Terra Search Pty Ltd
Specialists in Mineral Exploration, Geology and Computing

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Queensland Government

Geophysical signatures in the Charters Towers region – Implications for exploration

Queensland Exploration Council
2017 Technical Seminar
Technologies for Future Minerals & Energy
Brisbane, February 17,2017

Dr Simon Beams,
Contributions by Terry Hoschke, Dr Gregg Morrison, Tim Beams

Queensland Exploration Council
2017 Technical Seminar
Technologies for Future Minerals and Energy

Why Look at Geophysical Signatures of the Charters Towers Region? (1)

- **Metal endowment : > 20 million ounces of gold, significant base metals**
- **Excellent regional data sets : Gravity, Magnetics, Radiometrics**
- **Extensive exploration history : Many case histories of drilled geophysical anomalies**

Why Look at Geophysical Signatures of the Charters Towers Region? (2)

- **Prospect scale utilization of geophysics : Ground magnetics, IP,EM, other electrical techniques**
- **Advances in technology have led to higher resolution geophysics which has resulted in more reliable geology maps**
- **GSQ supported project has updated the geology and metallogeny**

Implications for Exploration from advances in Geophysical Data Capture & ProcessingTechnology (1)

- **Regional Gravity, magnetics can define deep seated origins of mineral provinces with high metal endowment**

- **Regional aero-magnetics, radiometrics can delineate mineral systems by their broader scale characteristics eg alteration patterns, age bracket, location on well defined structures**

Implications for Exploration from advances in Geophysical Data Capture & ProcessingTechnology (2)

- **Prospect scale high resolution data leads to better understanding of prospect geology, detail structure and 3D modelling of ore bodies and their envelope mineralisation : new generation Ground magnetics, IP,EM, other electrical techniques**

- **Direct Ore-Finders Physical property of ore is directly measurable and contrasts with the host rocks eg magnetite skarn (magnetics), conductive massive sulphide (EM), high uranium (radiometrics), large contrast in density (gravity) .**

- **Historical analogue is the Gold Pan.**

UPDATE OF GEOLOGY , METALLOGENY, EXPLORATION IMPLICATIONS

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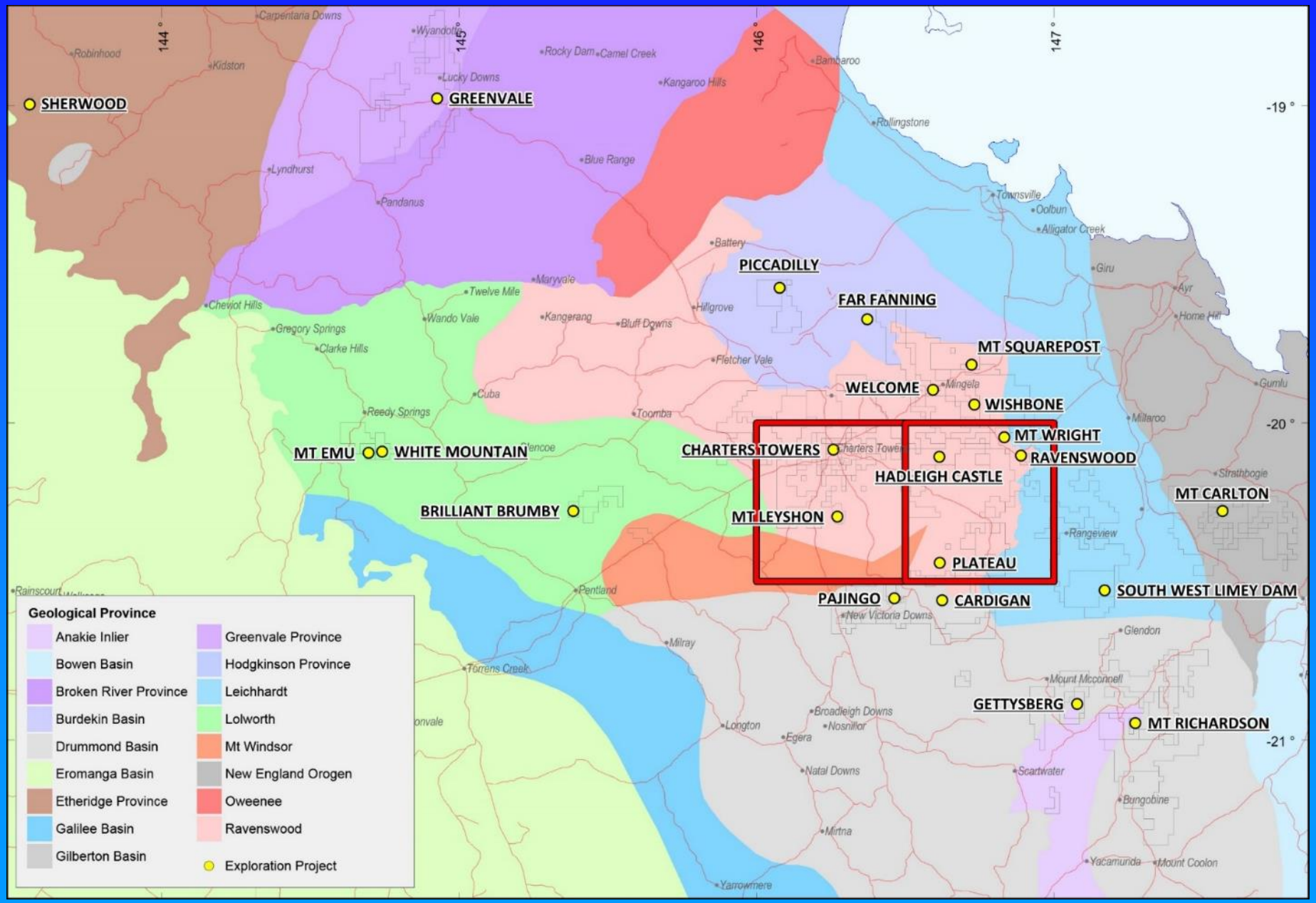
Characterization of Intrusion-related hydrothermal mineral systems in the Charters Towers Region, Northeast Queensland

A component of the Queensland Government Future Resources Program
-Industry Priorities Initiative-

Terra Search Team: Tim Beams, David Rubenach, Jennifer Vetali, Rachel Pala, Rebecca Murray, Iain Faichney, Lucy Chapman , Richard Lesh, Deb Lethbridge, Scott Stephan, Paul Markey & Nick Tate

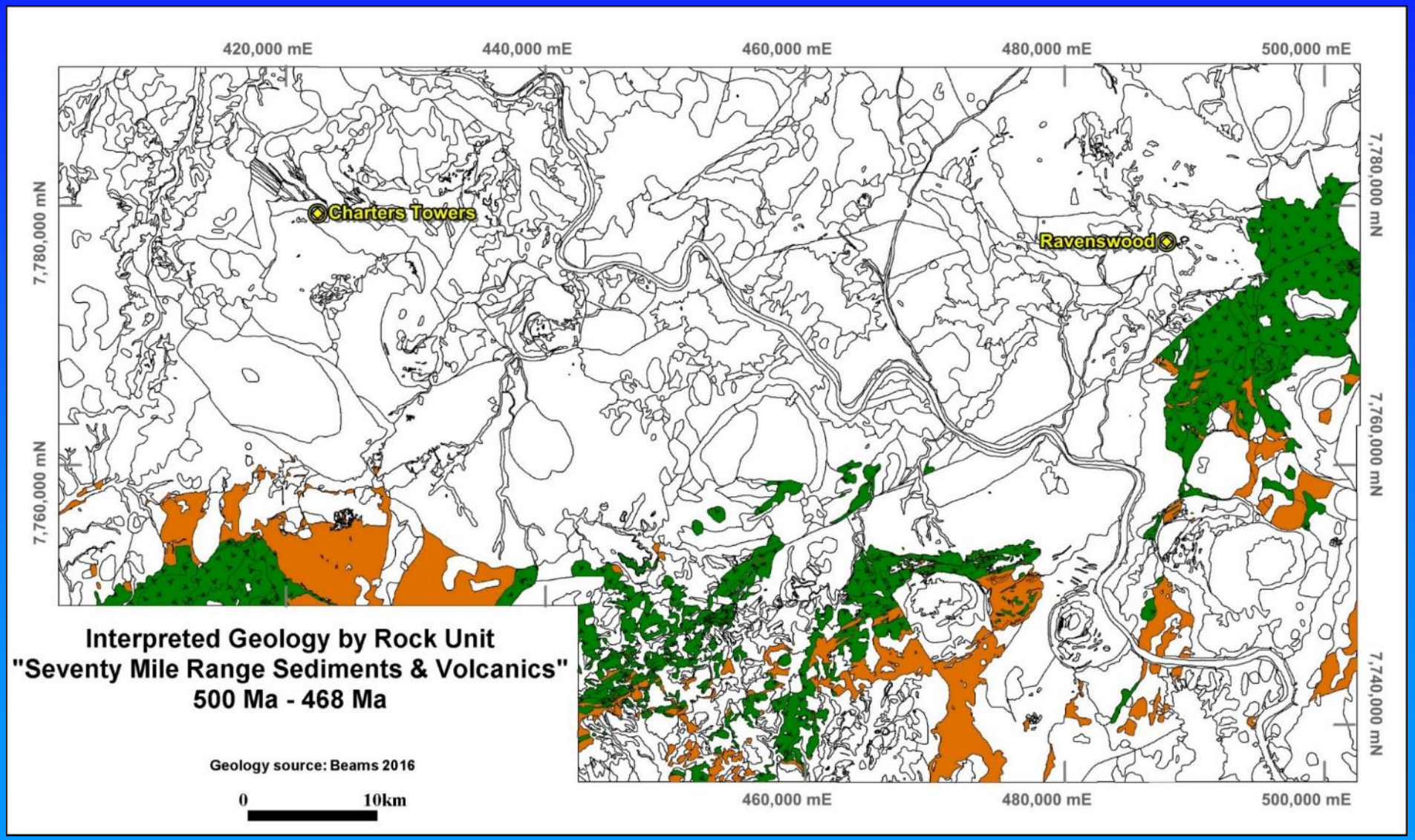
We acknowledge Cooperation by Industry Partners :
Resolute Mining Ltd, Mantle Mining Ltd, Ramelius Resources Ltd, Liontown Resources Ltd, Evolution Mining

Updated geology of the Ravenswood Batholith



AN ITERATIVE PROCESS OF GEOPHYSICAL INTERPRETATION

- **Regional geology maps should be consistent with good quality regional geophysics**
- **An unravelling of the complex geology is required to maximise the discovery potential of the geophysics data sets.**
- **Interpretation requires pre-requisite recognition of a 250 my long magmatic history, accompanied by mineralisation events, contrasting structural regimes , metamorphism and complex landscape evolution.**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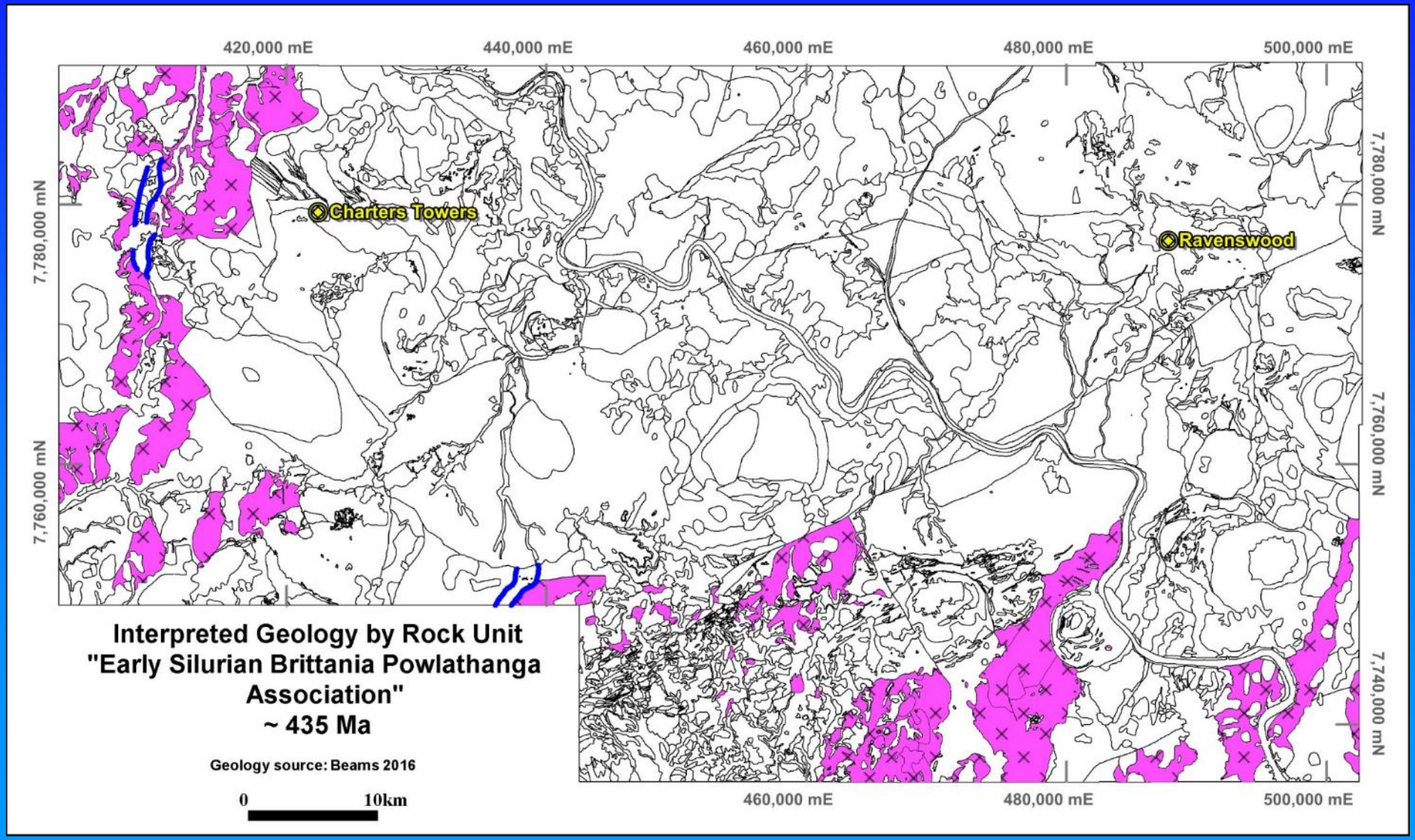
7,740,000 mN
Charters Towers
Ravenswood
Interpreted Geology by Rock Unit
"Seventy Mile Range Sediments & Volcanics"
500 Ma - 468 Ma
Geology source: Beams 2016
0
10km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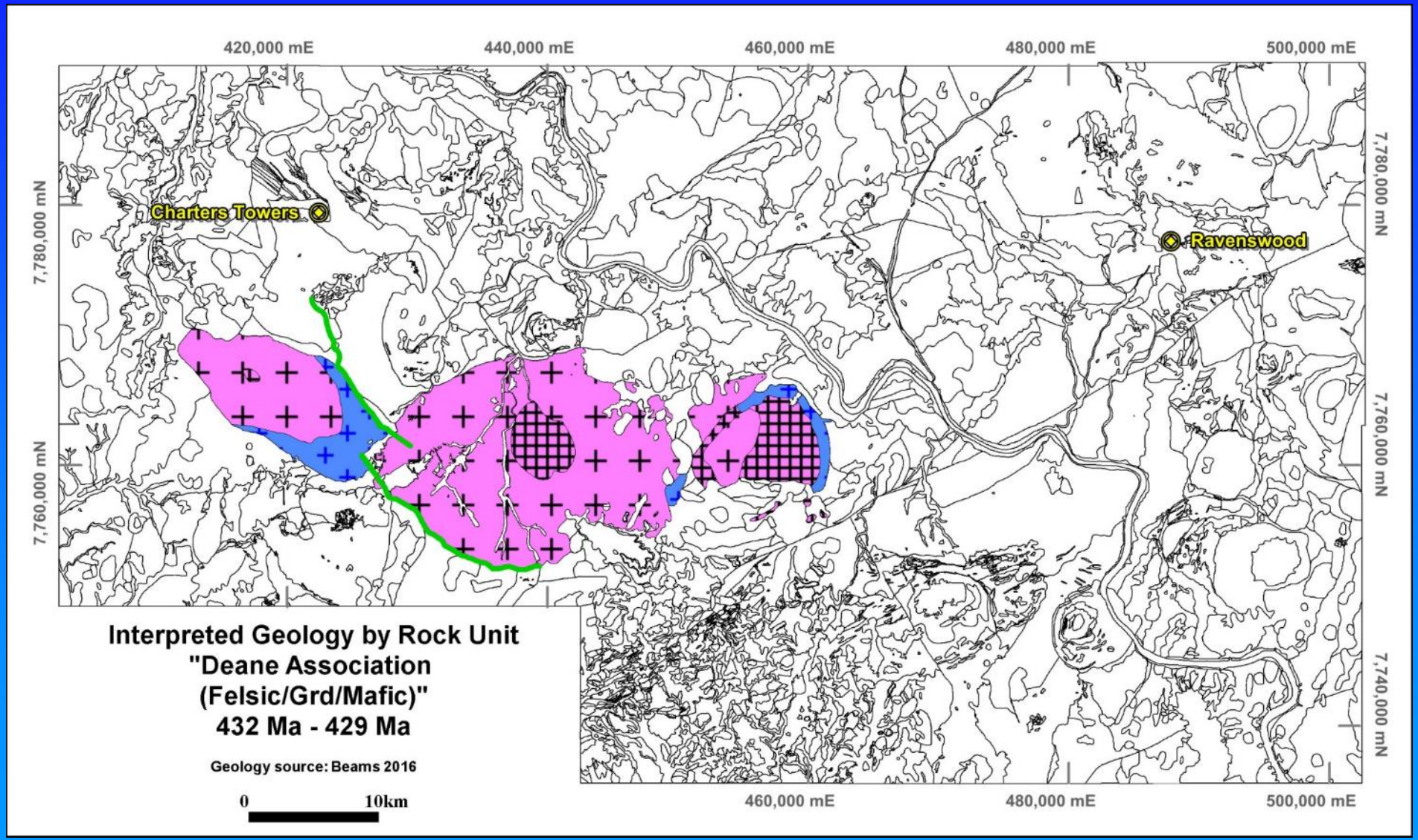
Charters Towers
Ravenswood
Interpreted Geology by Rock Unit
"Early Silurian Brittania Powlathanga Association"
~ 435 Ma
Geology source: Beams 2016
0
10km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Charters Towers
Ravenswood
Interpreted Geology by Rock Unit
"Deane Association
(Felsic/Grd/Mafic)"
432 Ma - 429 Ma
Geology source: Beams 2016
0
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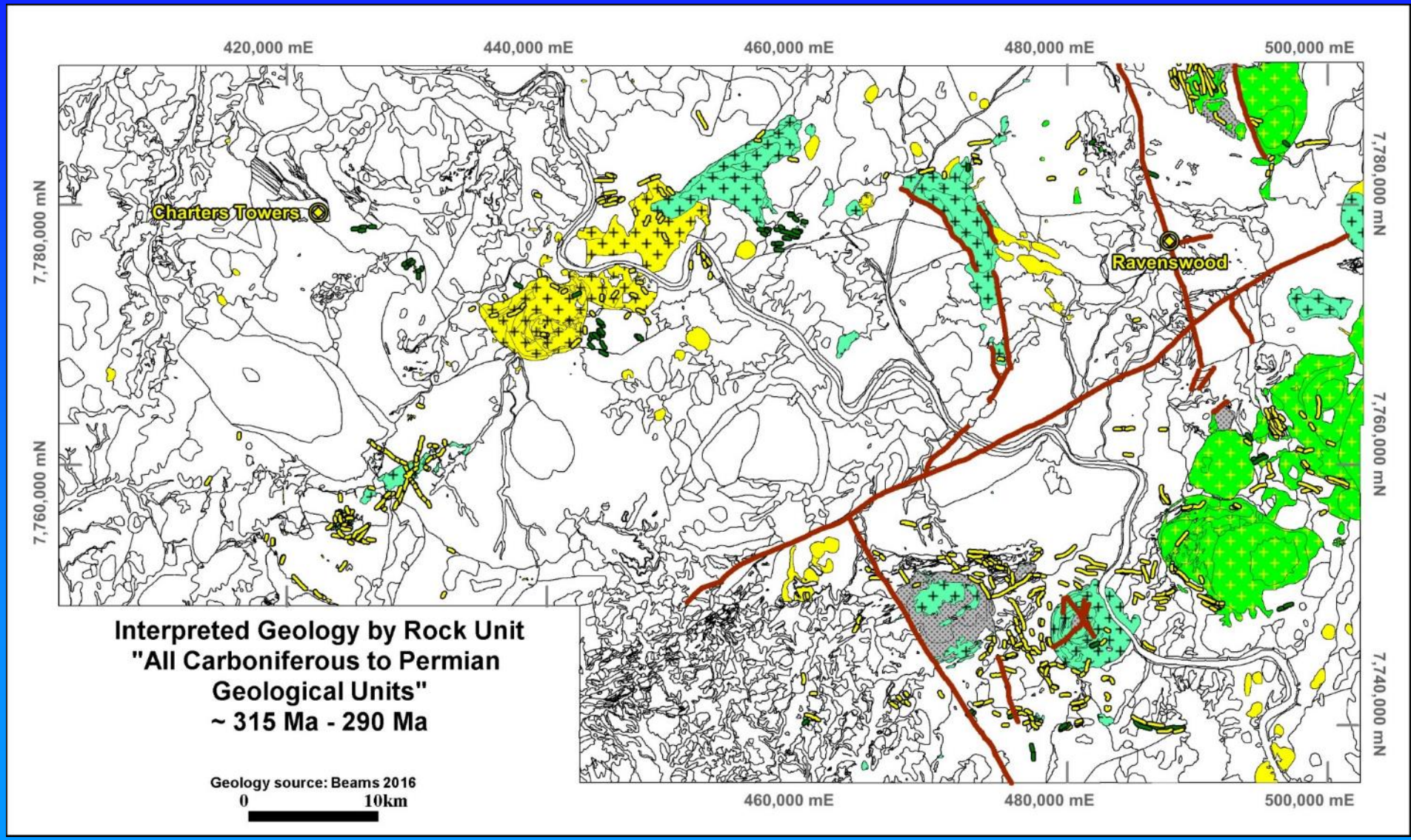
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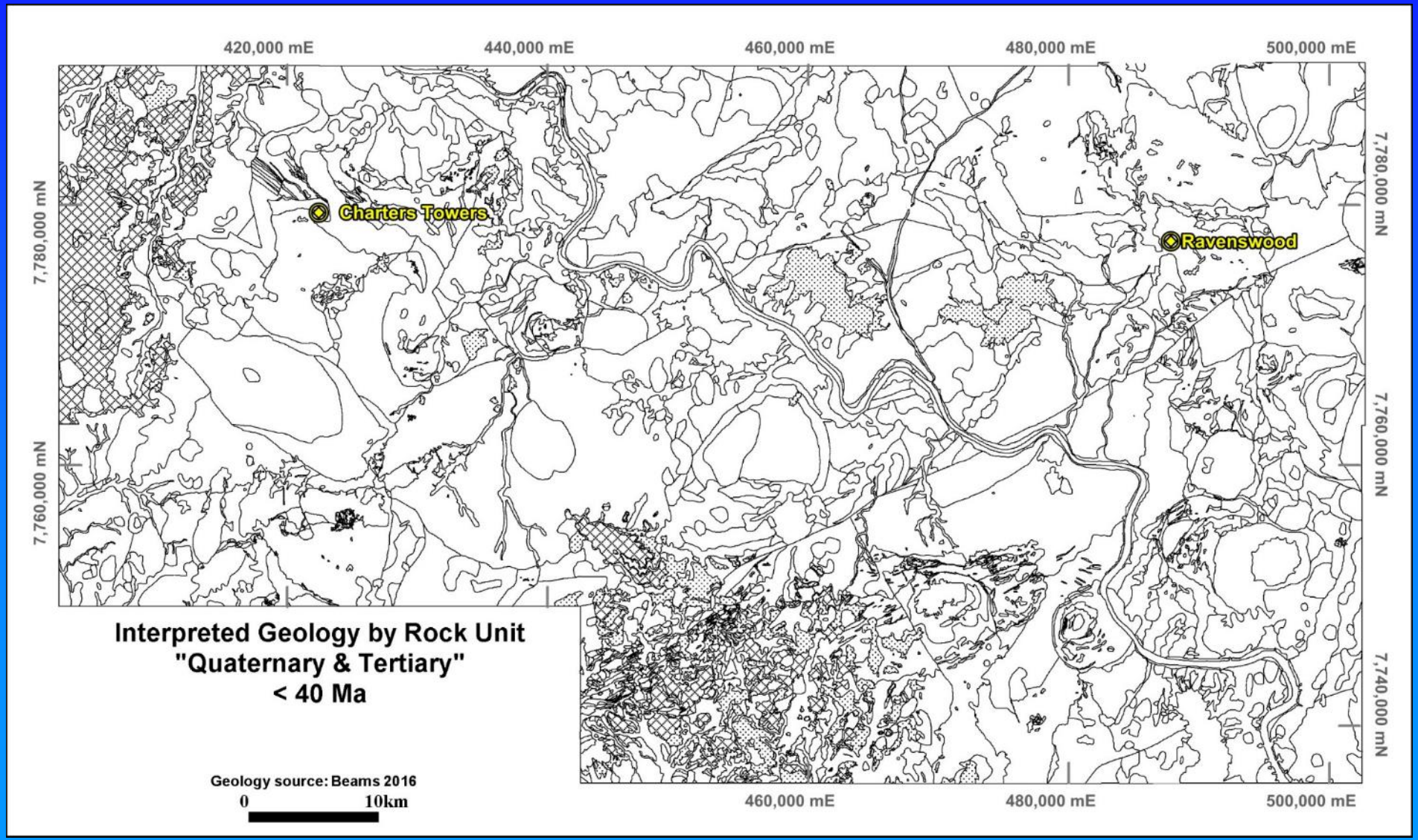
Charters Towers
Ravenswood
Interpreted Geology by Rock Unit
"All Carboniferous to Permian
Geological Units"
~ 315 Ma - 290 Ma
Geology source: Beams 2016
0
10km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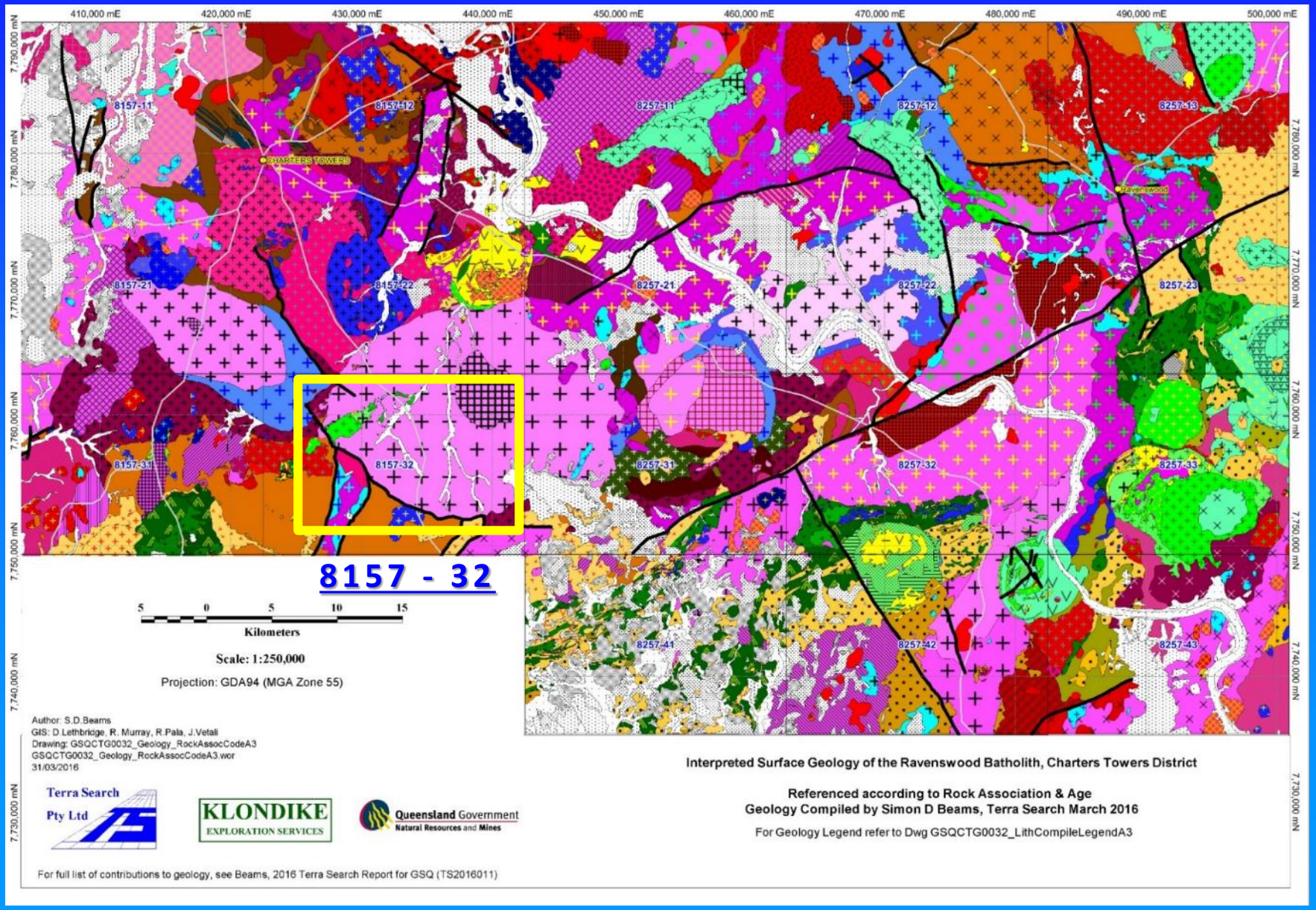
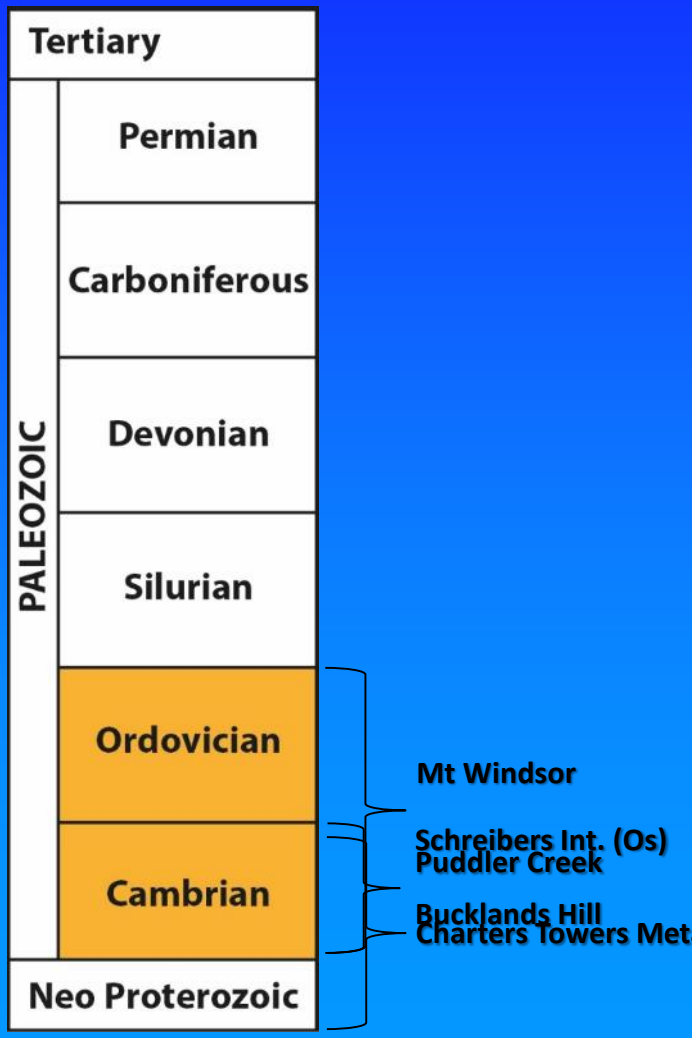
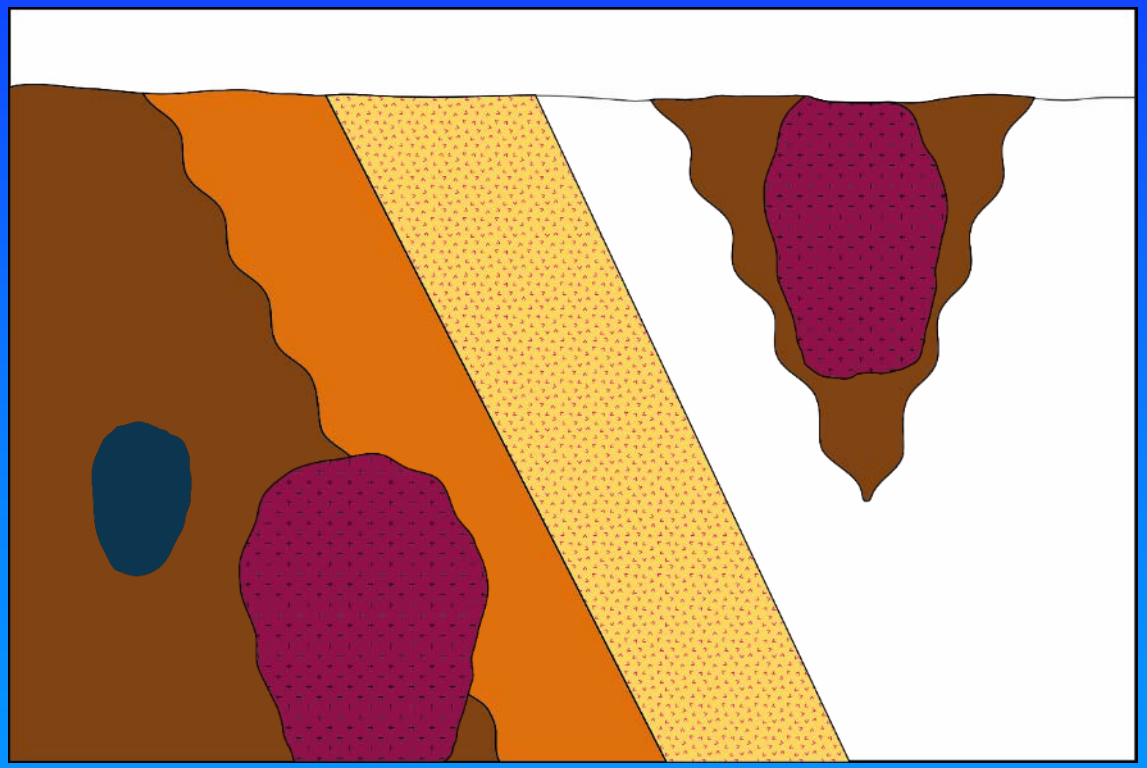
7,760,000 mN
7,740,000 mN
Charters Towers
Ravenswood
Interpreted Geology by Rock Unit
"Quaternary & Tertiary"
< 40 Ma
Geology source: Beams 2016
0
10km

