied to Top-of-STAVELEY

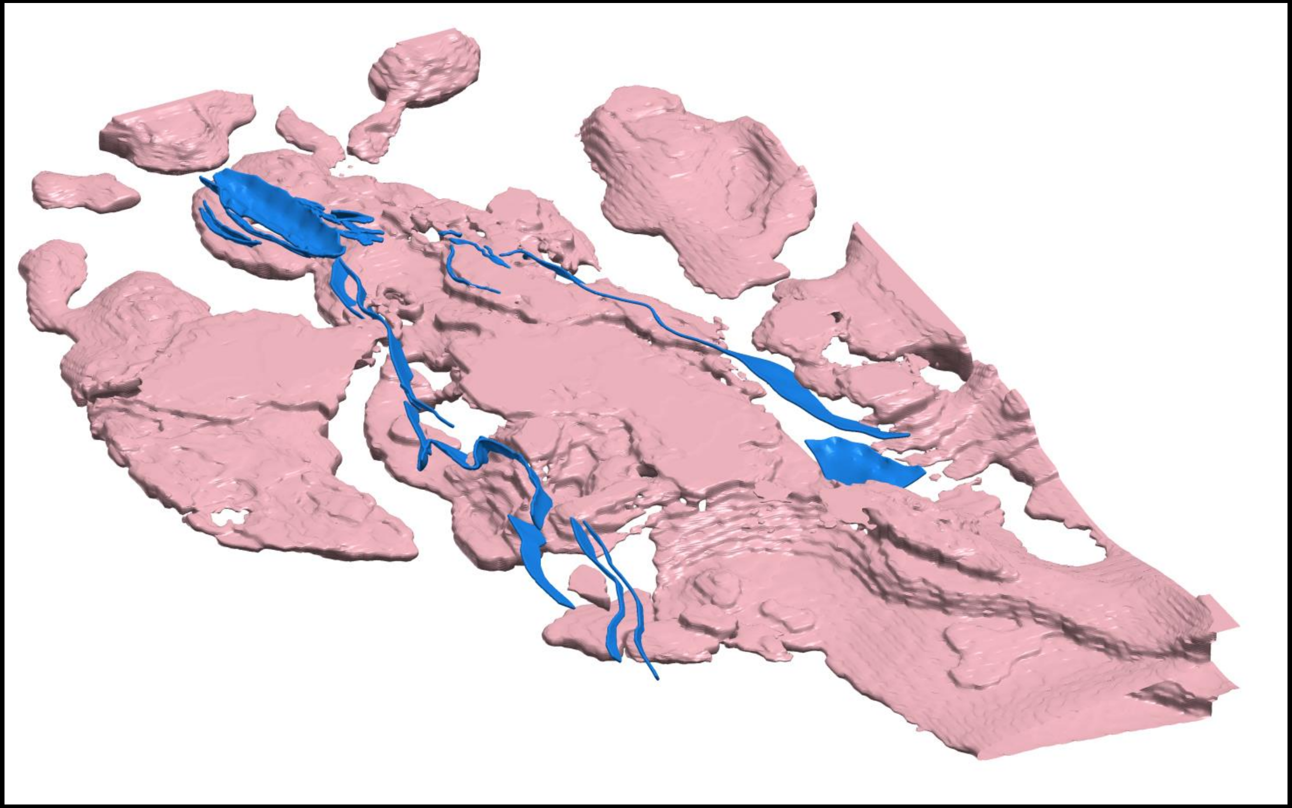
Pre-D4 Structures
with potential Redox juxtapositioning