Updated Geology Charters Towers-Ravenswood 100k Sheet areas

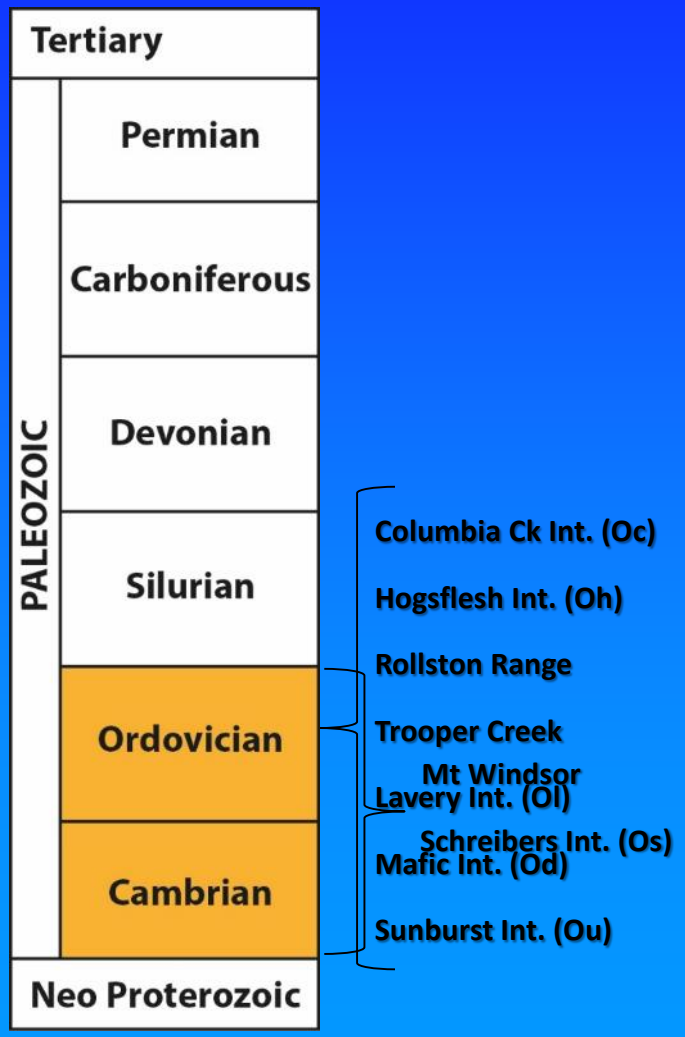


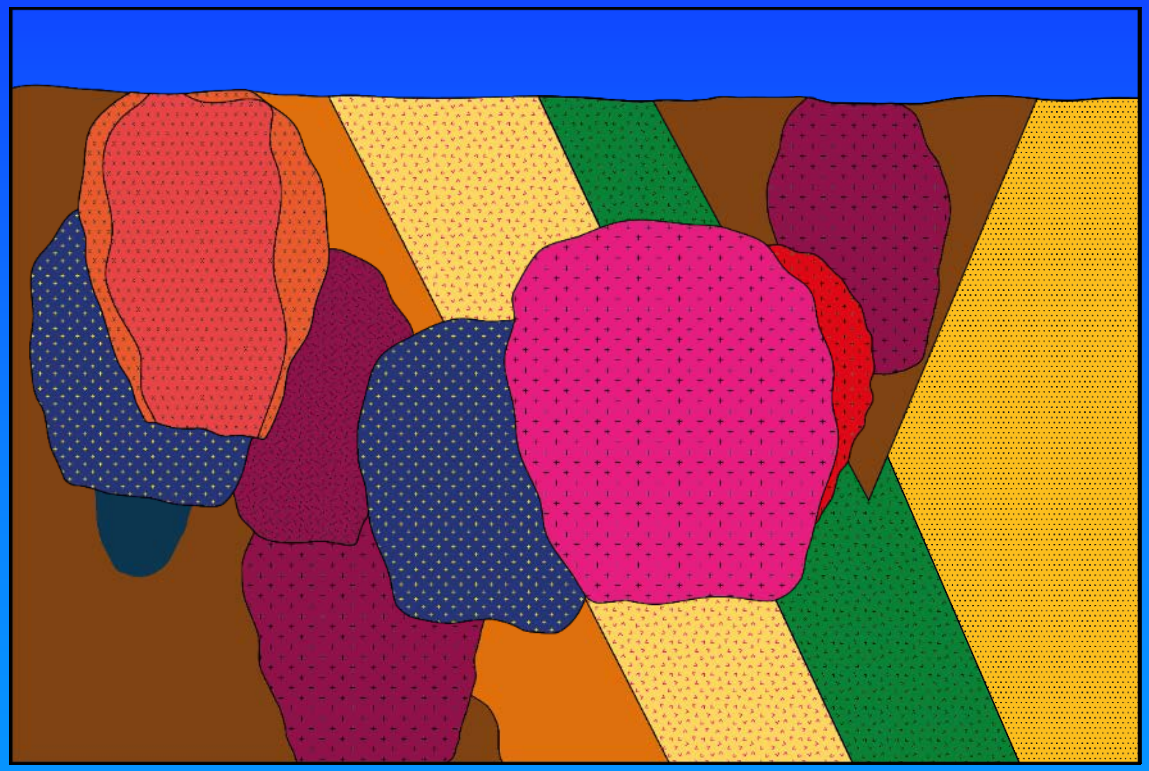
Geological History Ravenswood Batholith



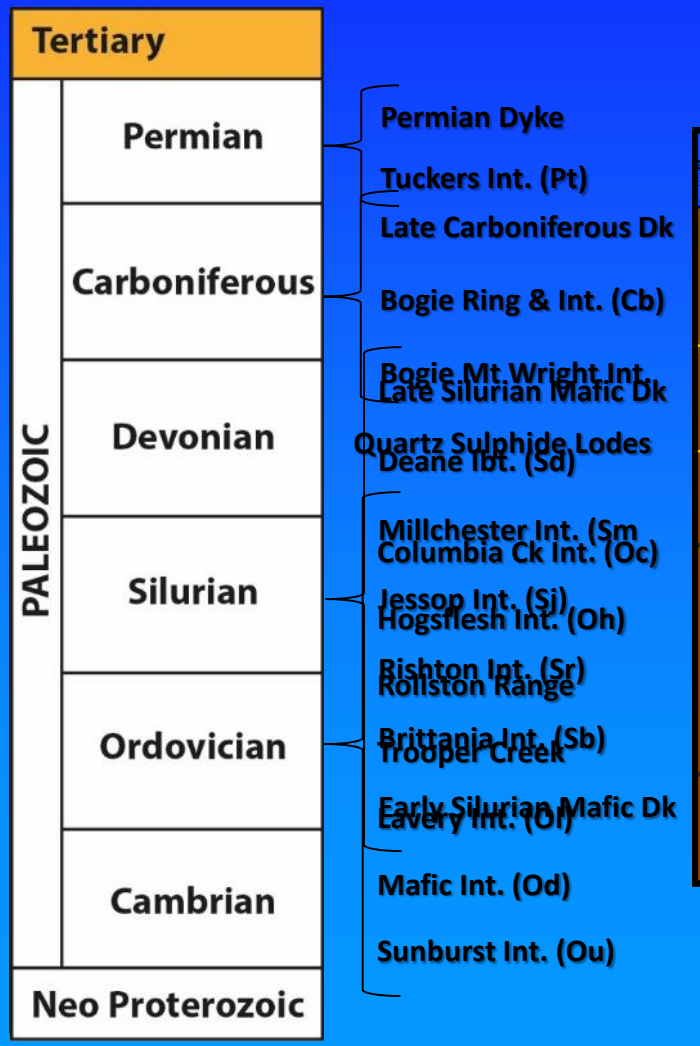


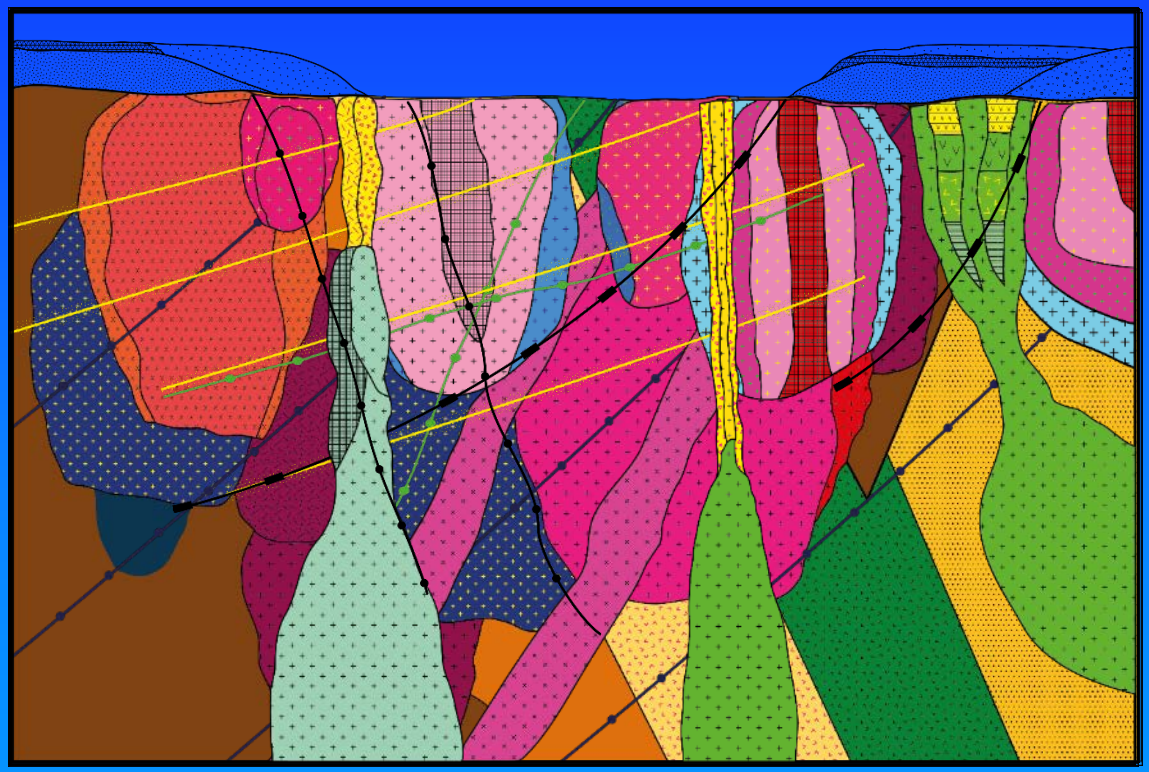
- Geological History Ravenswood Batholith



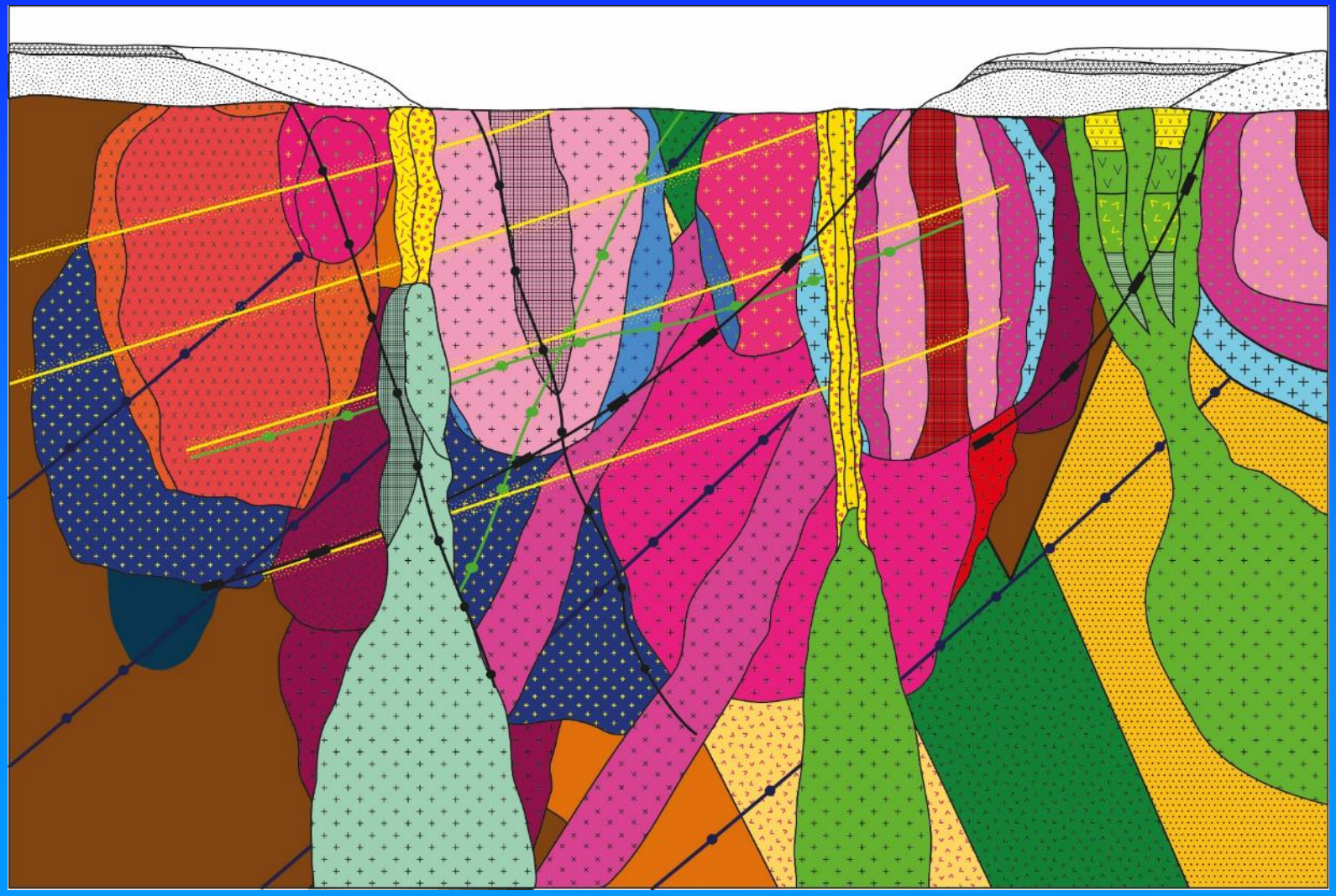


Geological History Ravenswood Batholith





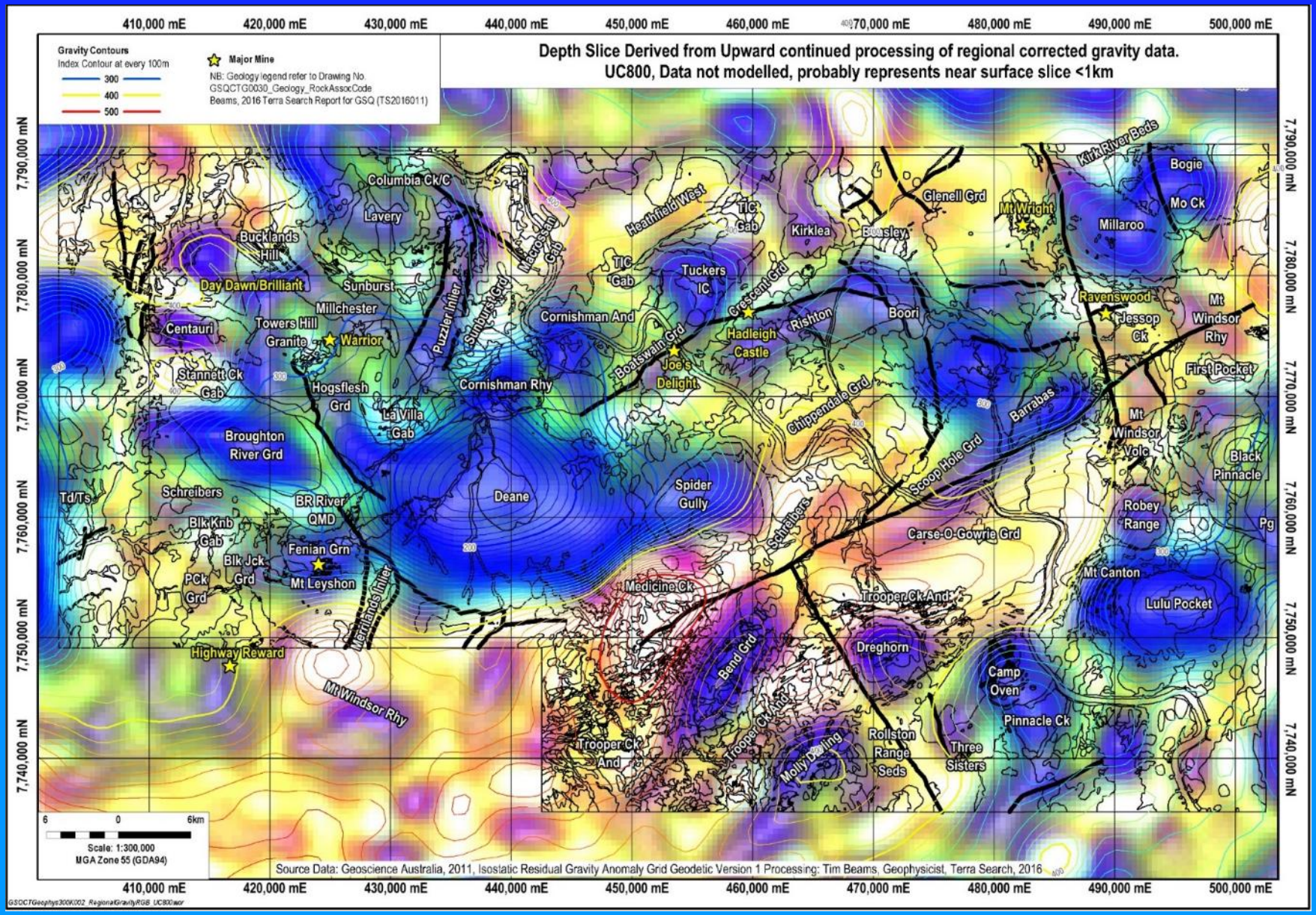
- Geological History Ravenswood Batholith



Charters Towers-Ravenswood Gravity regional data set –useful at the mineral province level

- Shallow gravity depth slice is in general agreement with many of the surface geology features.
- In general , Silurian and Permo-Carboniferous granitic rocks are gravity lows – suggesting overall granodioritic composition
- Ordovician granitic rocks and meta-sedimentary, meta-volcanic basement have higher gravity – suggesting denser underlying dioritic to meta-mafic compositions.

Charters Towers-Ravenswood Bouger Corrected Gravity, Shallow Depth slice

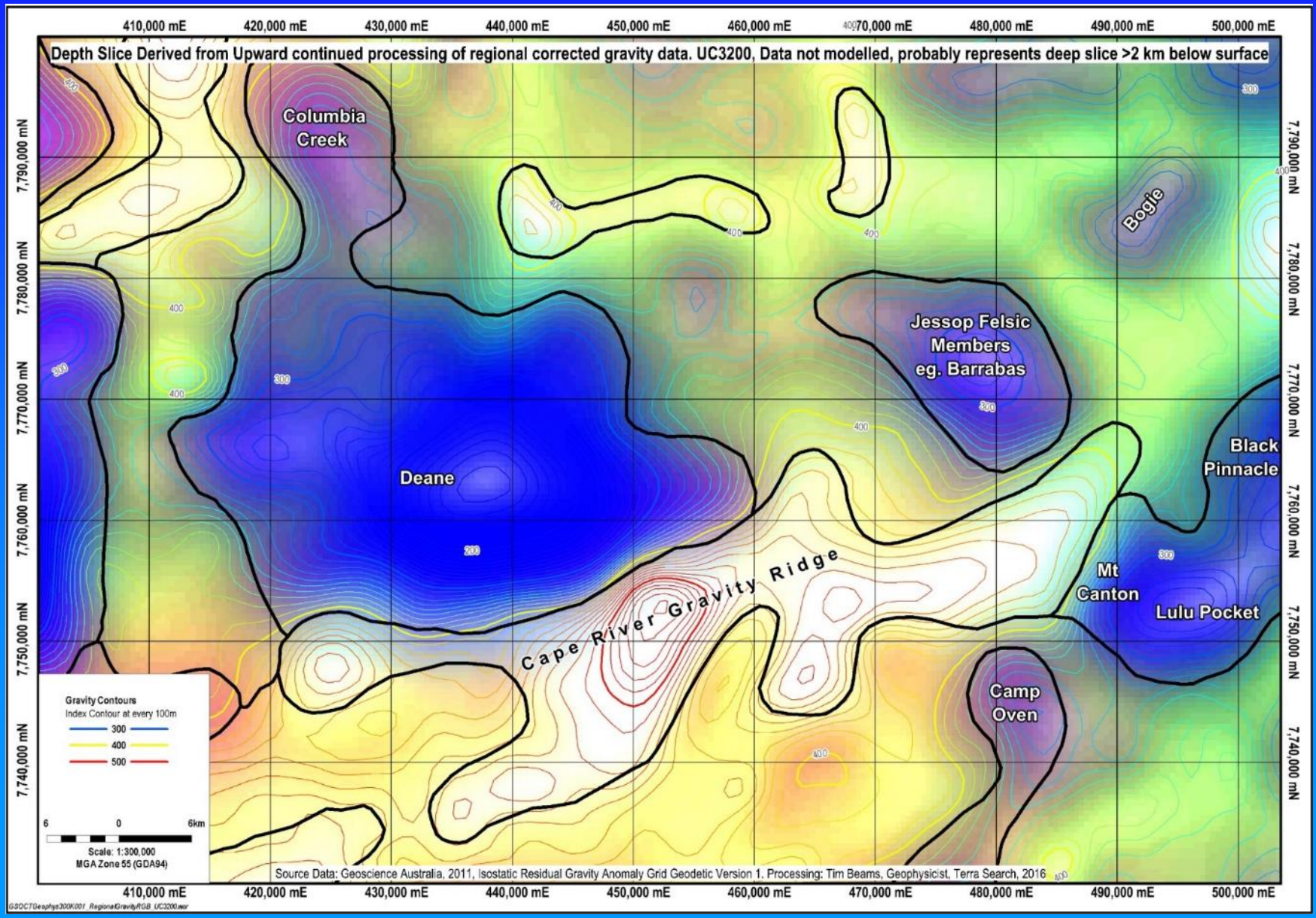


Deep Gravity Slice

Deep gravity depth slice highlights deep-seated crustal architecture, examples:

1. The boundary between the Ravenswood and Lolworth batholiths.
2. The felsic roots of the large Silurian granitic bodies (eg the Deane and Jessop Rock Associations) .
3. The general higher density areas underlain by a basement in which Ordovician mafic/intermediate compositions are dominant .
4. The prominent east west gravity ridge corresponding to the mafic root to the Cambro-Ordovician volcano-sedimentary Seventy Mile Range Group.

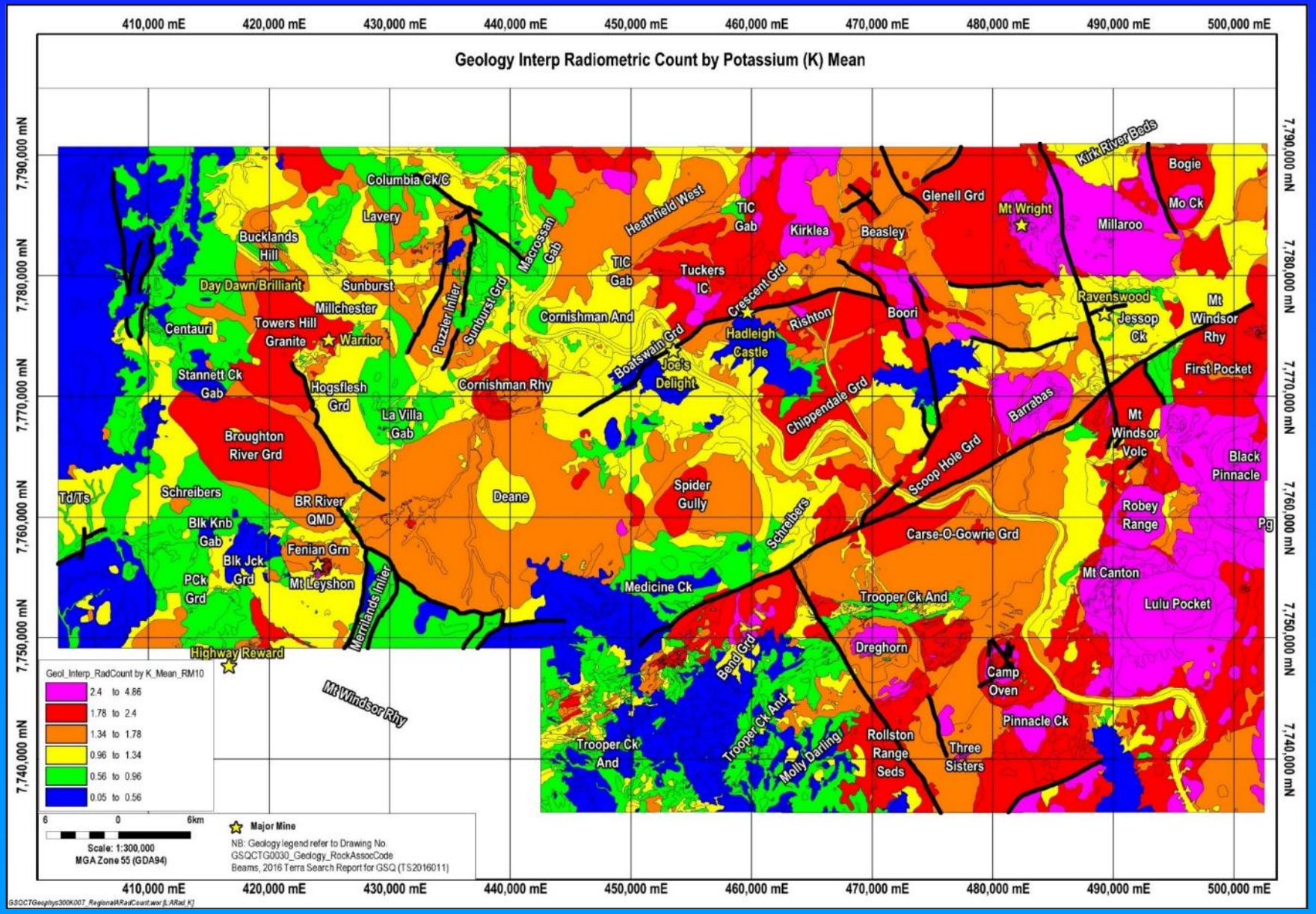
Charters Towers-Ravenswood Bouger Corrected Gravity, Deep Depth slice



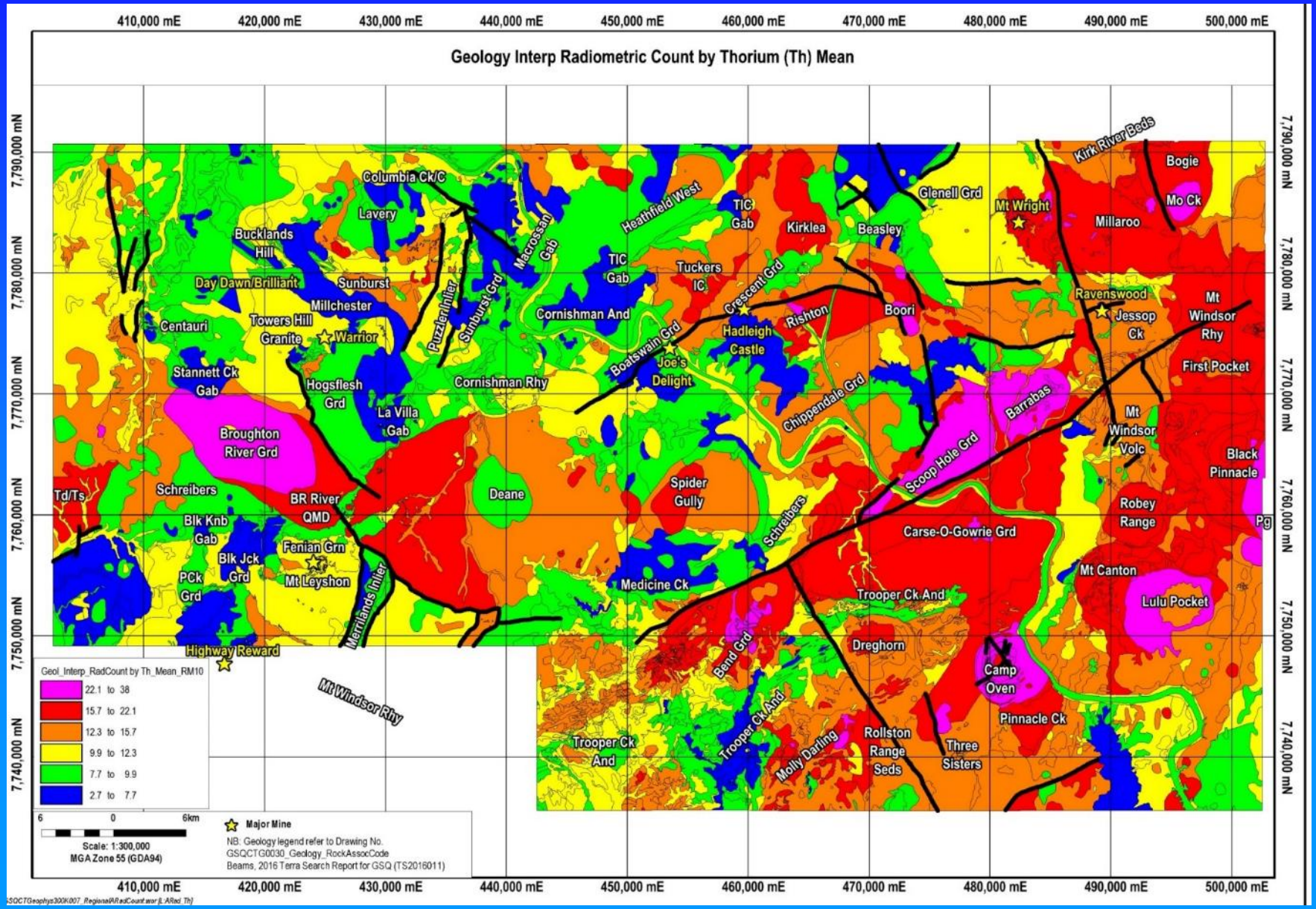
Aero-Radiometrics Regional Tool for mapping out surface geology and mineral systems (alteration zones)

- Radiometrics has proven particularly useful for discriminating individual intrusive bodies and also felsic units within the basement.
- obtaining consistencies in surface geology .
- delineating areas of conflict between mapped geology.
- clarifying the compositions, shapes and relationships for the larger intrusions .
- highlighting the zoned intrusions and some alteration zones.
- variations of the radiometric elements K, Th, U are large enough across the batholith to uniquely discriminate most of the rock types within the region,

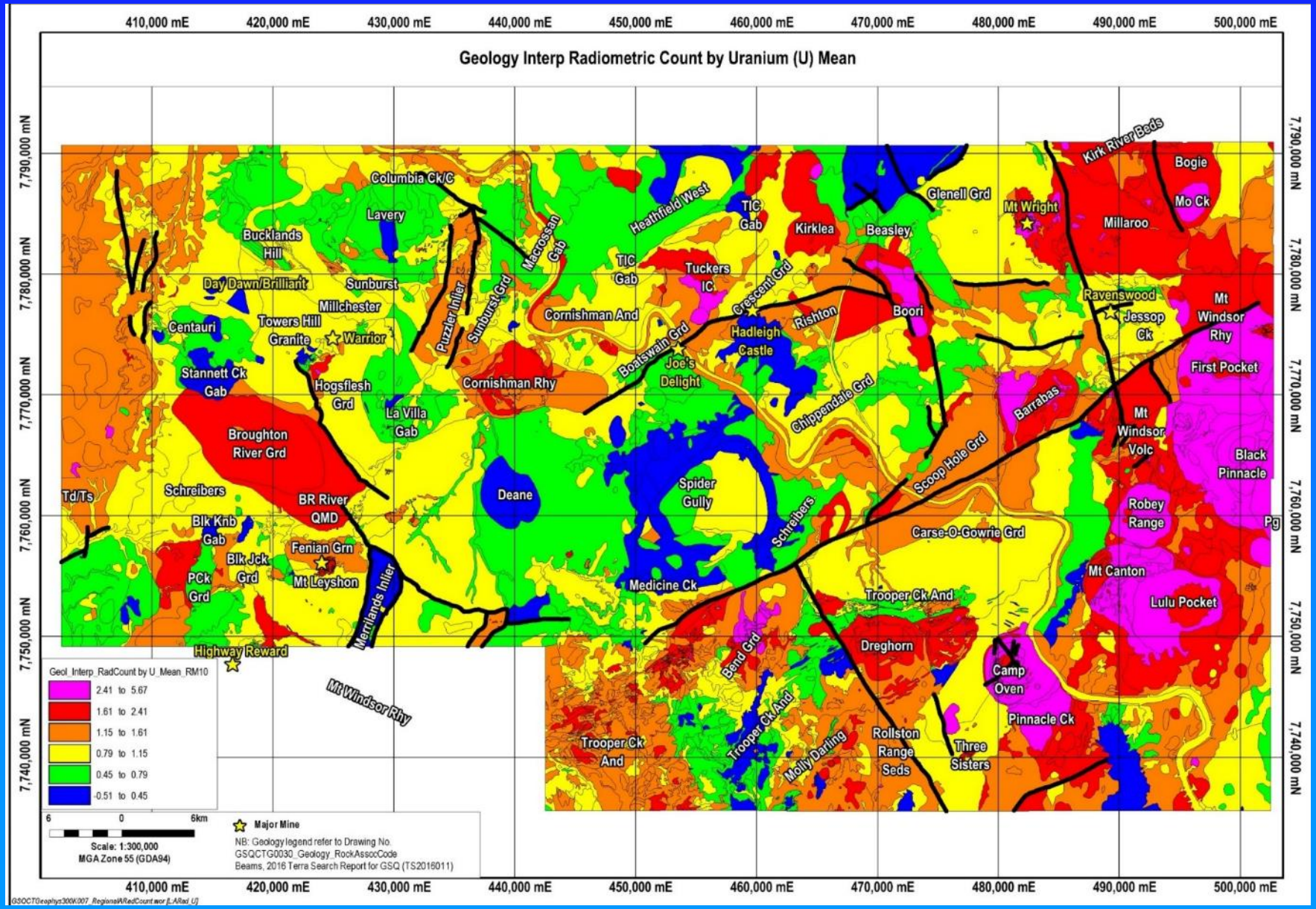
Charters Towers-Ravenswood Mean K per geology unit