STAVELEY
Structural
Redox Contact

BUFFER

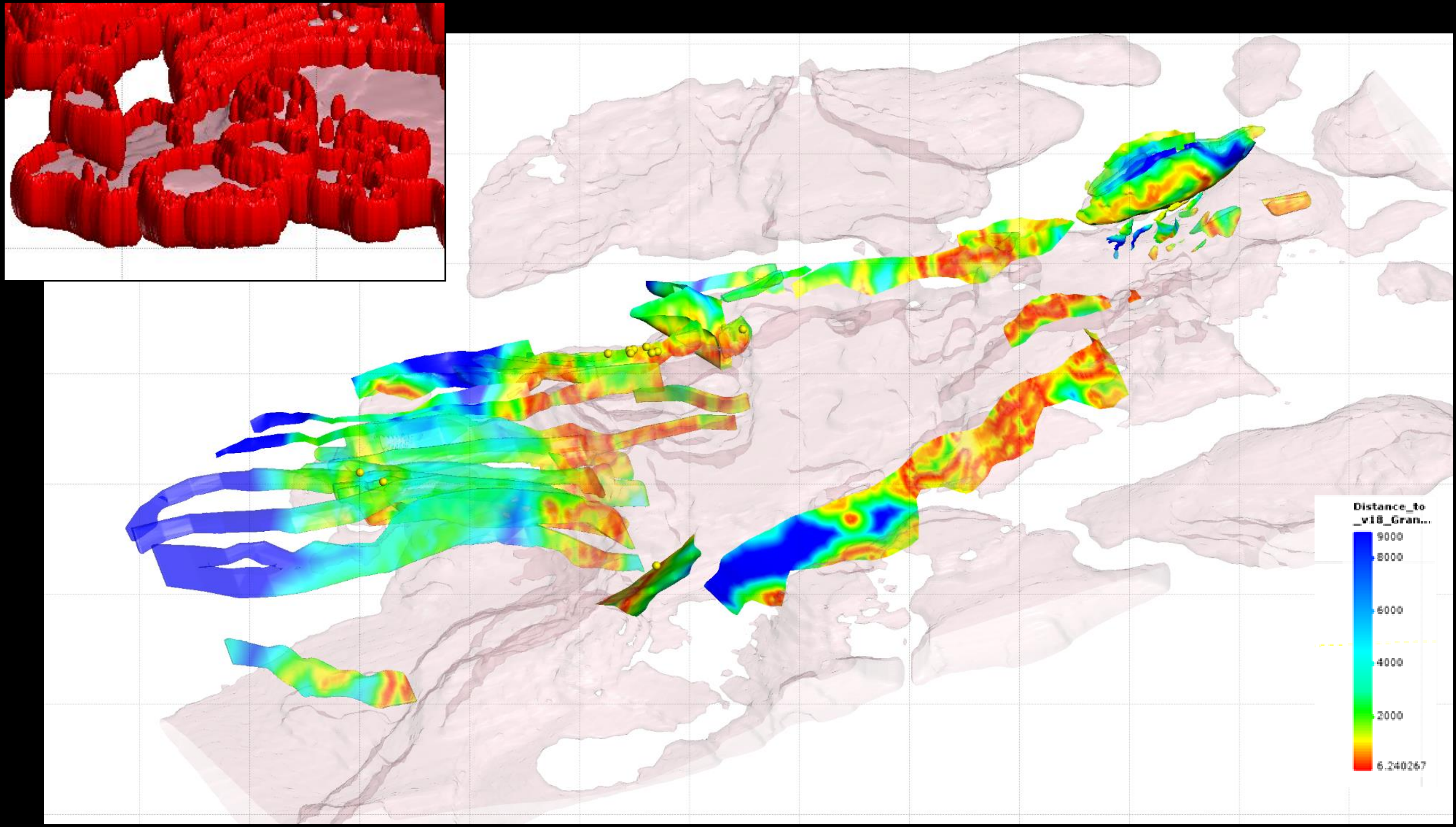


Pre-D4 Structures with potential Redox juxtapositioning