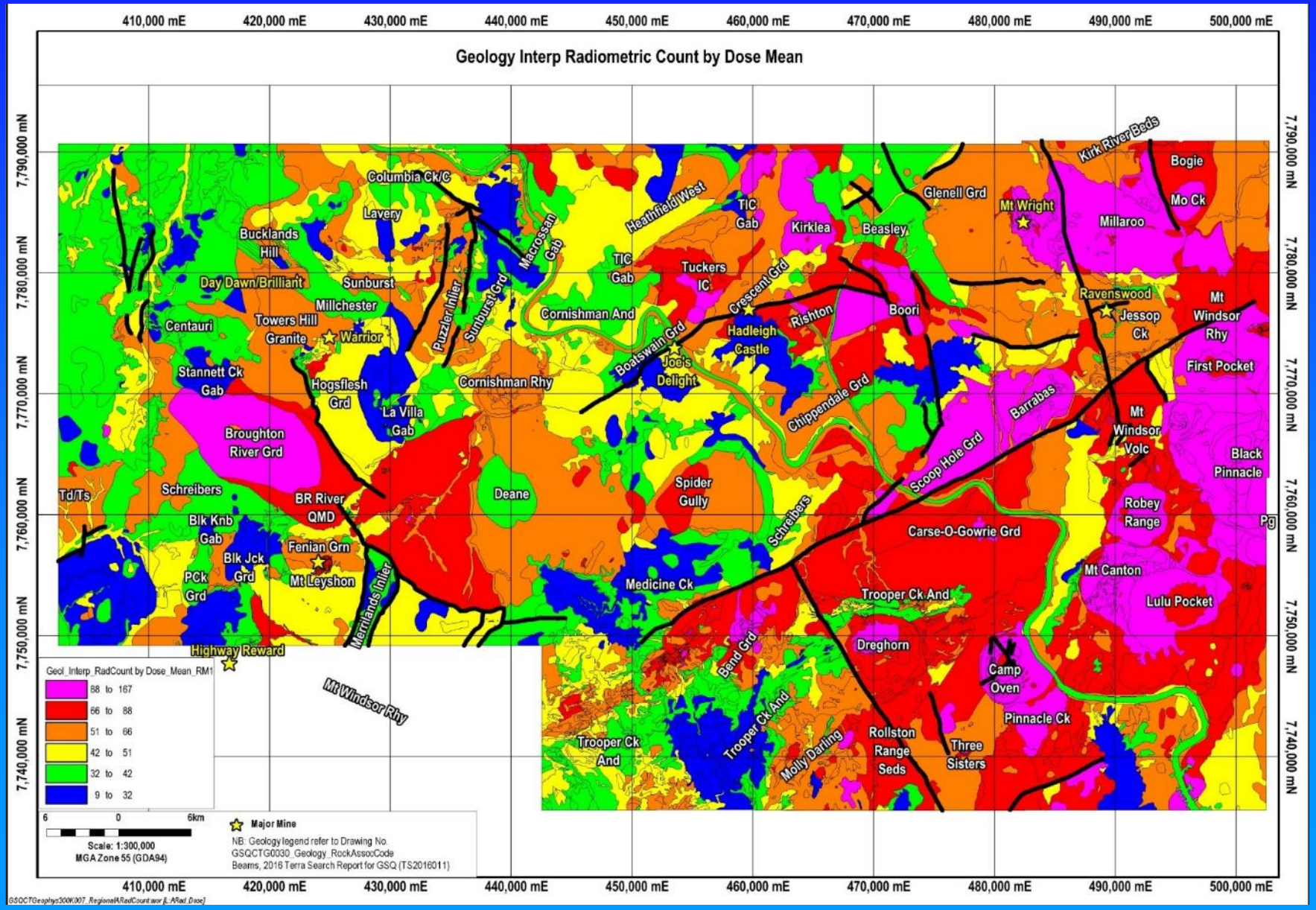
Charters Towers-Ravenswood Mean Th per geology unit



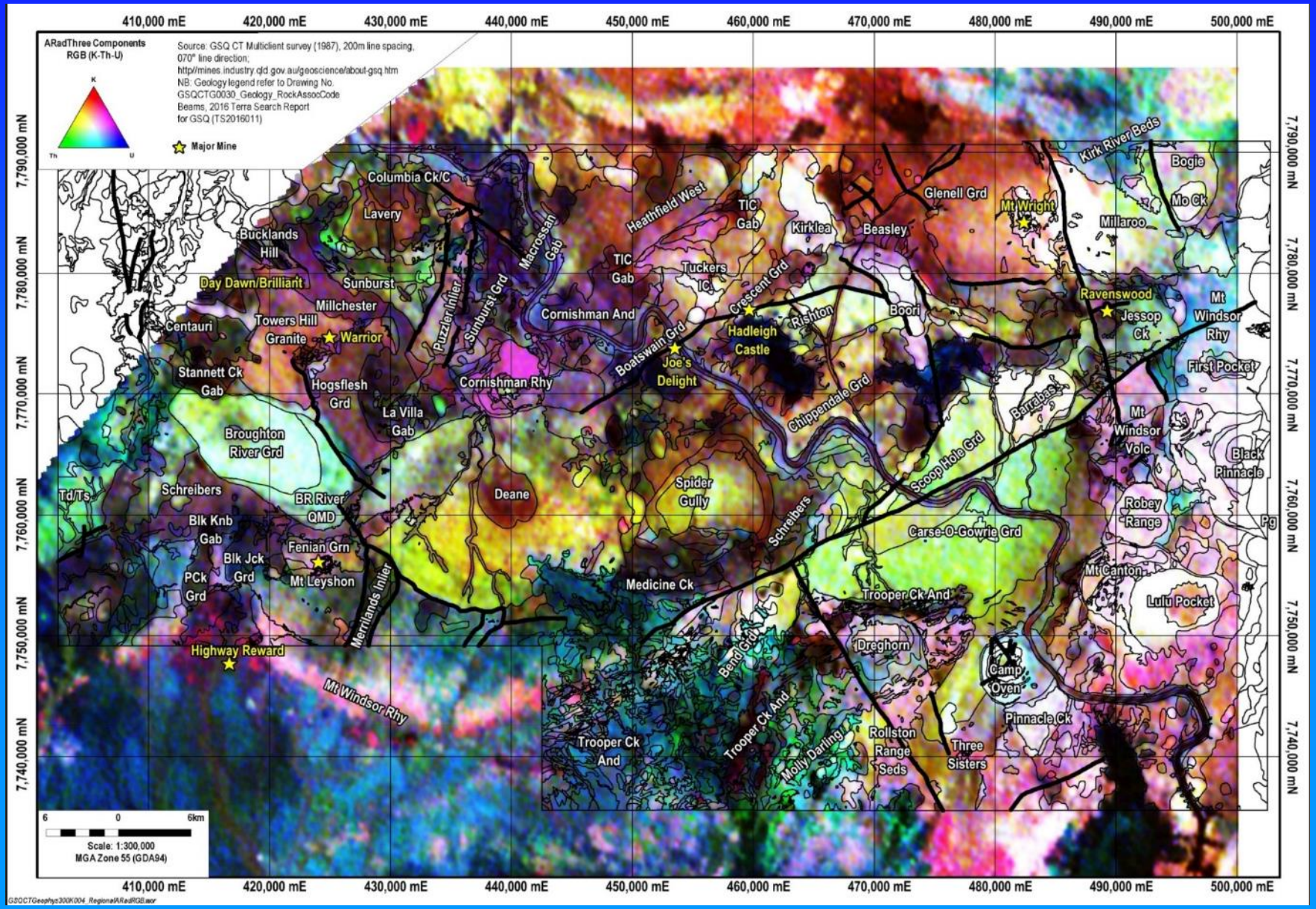
Charters Towers-Ravenswood Mean U per geology unit



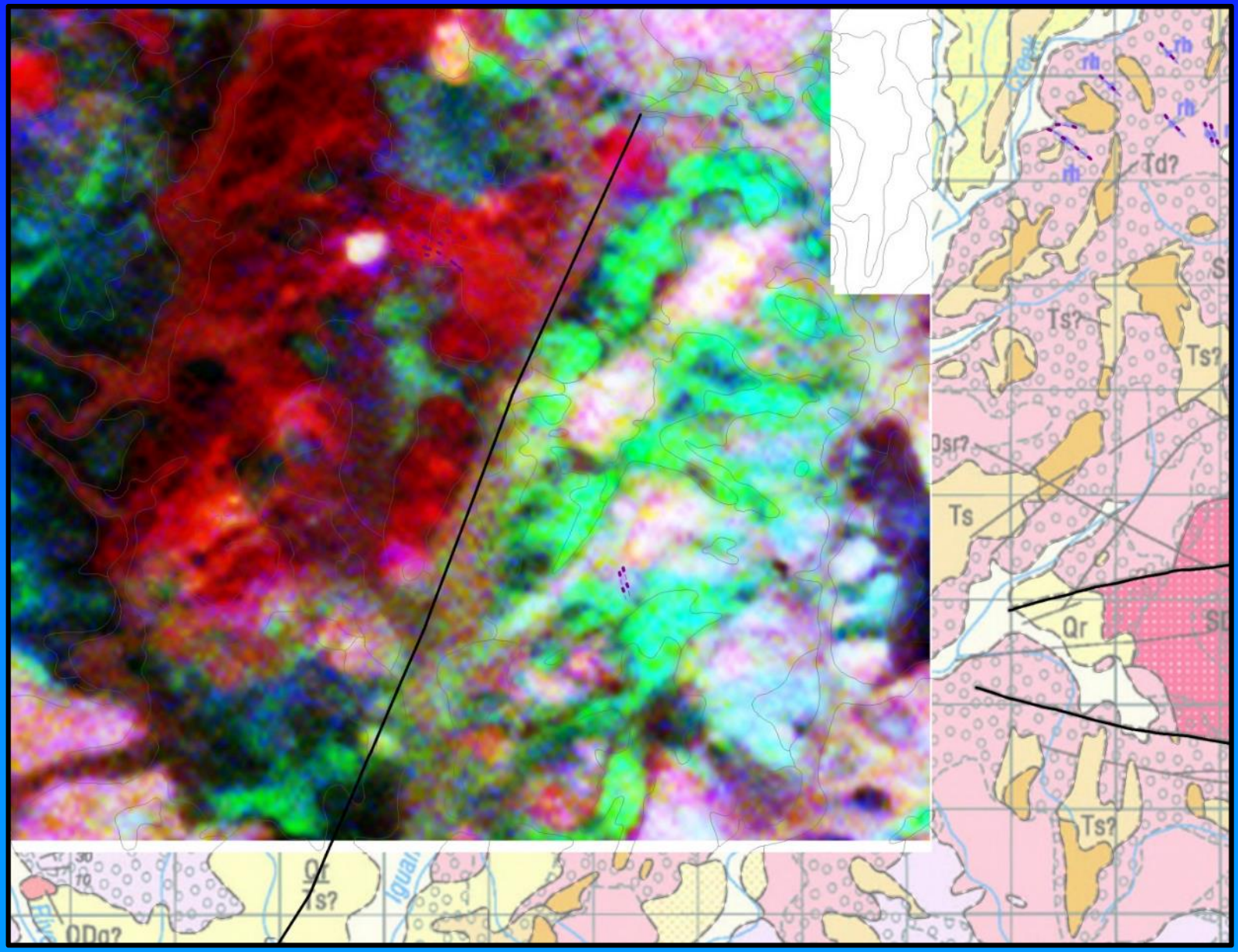
Charters Towers-Ravenswood Mean dose per geology unit



Charters Towers-Ravenswood RGB Radiometrics



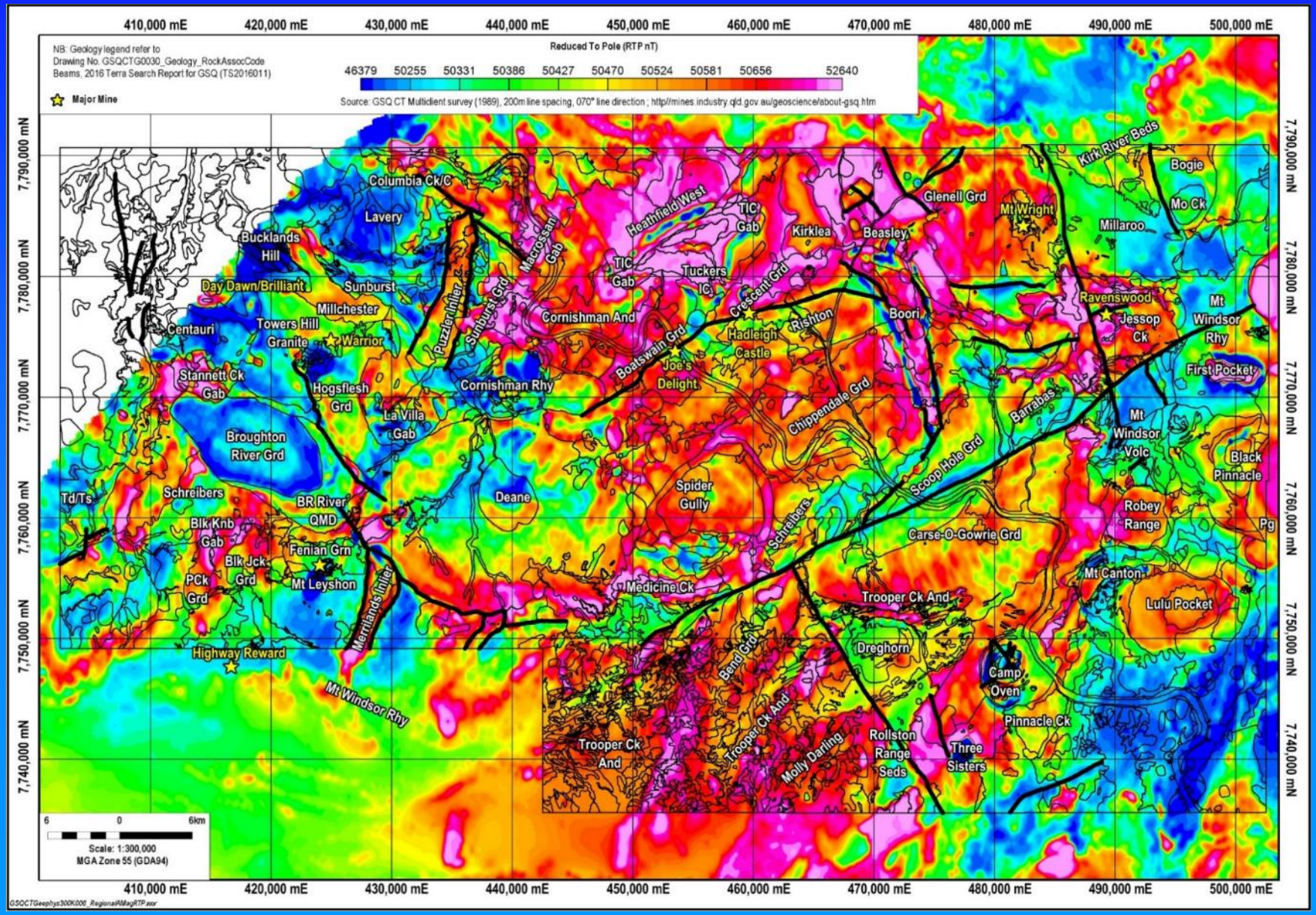
Radiometrics targeting altered intrusive systems
Example Plateau Prospect : SE Ravenswood100k



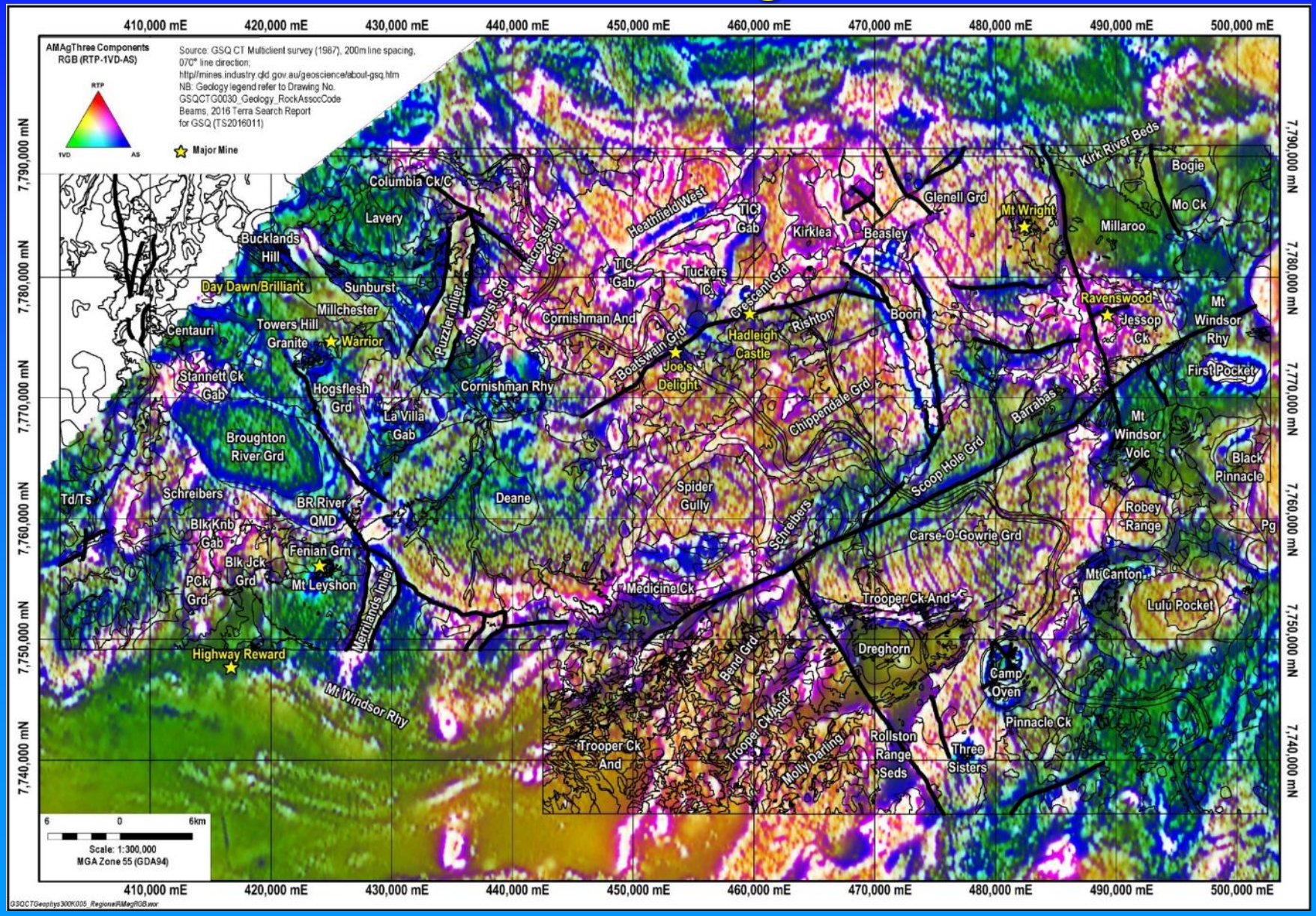
Charters Towers-Ravenswood Aeromagnetics

- Aero-magnetic features can at times closely delineate surface geology.
- Magnetics can of course “see“ below the surface, so it is particularly useful chasing units under transported or regolith cover.
- By the same token, magnetic patterns can be confusing if the magnetic anomaly results from a deeply buried feature or magnetic remanence is involved.

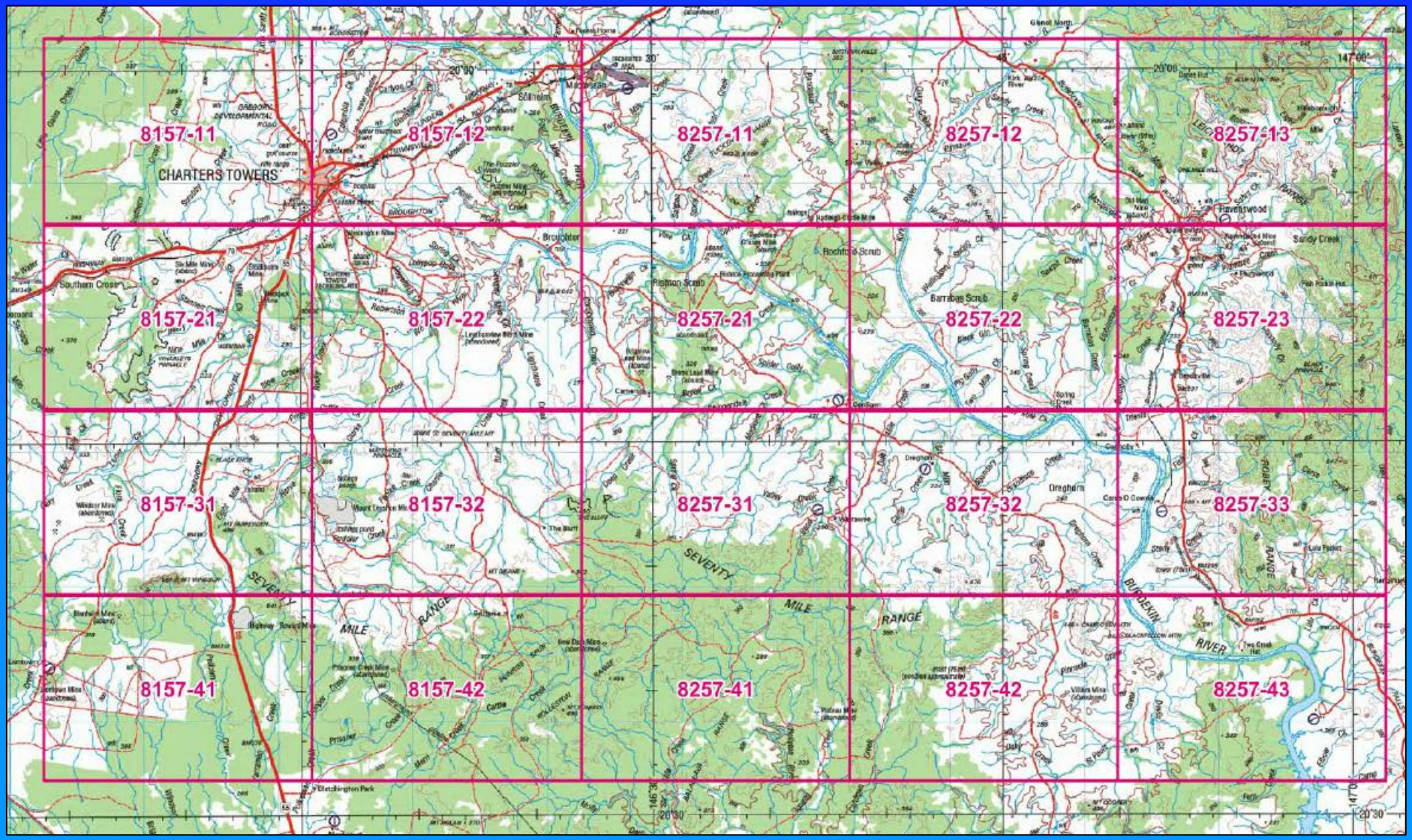
Charters Towers-Ravenswood RTP aero-magnetics

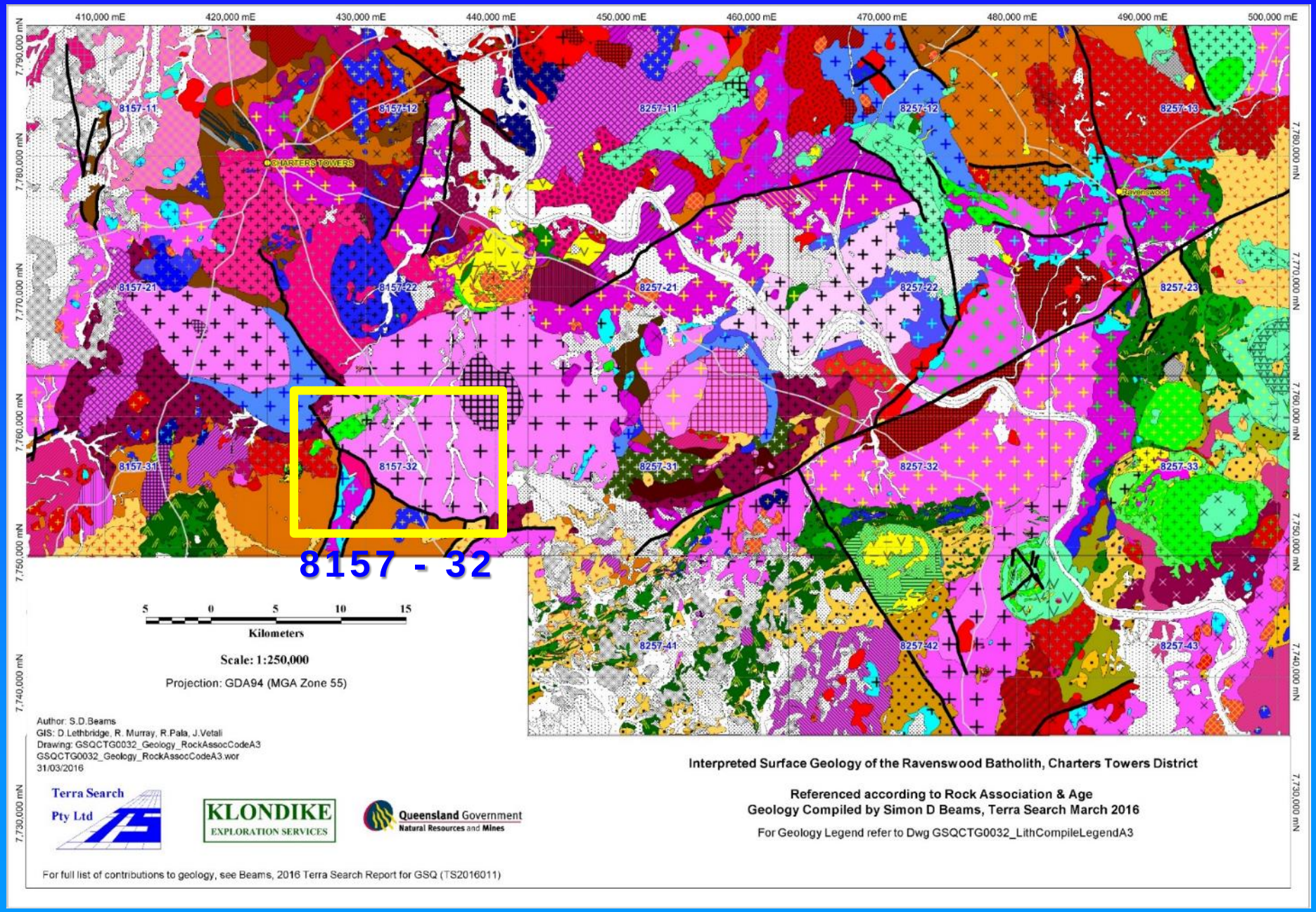


Charters Towers-Ravenswood 3 Component RTP-1VD-AS magnetics



Reprocessed & Restretched Geophysical data sets available across Ravenswood Batholith - map out regional geology