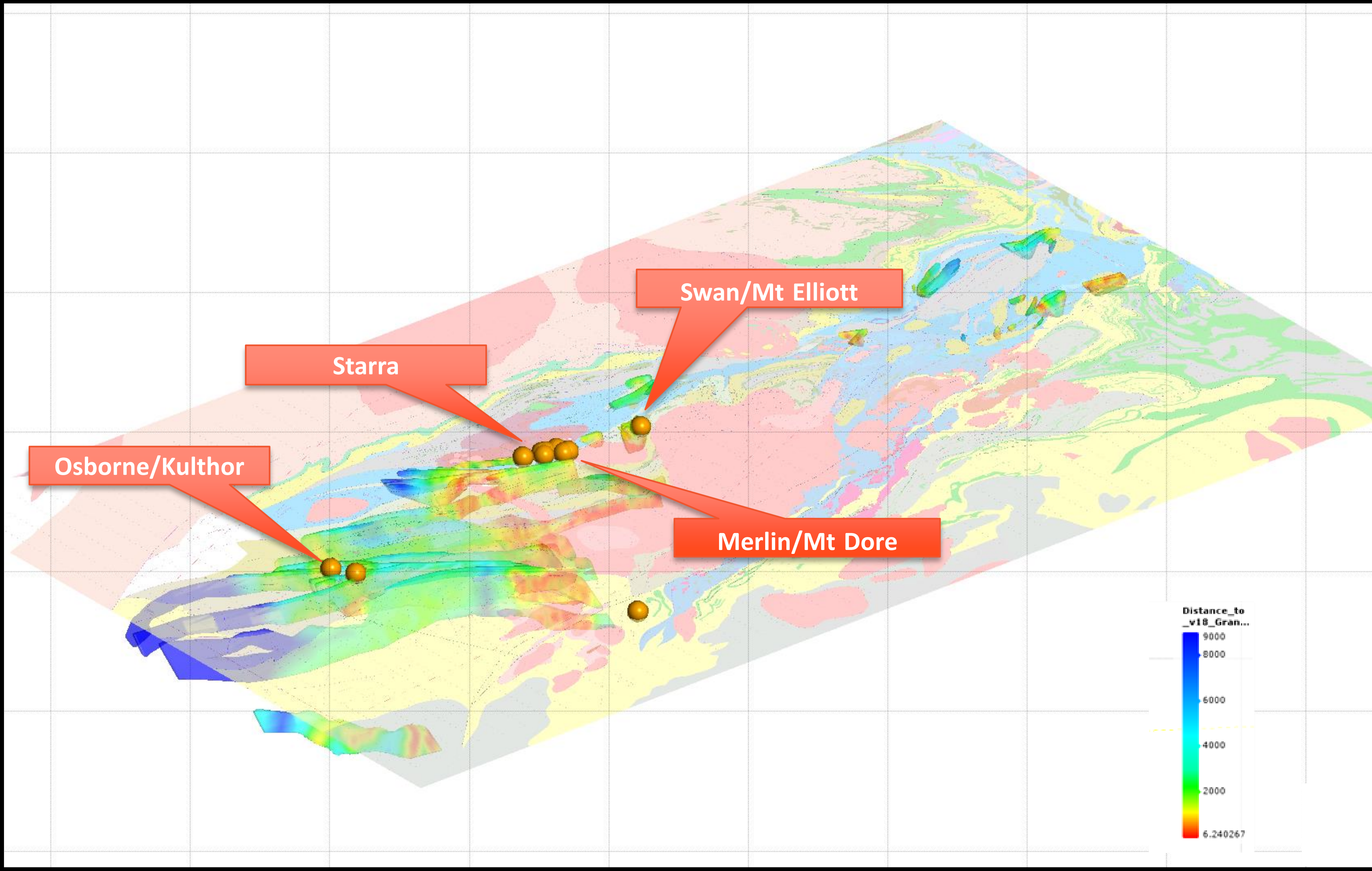
Asymmmetric BUFFER applied to STAVELEY structural juxtapositioning