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CHARTERS TOWERS
Ravenswood
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Kilometers
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Projection: GDA94 (MGA Zone 55)
Author: S.D.Beams
GIS: D.Lethbridge, R. Murray, R.Pala, J.Vetali
Drawing: GSQCTG0032_Geology_RockAssocCodeA3
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31/03/2016
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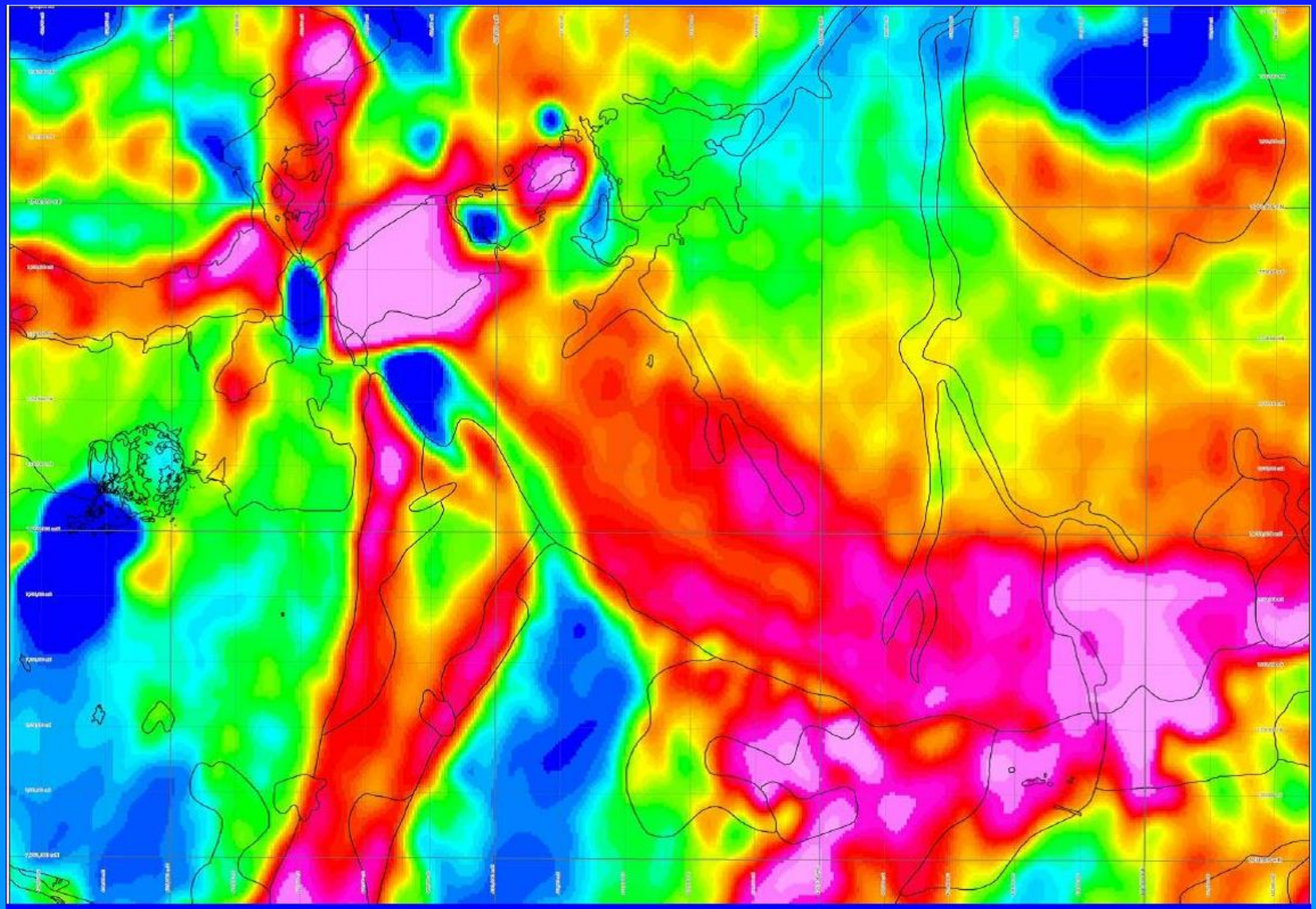
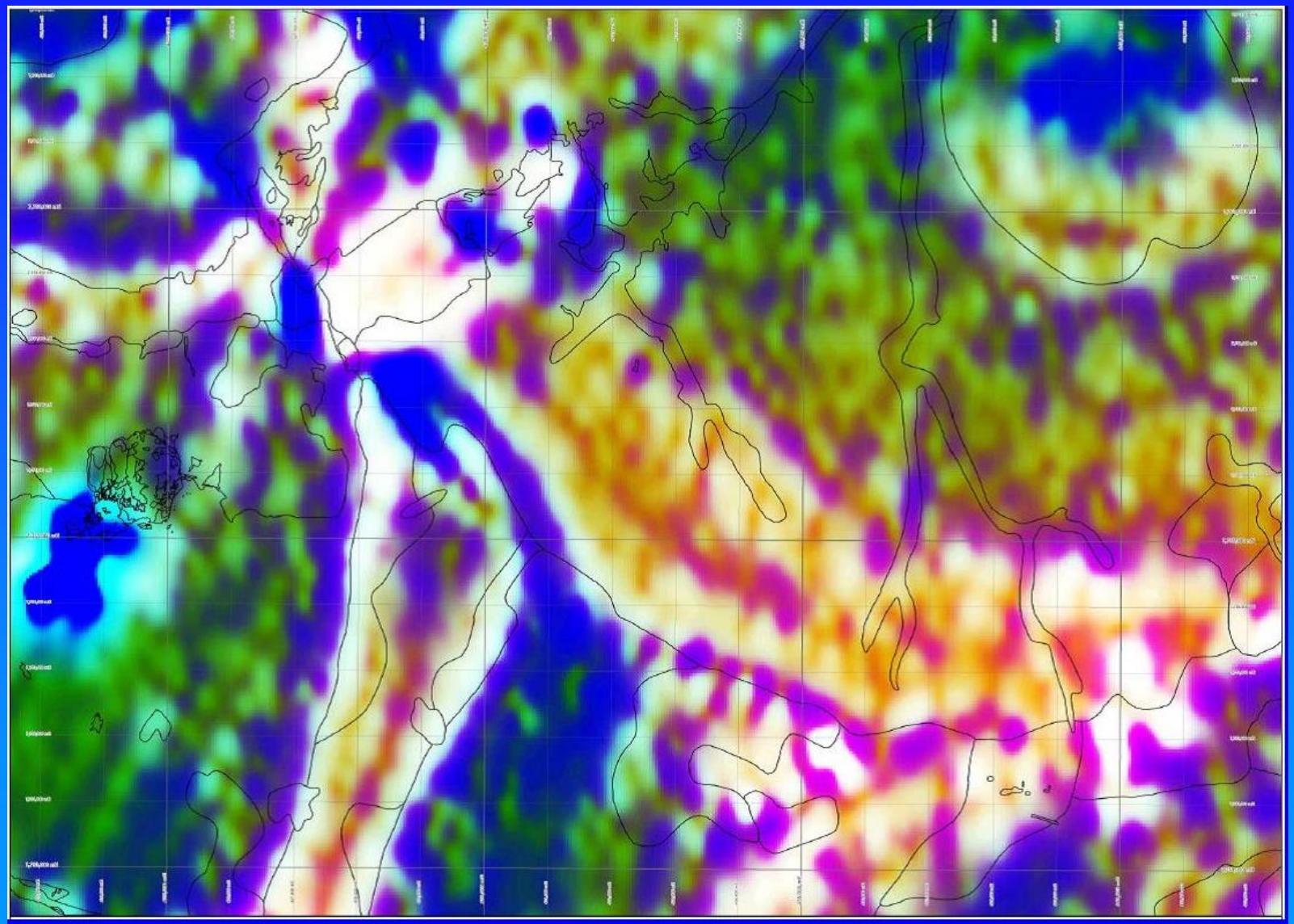
Queensland Government Natural Resources and Mines
For full list of contributions to geology, see Beams, 2016 Terra Search Report for GSQ (TS2016011)
Interpreted Surface Geology of the Ravenswood Batholith, Charters Towers District
Referenced according to Rock Association & Age
Geology Compiled by Simon D Beams, Terra Search March 2016
For Geology Legend refer to Dwg GSQCTG0032_LithCompileLegendA3

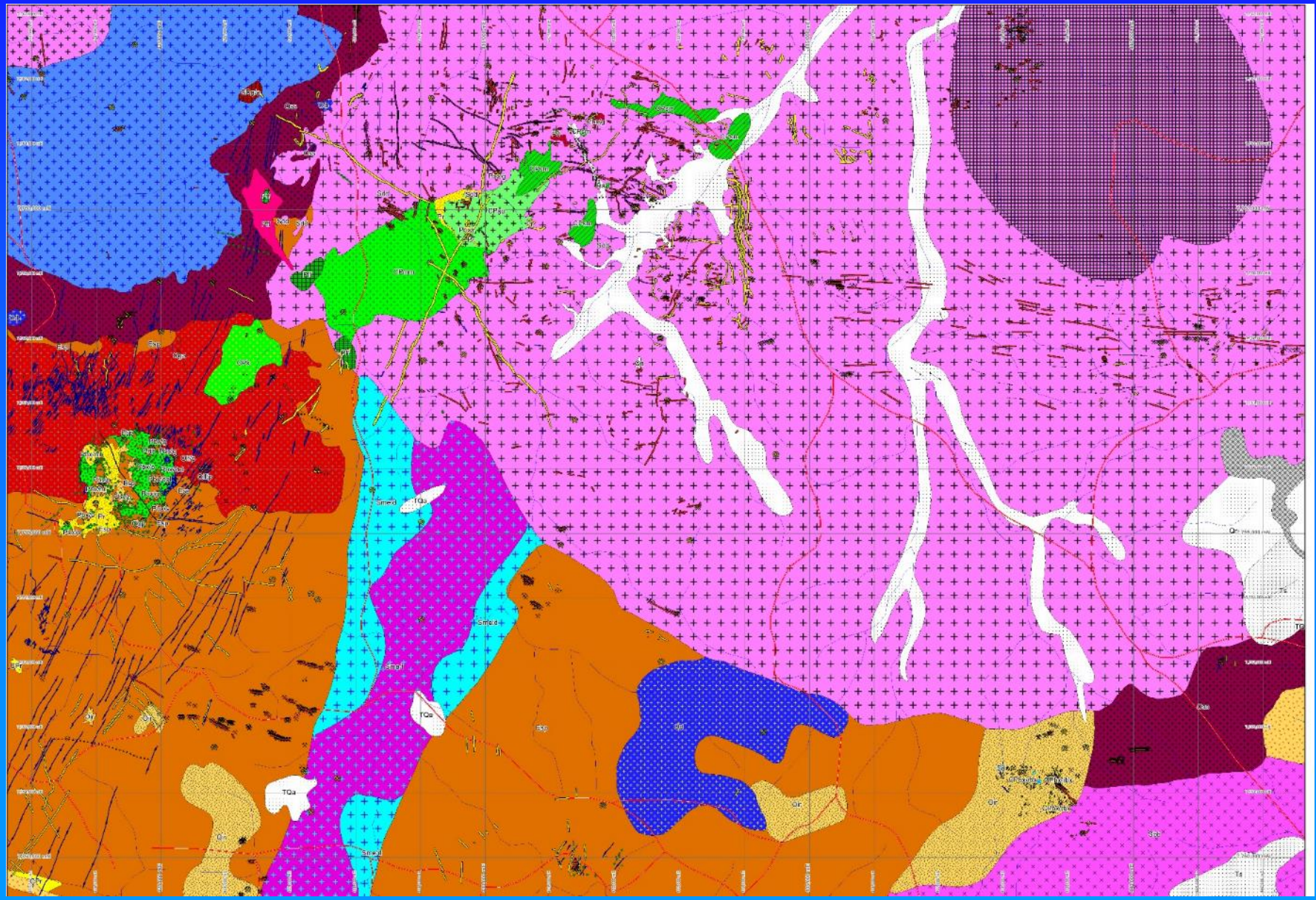


1:25k RTP Aero-mag 8157-32 Mt Leyshon area

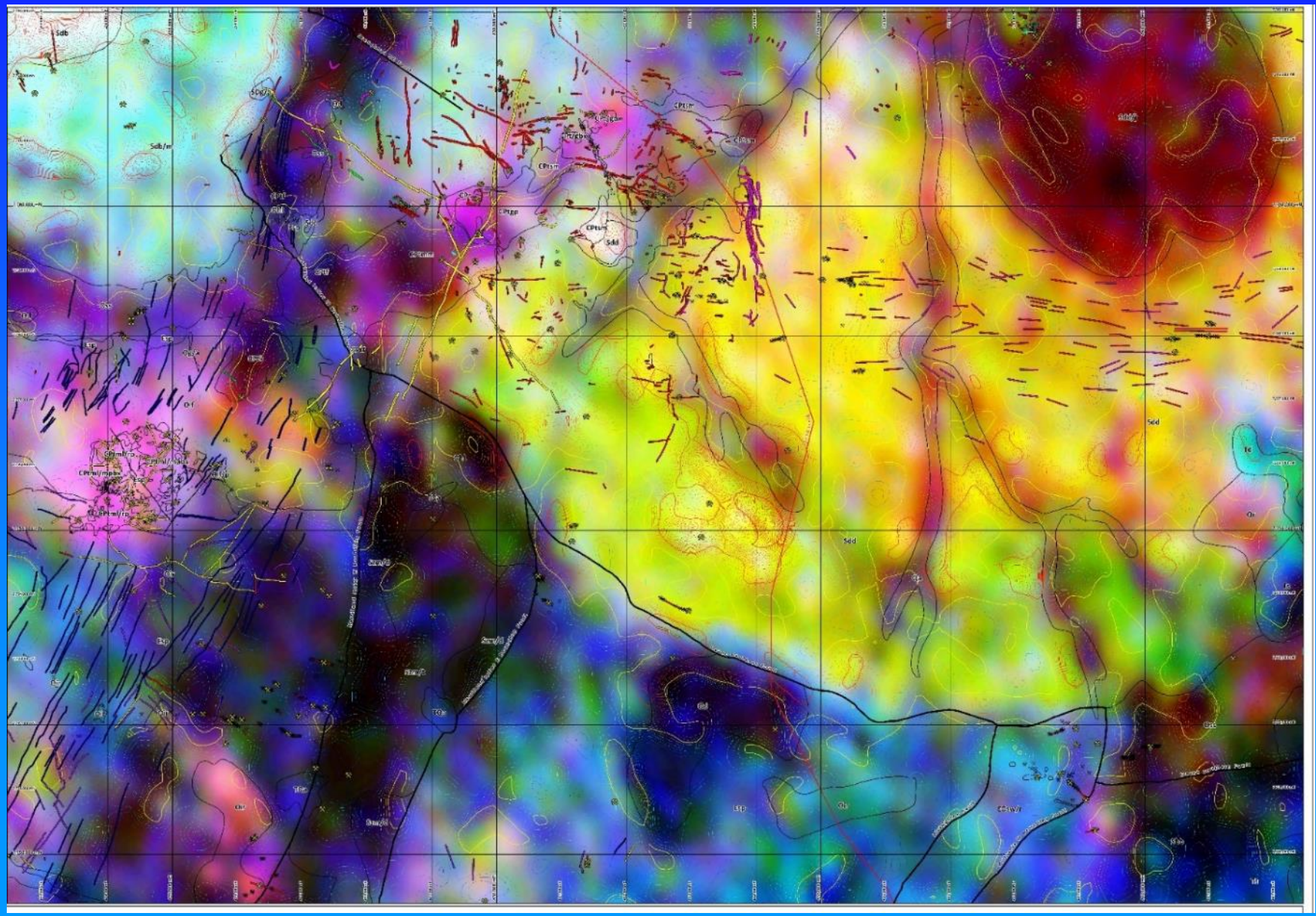


1:25k 3 component RGB RTP-1VD-AS Aero-mag 8157-32

8157-32 1:25k Geology



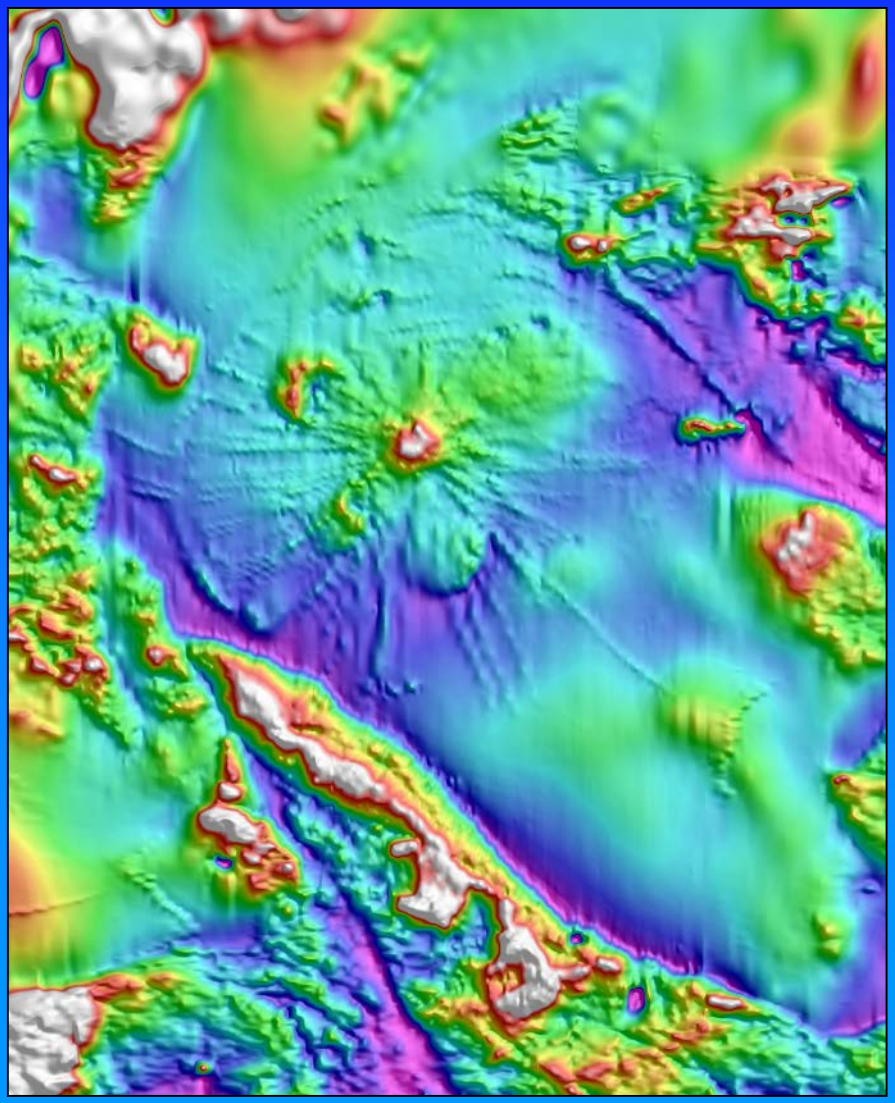
8157-32 RGB Radiometrics beautifully mapping out geology & alteration

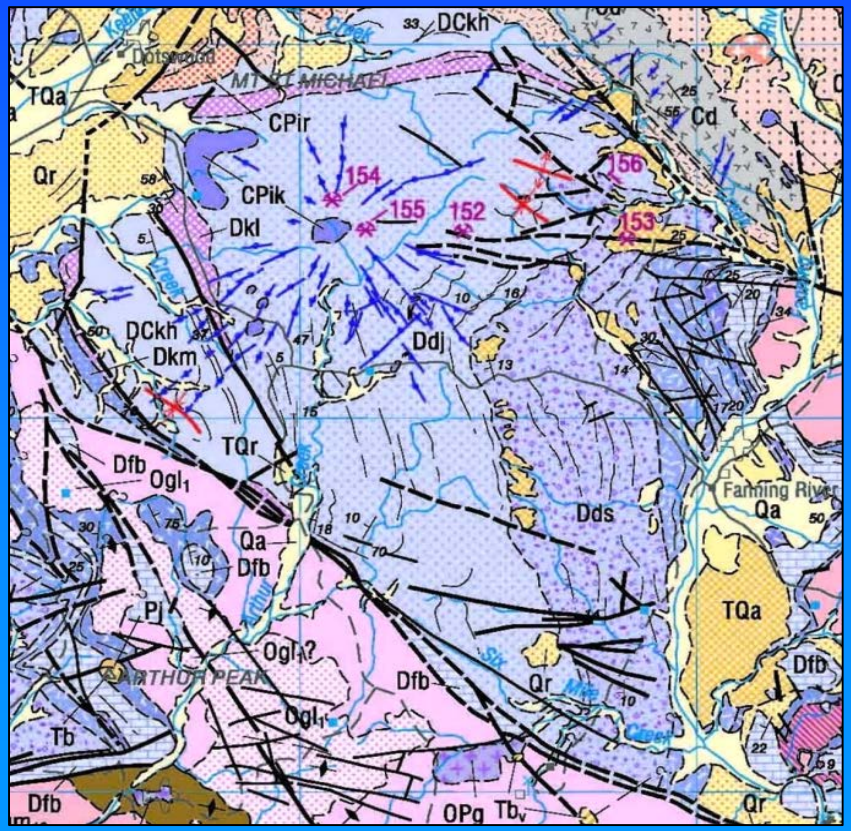


Magnetics can reveal full extent of Intrusive system eg Kitty O'Shea

- Prominent in the magnetics partly because it intrudes the magnetically quiet Devonian-Carboniferous sediments of the Burdekin Basin.
- The overall complex has a 9 km radius with the margin marked by a ring fault that most likely reflects the extent of the underlying pluton.
- A central exposed diorite plug is the source of the radial dyke swarm.
- Multiple satellite plugs with their own ring faults and breccia bodies and mineralisation reflected in the mag highs and structures e.g. the Macalite Hill gold breccia east of the plug, Far Fanning gold mine and Middle Ridge that are on dyke swarm and structures 3.5-5 km east of the plug.

Magnetics can reveal full extent of Intrusive system eg Kitty O'Shea





Magnetic Reversals in N Qld : An inherited signature that can link the age of an intrusion to the main gold mineralizing epoch.

- Late Carboniferous – Early Permian is the main epoch associated with intrusive related gold mineralization in the Charters Towers Province
- Late Carboniferous – Early Permian was a time when the earth's magnetic field was dominantly reversed. Kiama Superchron (312-262Ma).
- The majority of the large systems are reverse magnetic anomalies

Magnetic Reversals in N Qld : Providing an indication of Intrusive Level (1)

- The most prospective exploration targets are buried systems, close enough to surface that their character can still be discerned.

- Favourable intrusions for mineralisation are those that are zoned and have internal complexity due to multiple intrusions, cross-cutting relationships, with signs of hydrothermal activity such as alteration, sulphide development, and fluidized and mineralized breccia zones. These features show up well in magnetics, radiometrics and I.P.

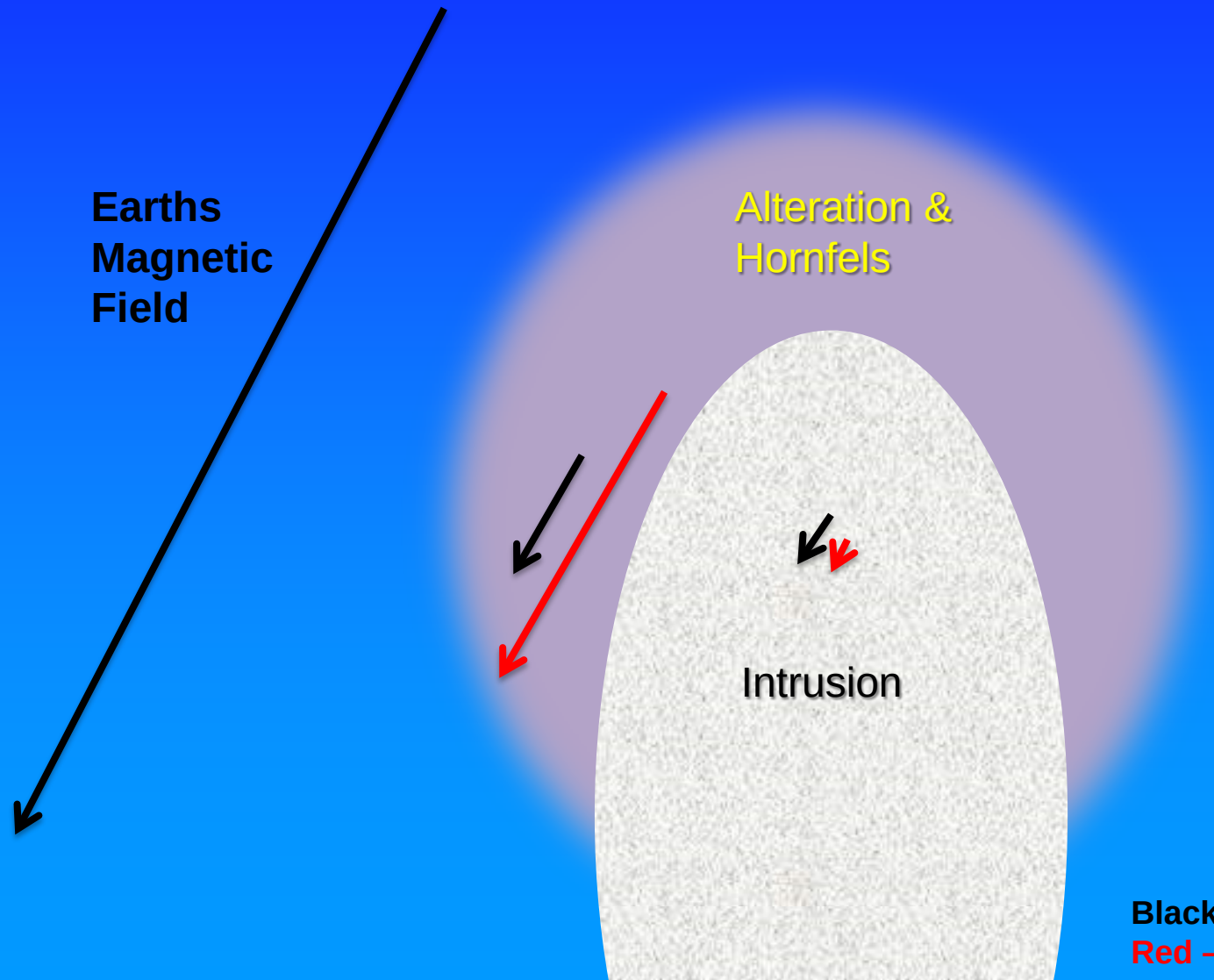
Magnetic Reversals in N Qld : Providing an indication of Intrusive Level (2)

- These reverse anomalies have strong remanent magnetisation resulting from magnetite-biotite alteration or hornfels on the margins of Permo-Carboniferous zoned sub-volcanic intrusions.

- a valuable indicator of intrusive-hydrothermal systems with potential for intrusion-related gold systems (IRGS).

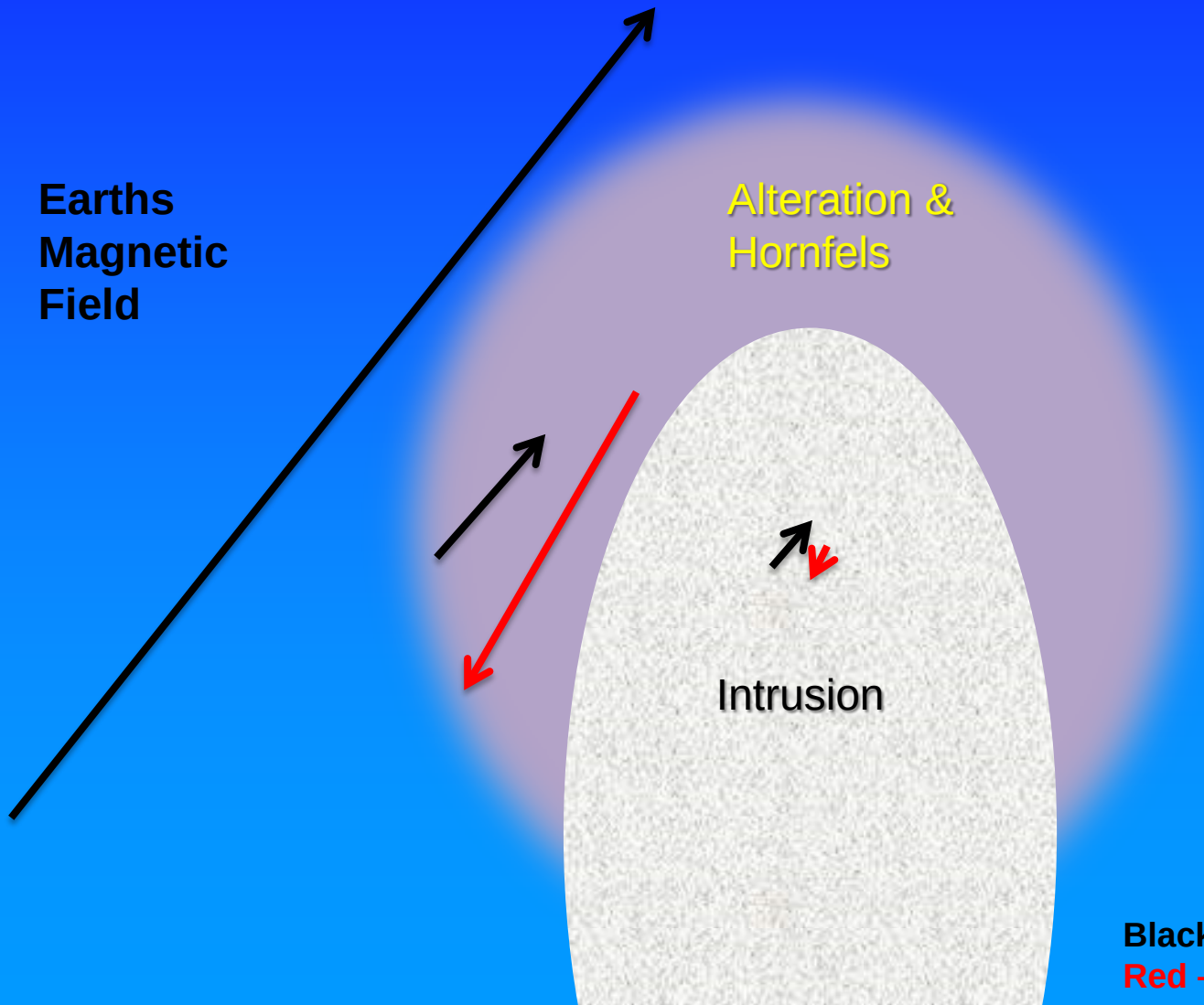
- IRGS that have distinctive magnetic features, such as the Tuckers and Boori Complexes, are eroded to pluton level, so that any associated mineralisation has already been lost.

Permo-Carb Field



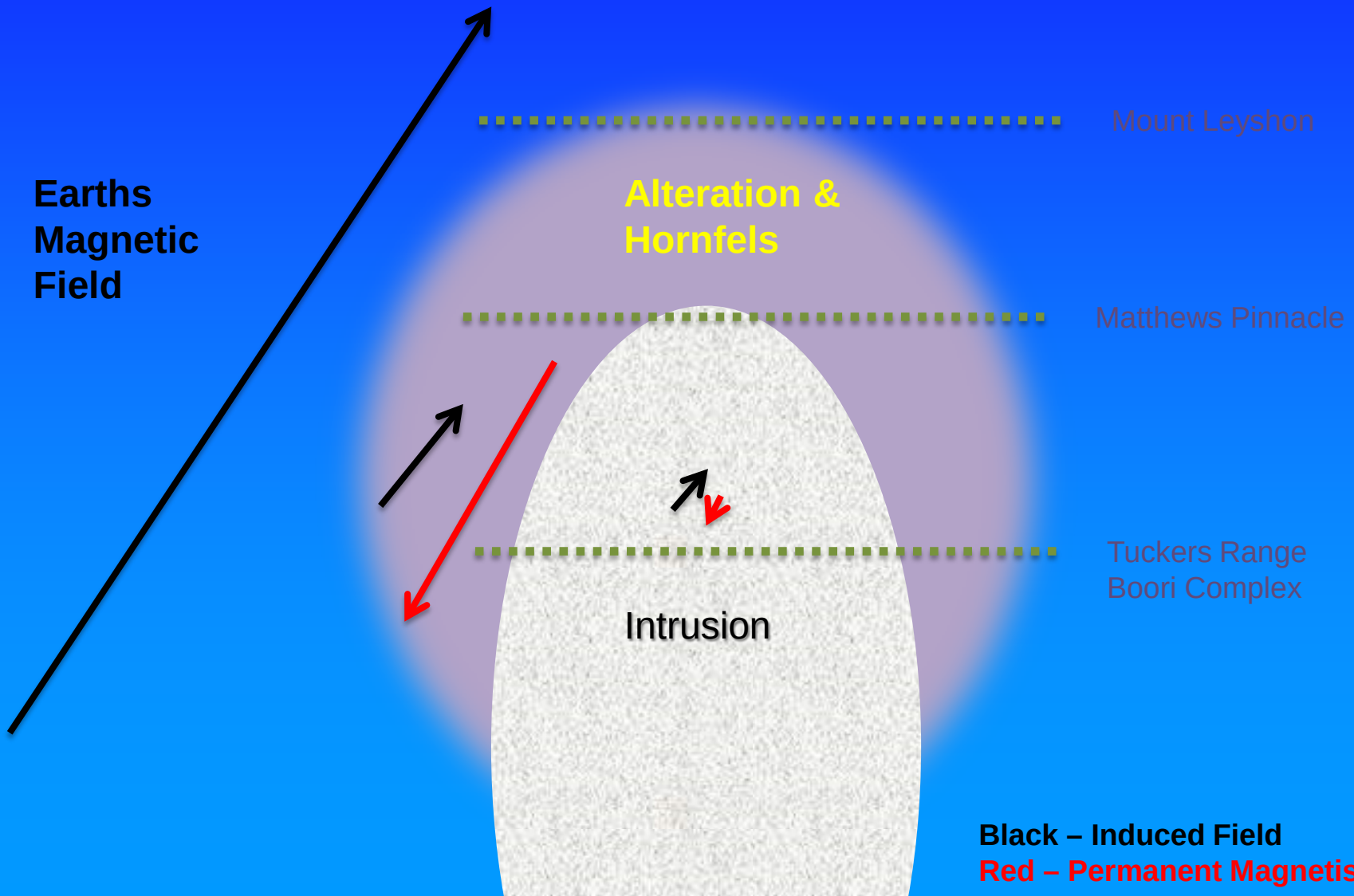
Black – Induced Field
Red – Permanent Magnetisation

Present Field



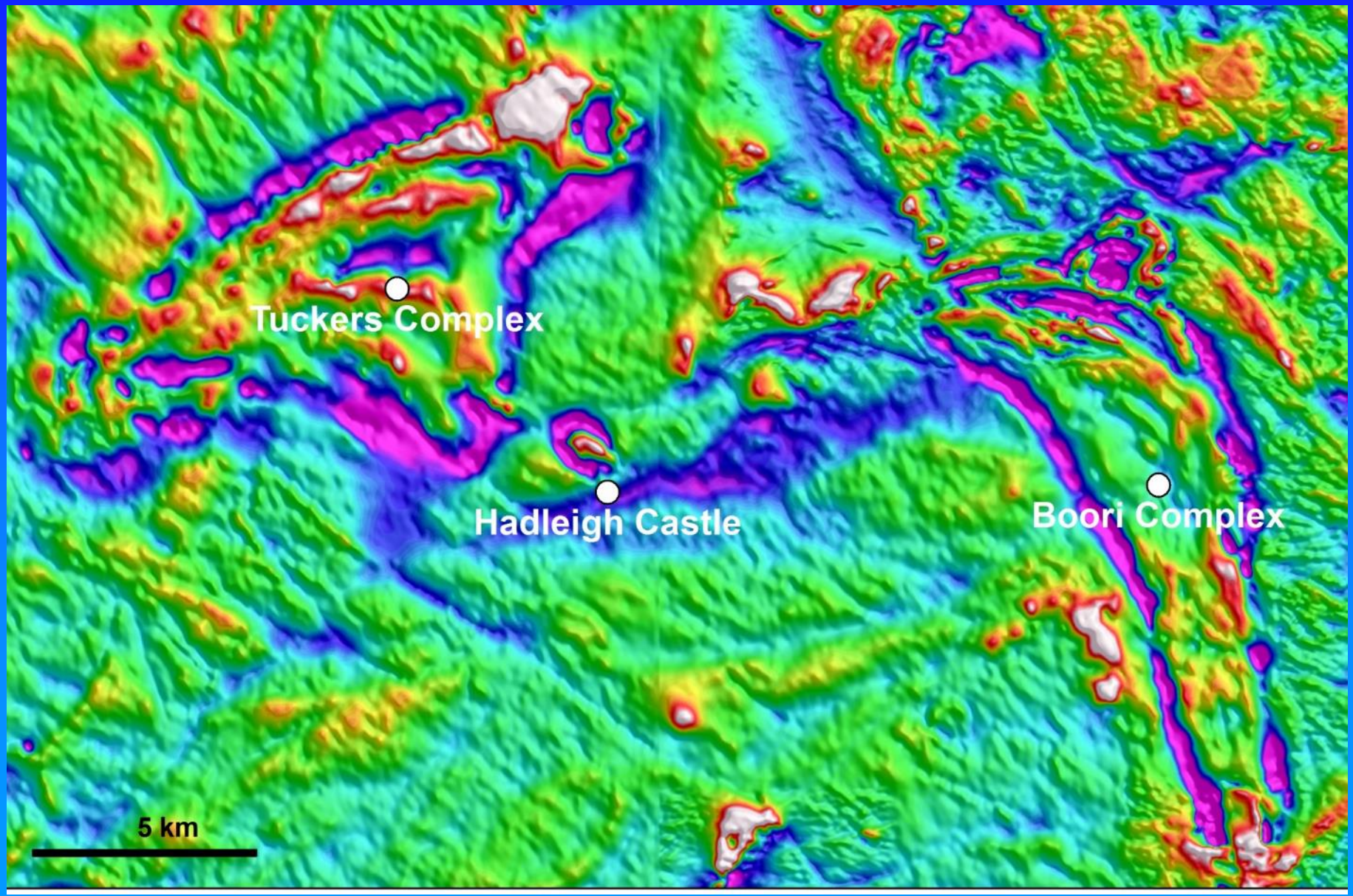
Black – Induced Field
Red – Permanent Magnetisation

Present Field

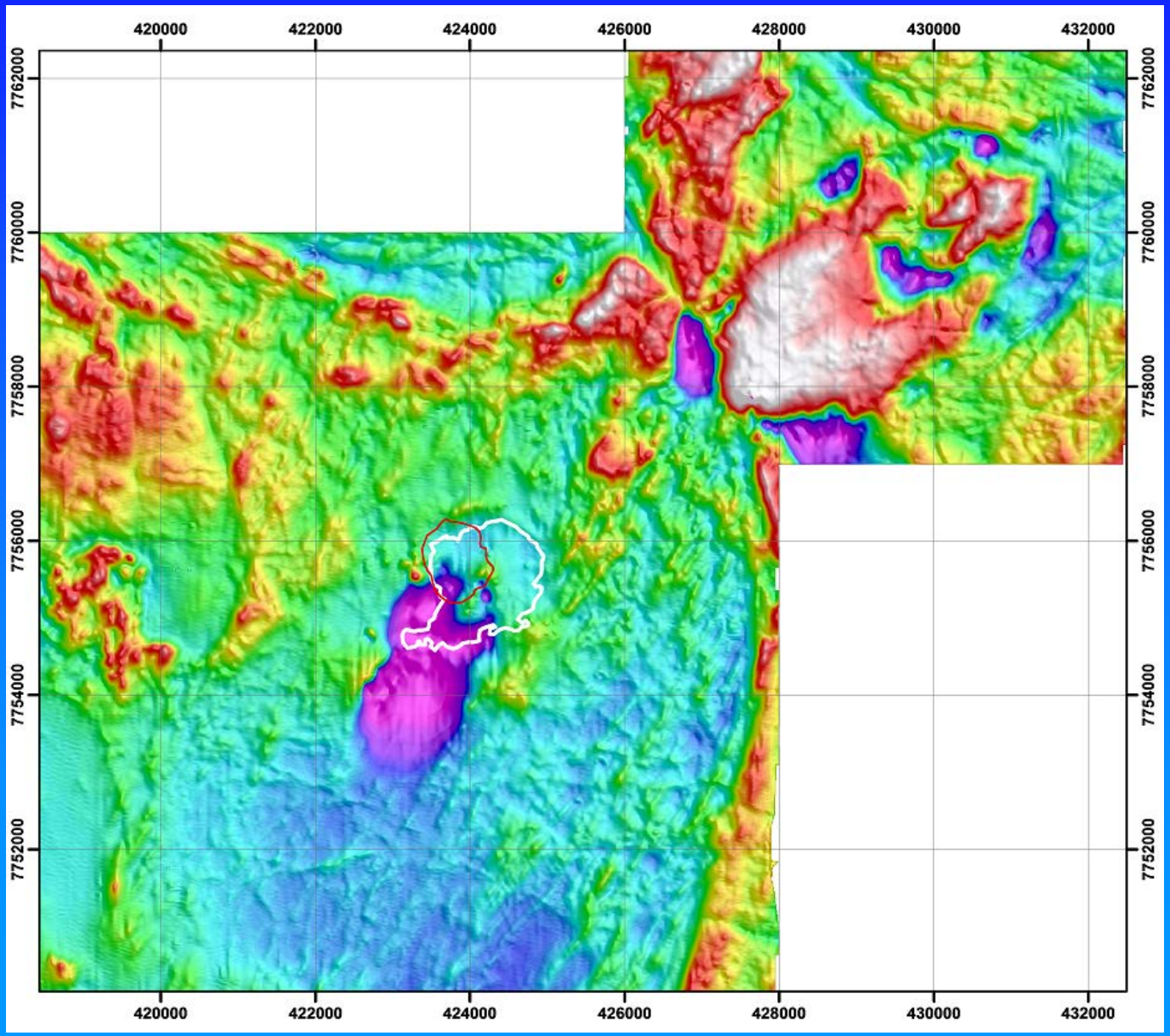


Black – Induced Field
Red – Permanent Magnetisation

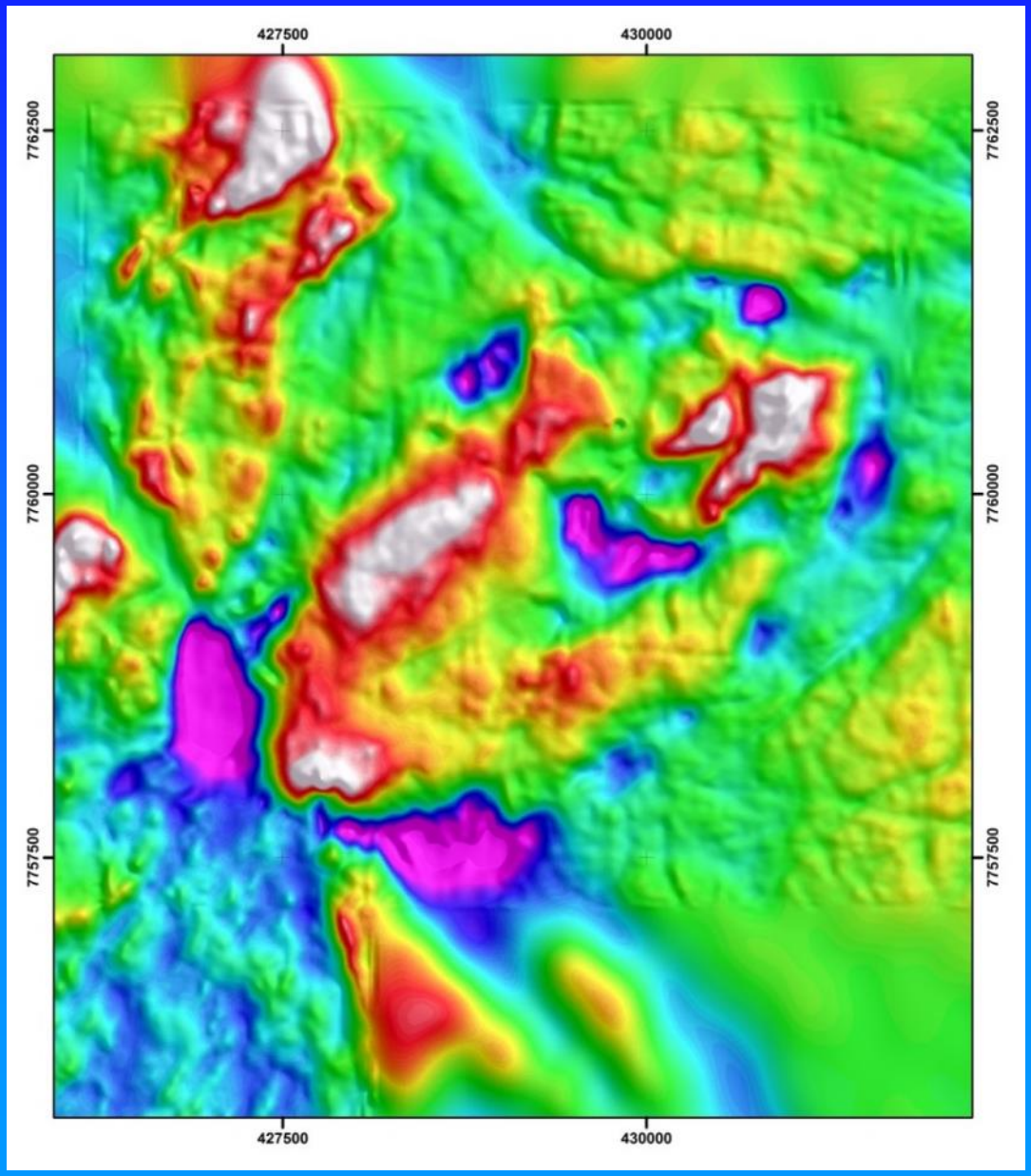
Tuckers Range and Boori Complex – RTP Plutonic Level