… Footwall & Hangingwall

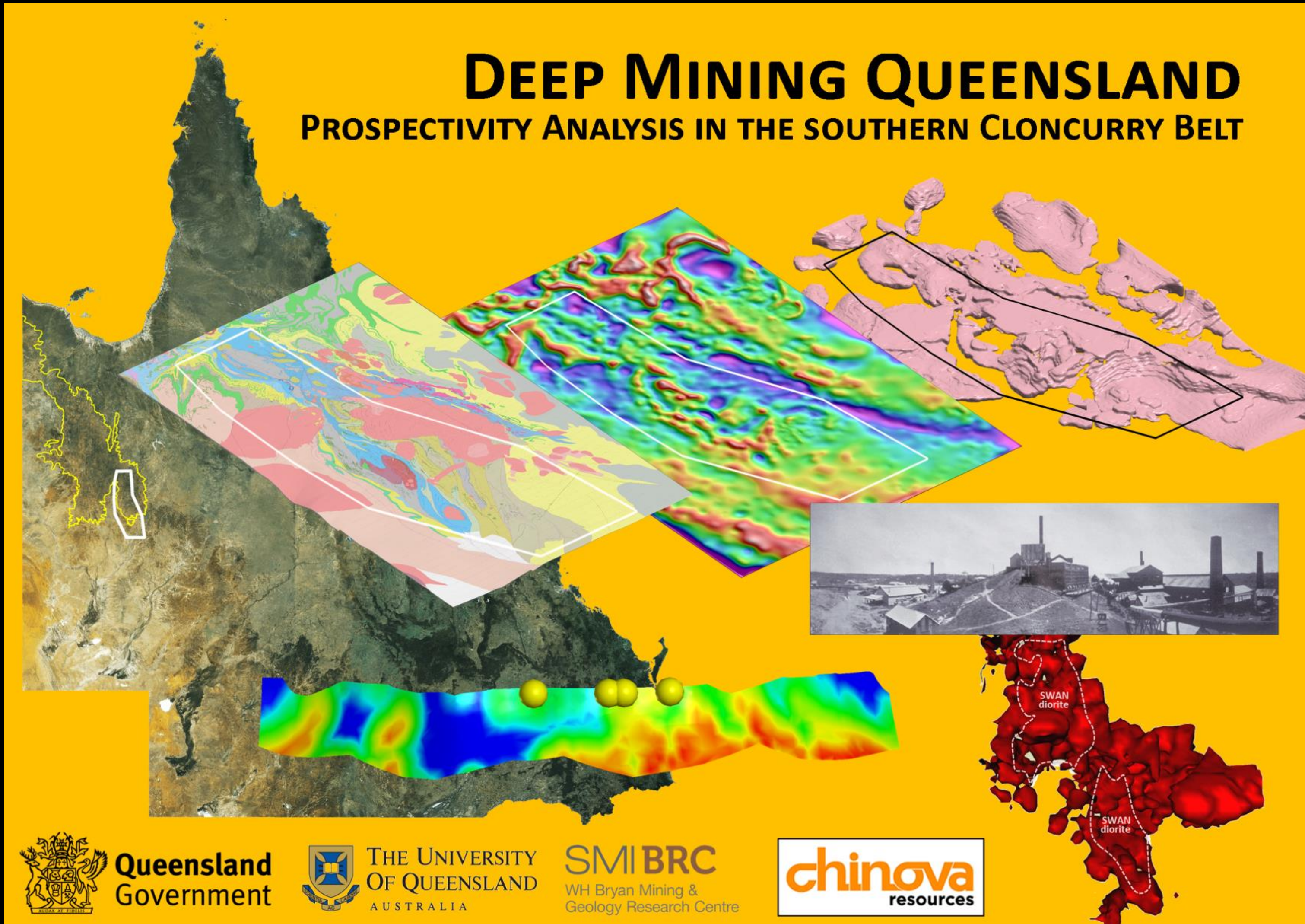
Combined Redox Stratigraphic & Structural BUFFERs … intersected with WILLIAMS intrusive BUFFER Distance



Hot colours indicate proximity to projected WILLIAMS Margins, Shoulders & Apophyses at depth



Successful Prediction ….
…. & Lots of Upside Potential at depth !



Detailed presentations at ***https://brc.uq.edu.au/project/brc-deep-mining-queensland***

DMQ FINAL REPORT to be released on QDEX *…. after review*

T-x Chart, GIS Solid Geology, EFB Assembly Model, Leapfrog Viewer Model, DXFs, Geophysical Library, Geochemistry Review, Prospect Evaluation Tool-PEET, on-line A3 Report