Matthews Pinnacle & Mt Leyshon RTP

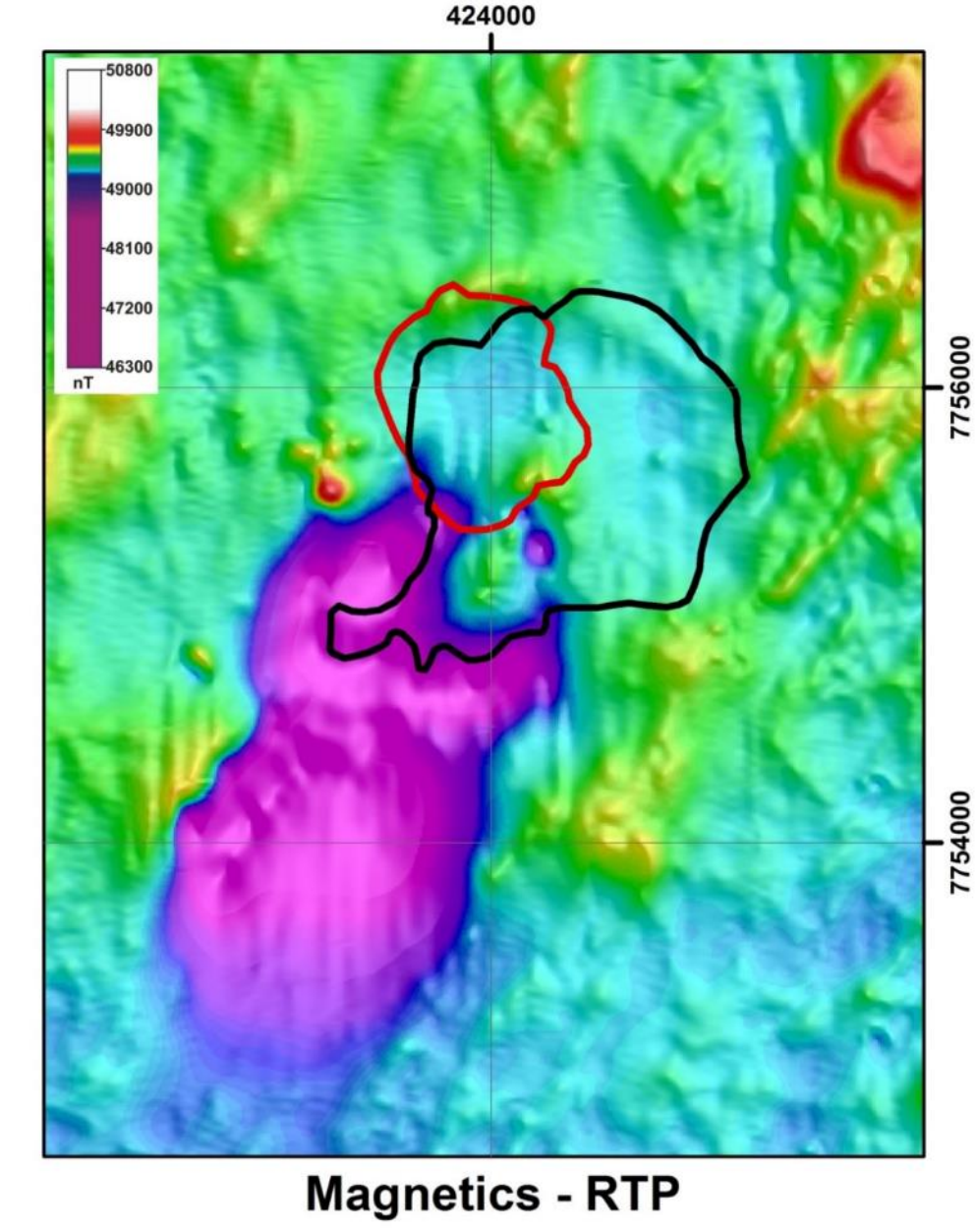


Matthews Pinnacle High Level Plutonic Level



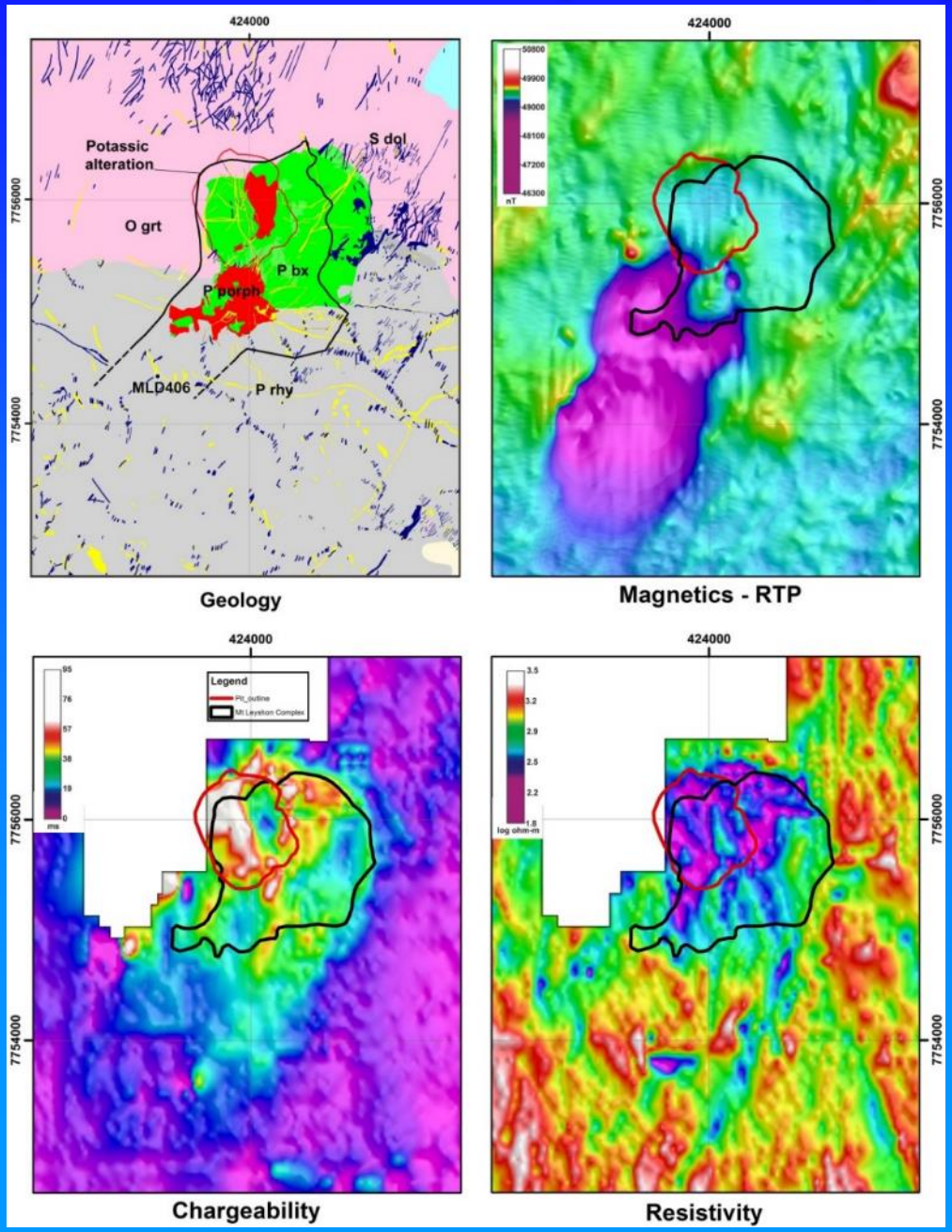
- Intrusive complex zoned inwards from diorite, qtz diorite, granodiorite to granite
- Multiple lobes of remanently magnetised, magnetite-biotite altered diorite forming a halo around complex
- similar measured remanence direction to Mt Leyshon

Mount Leyshon Sub Volcanic Level



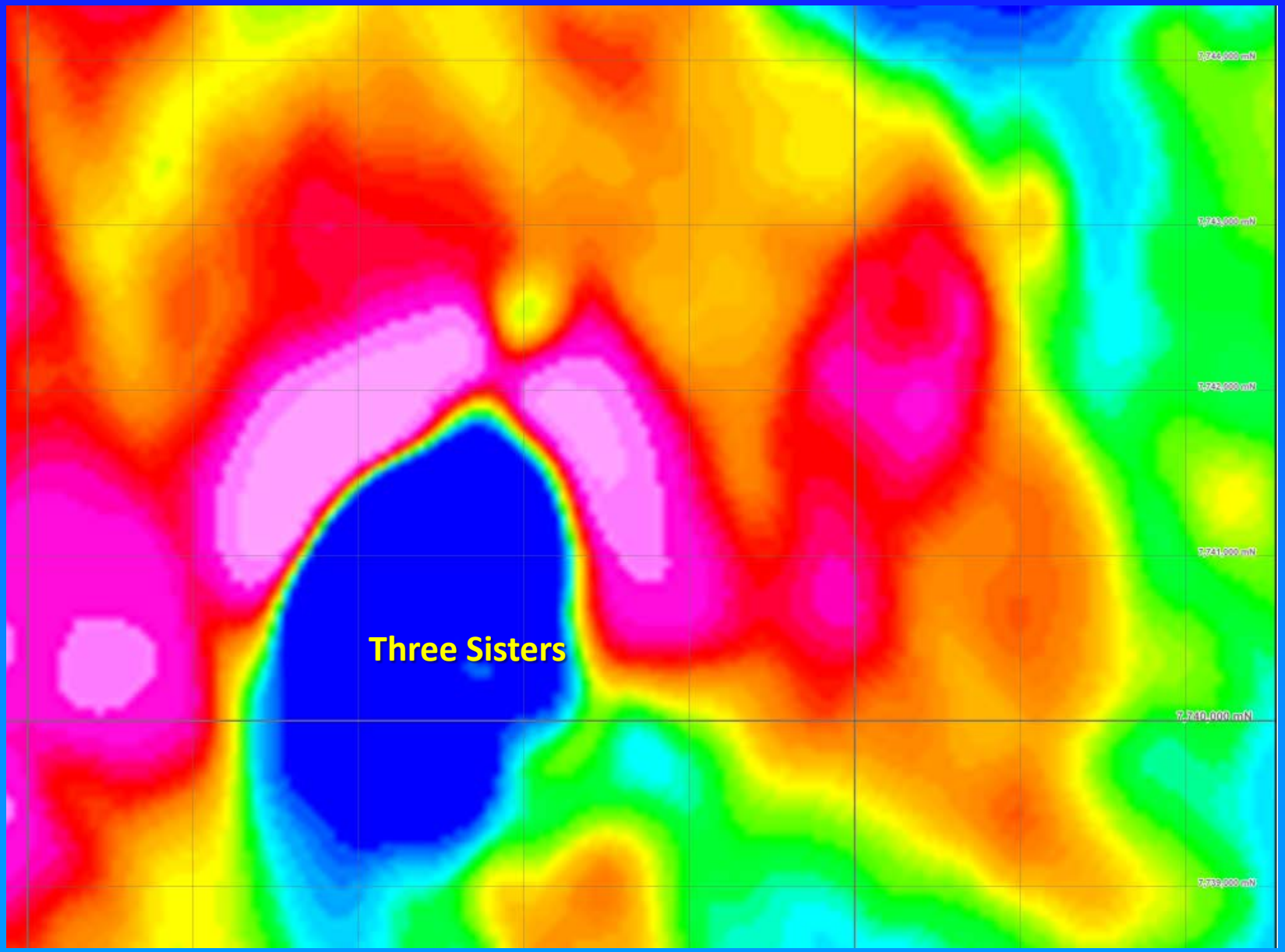
- Early phase biotite-magnetite alteration of dolerite and metasiltstones(hornfells?) and associated quartz magnetite veins.
- Intrusion not exposed
- The magnetite is fine grained and retains a stable remanence with Qs ~ 3-10
- Complex formed during long period of magnetic field reversal with the remanence direction S and steep down

Mount Leyshon Geophysical Response

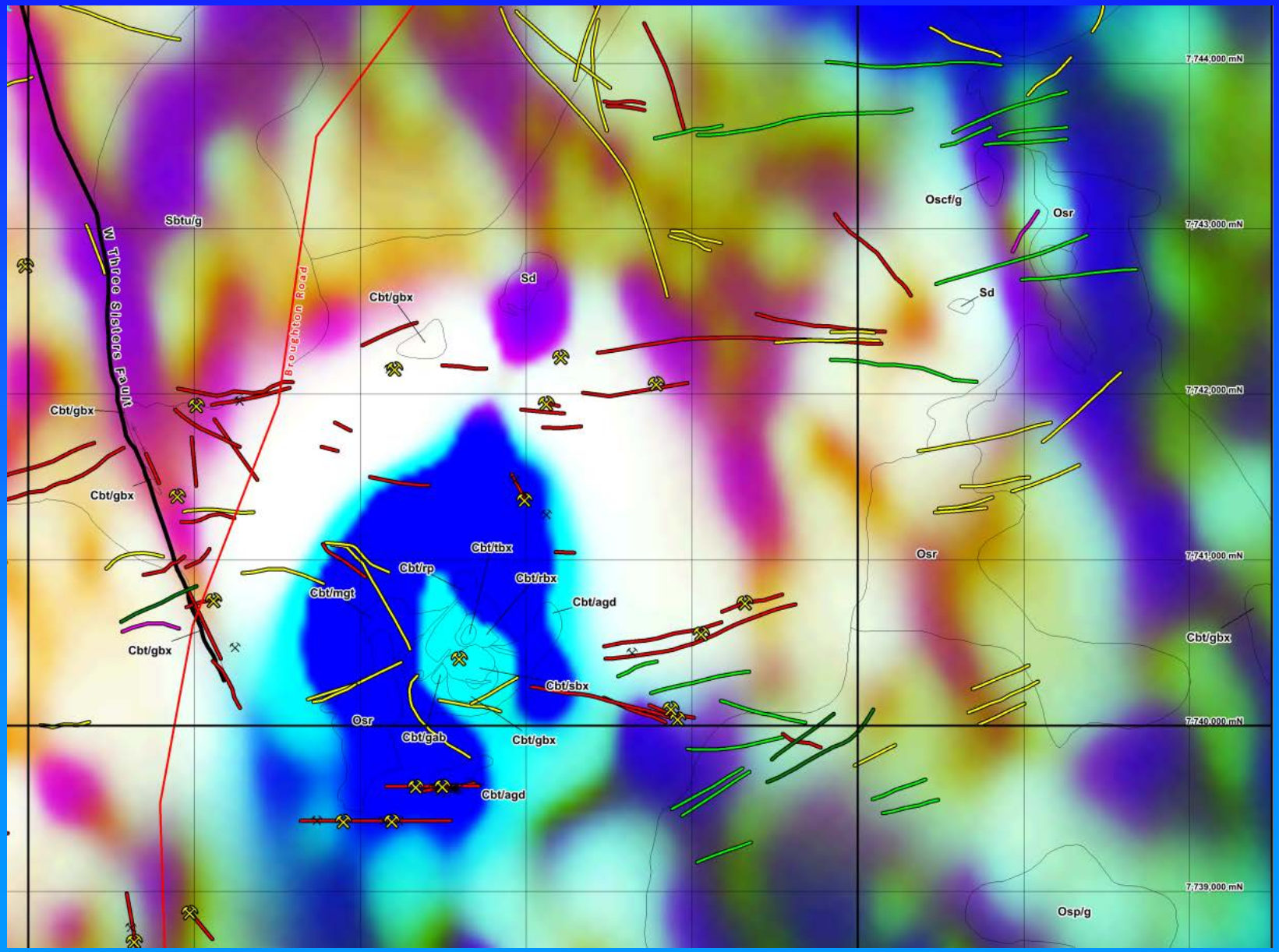


- Broad intense magnetic low of about 2000nT immediately SW of the breccia complex.
- Intense phyllic alteration associated with the complex has destroyed magnetite.
- Intense chargeability anomaly of >60ms due to pyrite sericite alteration
- Resistive low due to interconnected sulphides in breccia matrix or clay in the weathered zone

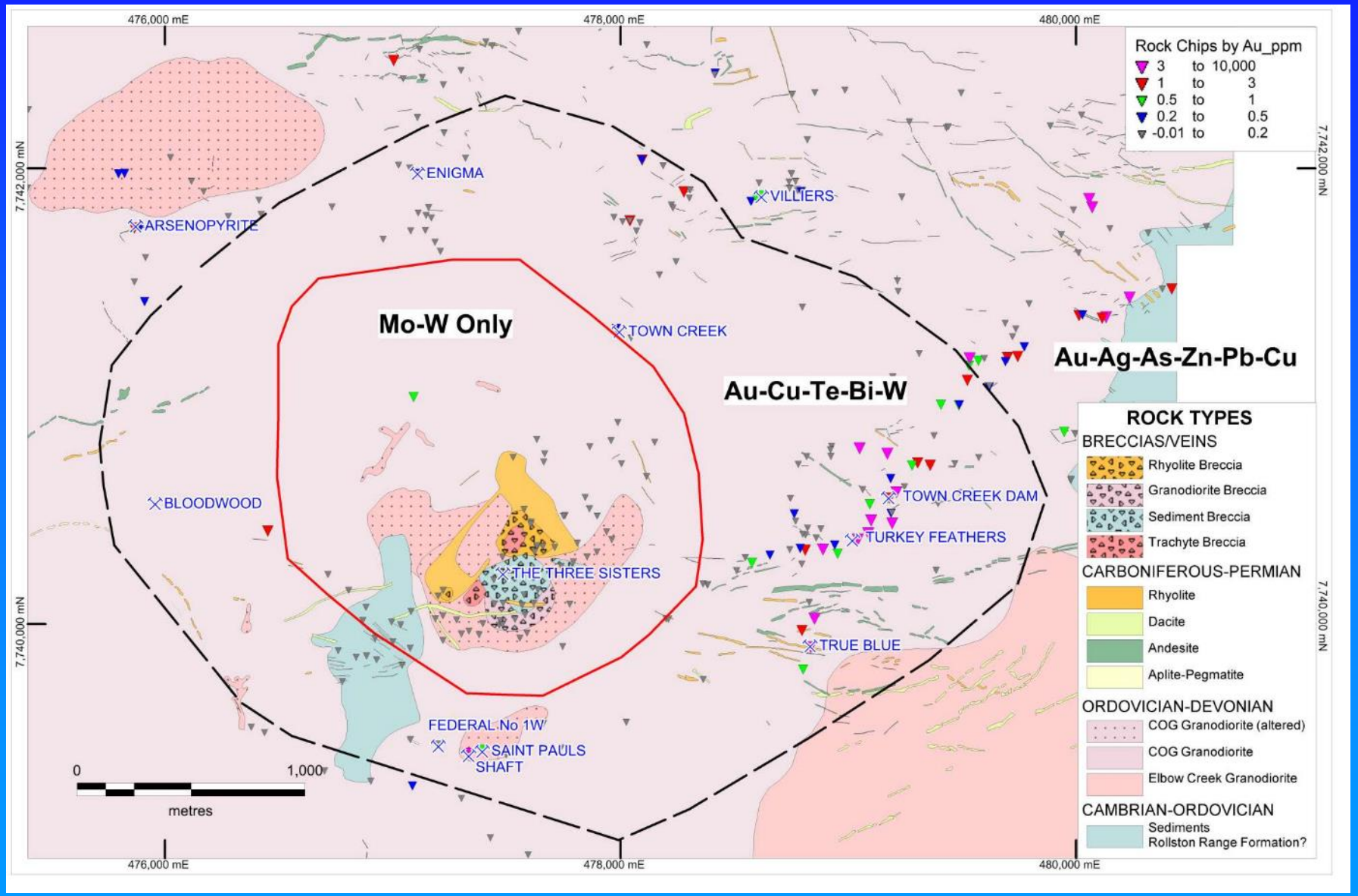
Three Sisters : Aeromagnetics RTP



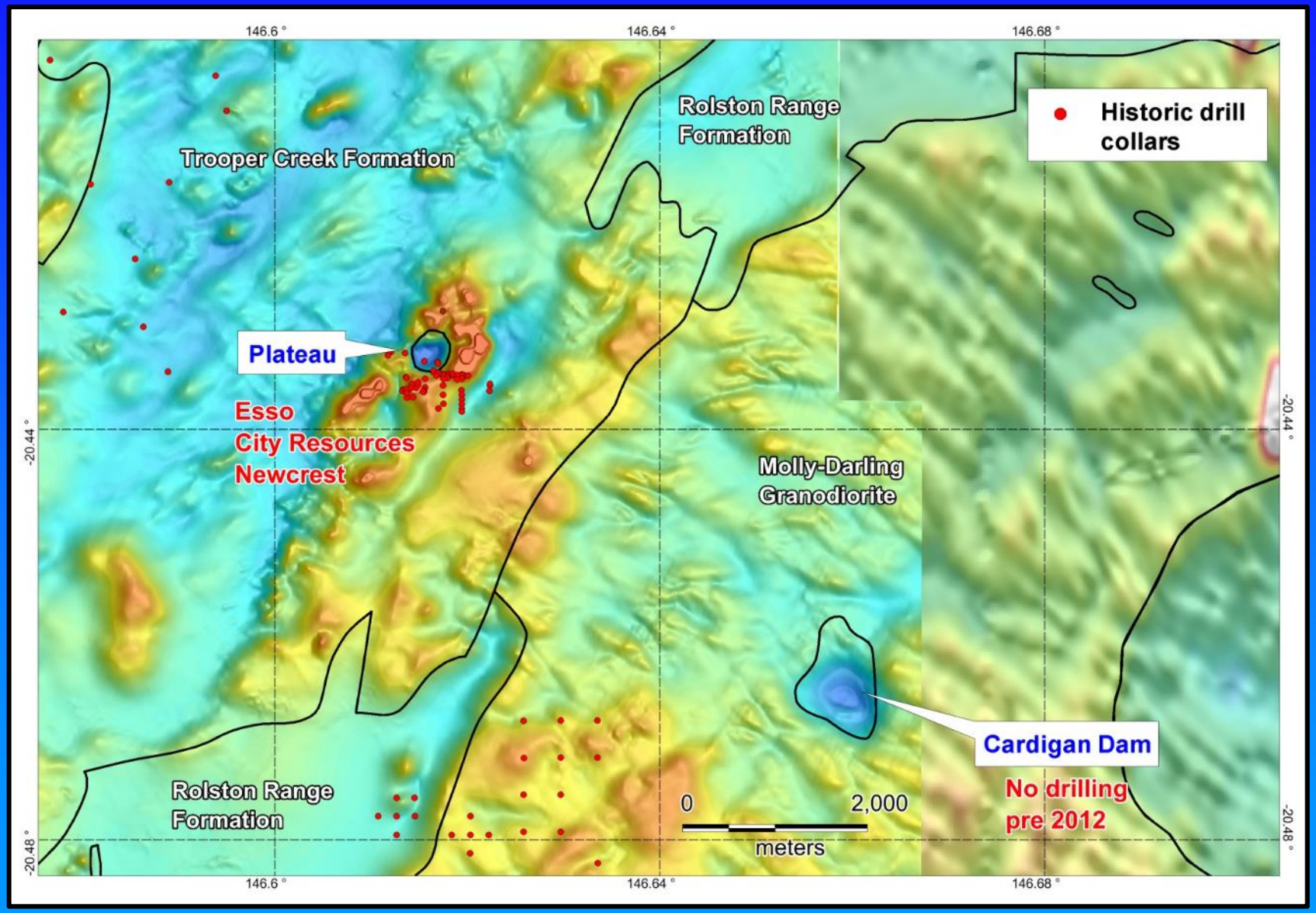
Three Sisters : Aeromagnetics RGB



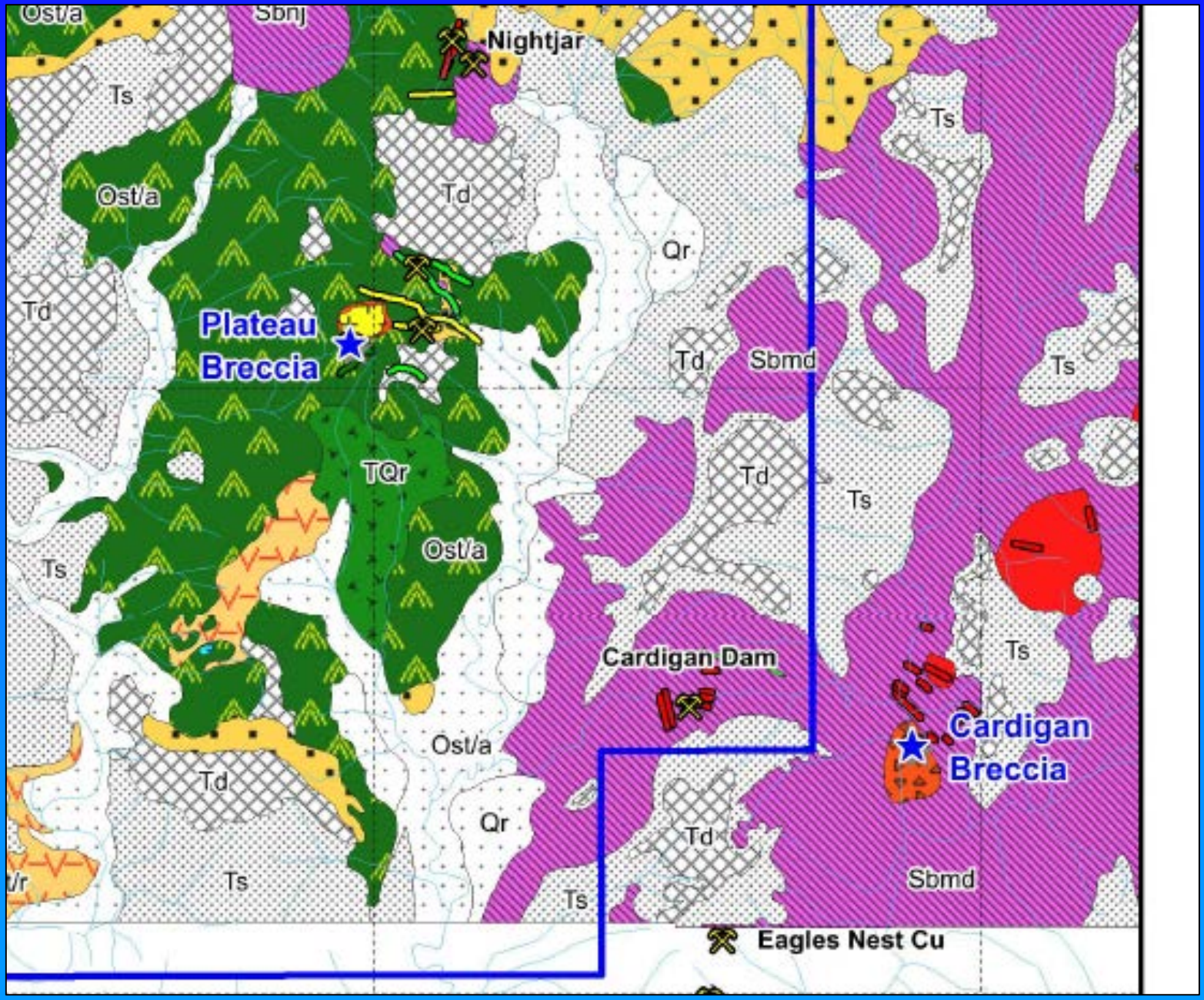
Ravenswood District: Three Sisters metal zoning



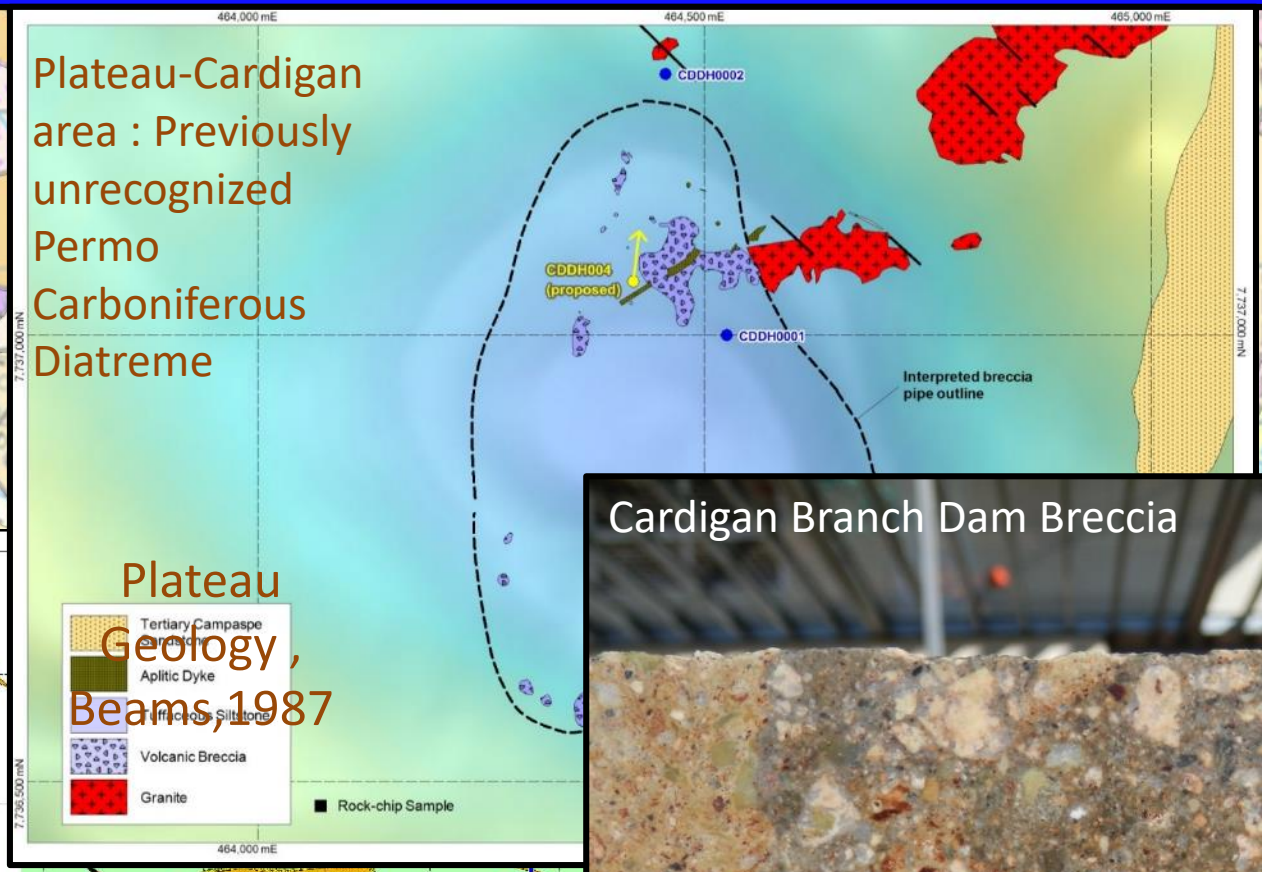
Plateau Cardigan Dam Aeromagnetic Lows



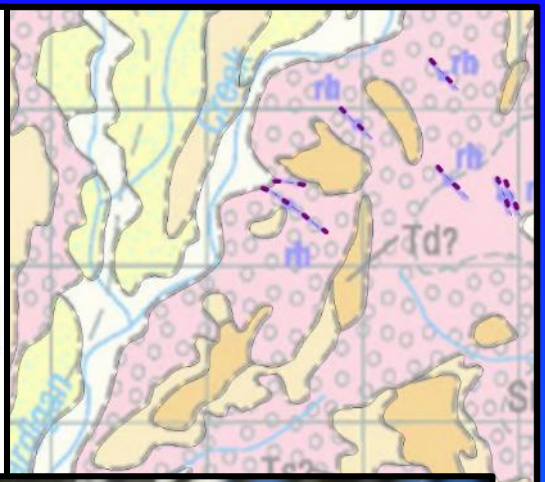
BGM Investments

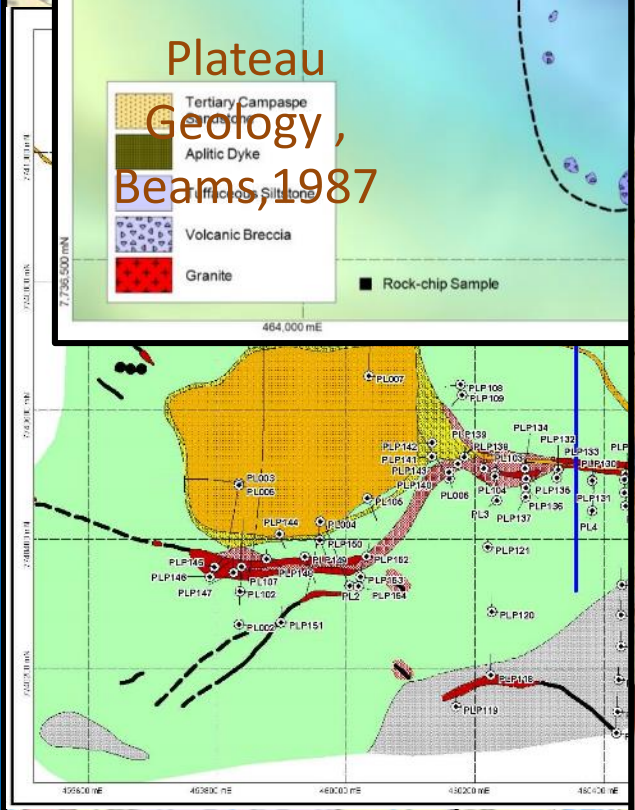

Ost/a
Sbnj
Nightjar
Ts
Ost/a
Td
Qr
Td
Plateau
Breccia
Td
Sbmd
Ts
TQr
Td
Ts
Ost/a
Ts
Cardigan Dam
Ts
Cardigan
Breccia
Ost/a
Td
Qr
Td
Ts
Ts
Sbmd
Eagles Nest Cu

Plateau-Cardigan area : Previously unrecognized Permo Carboniferous Diatreme



Plateau Geology , Beams,1987





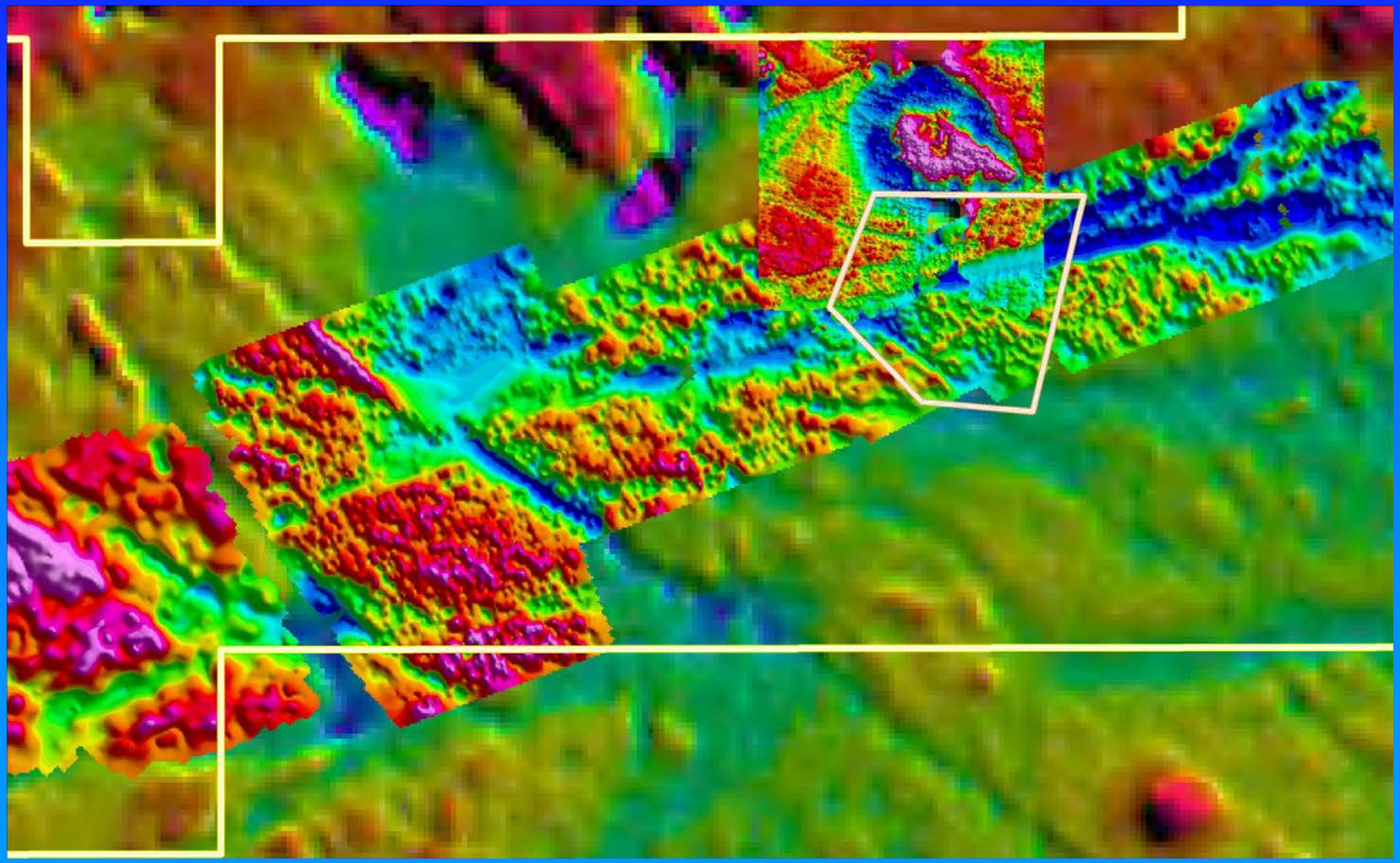
Cardigan Branch Dam Breccia

Grd

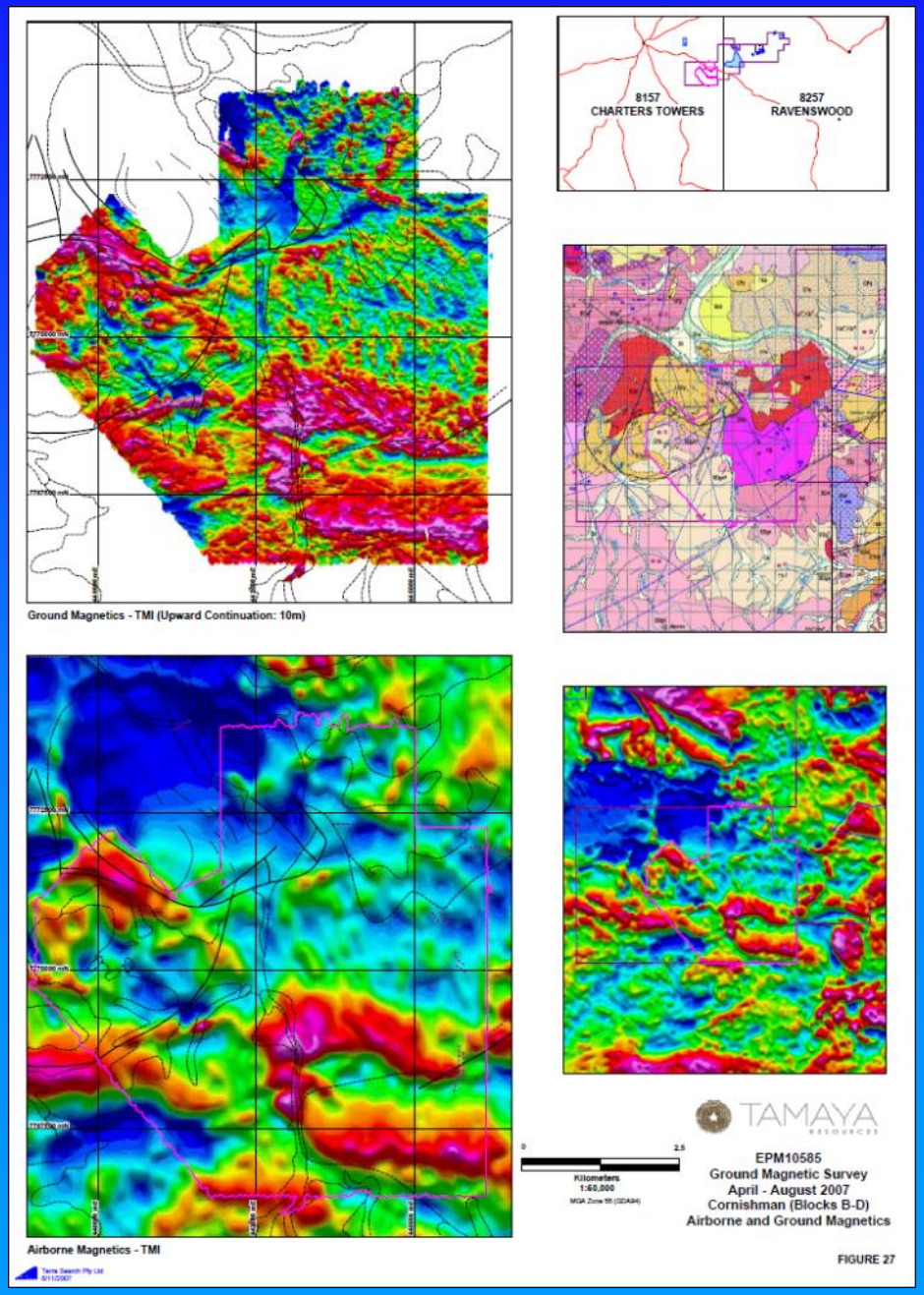
Grd

Sed

High Resolution Ground Magnetics Hadleigh Castle Ground Magnetic Data (Denjim Pty Ltd)

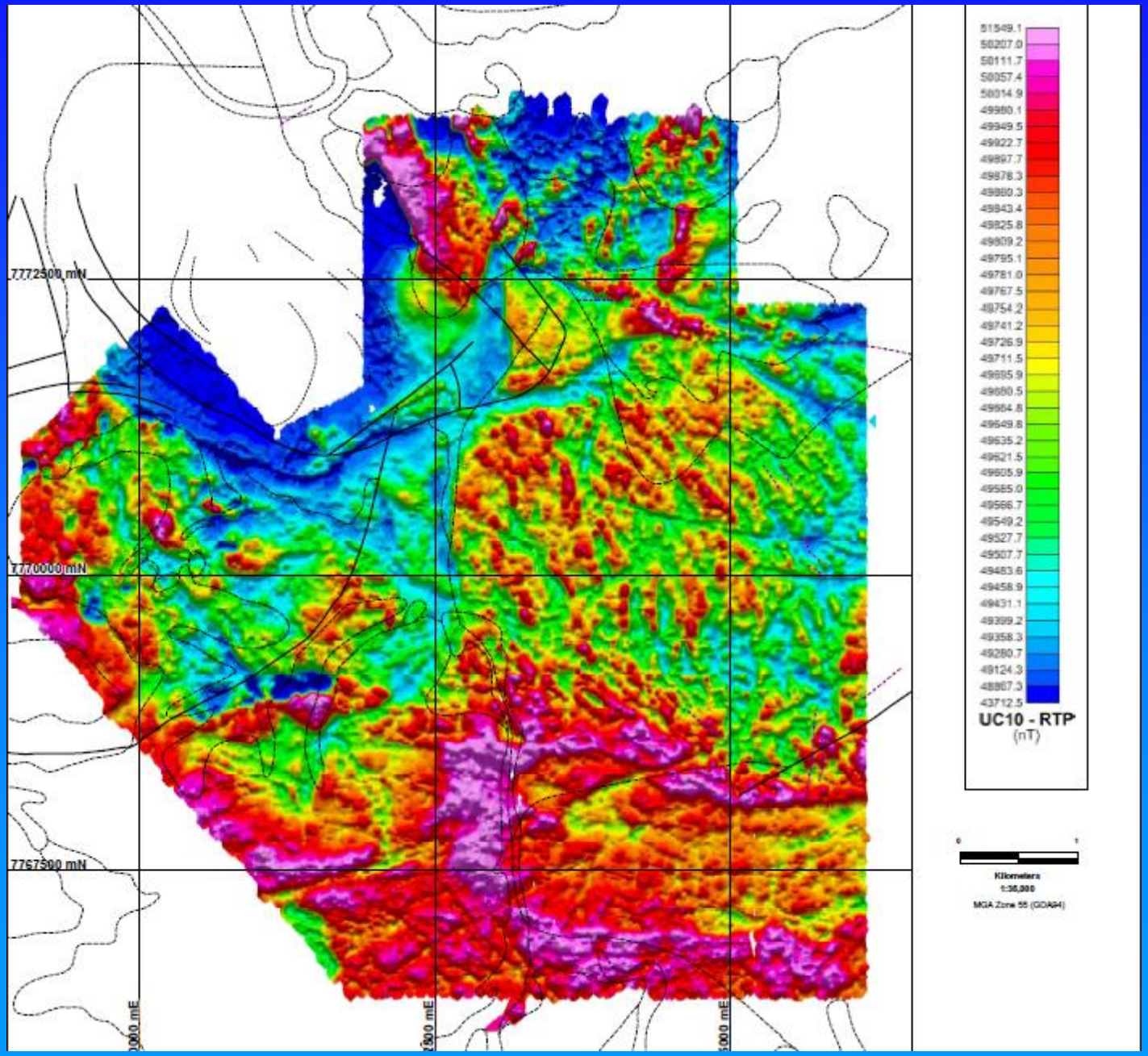


Cornishman Project: Magnetic Comparison

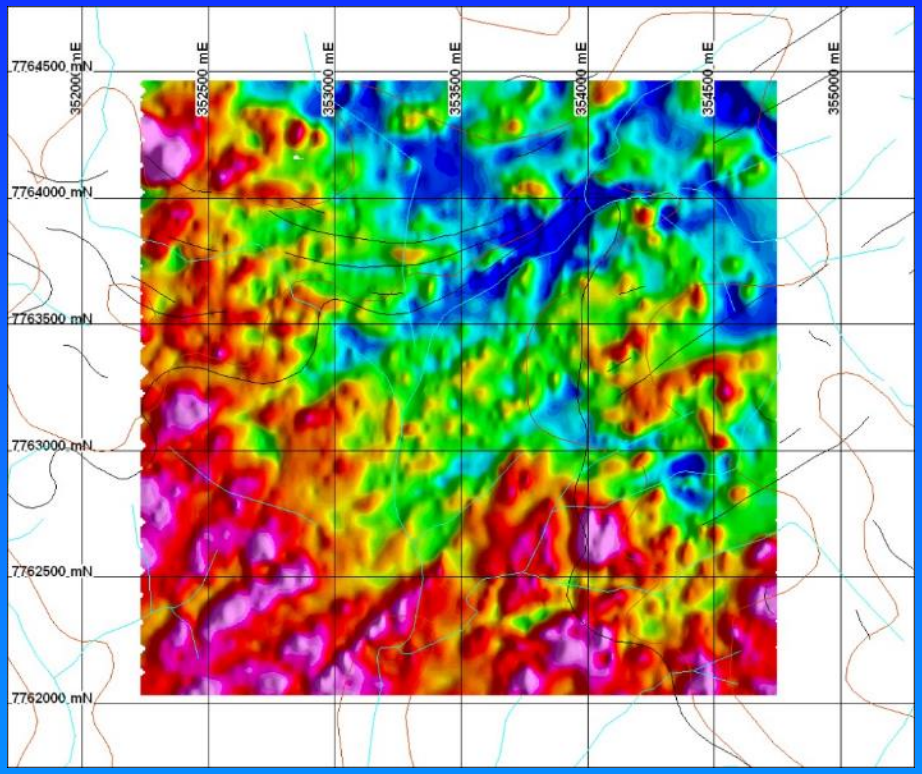


Cornishman Project:

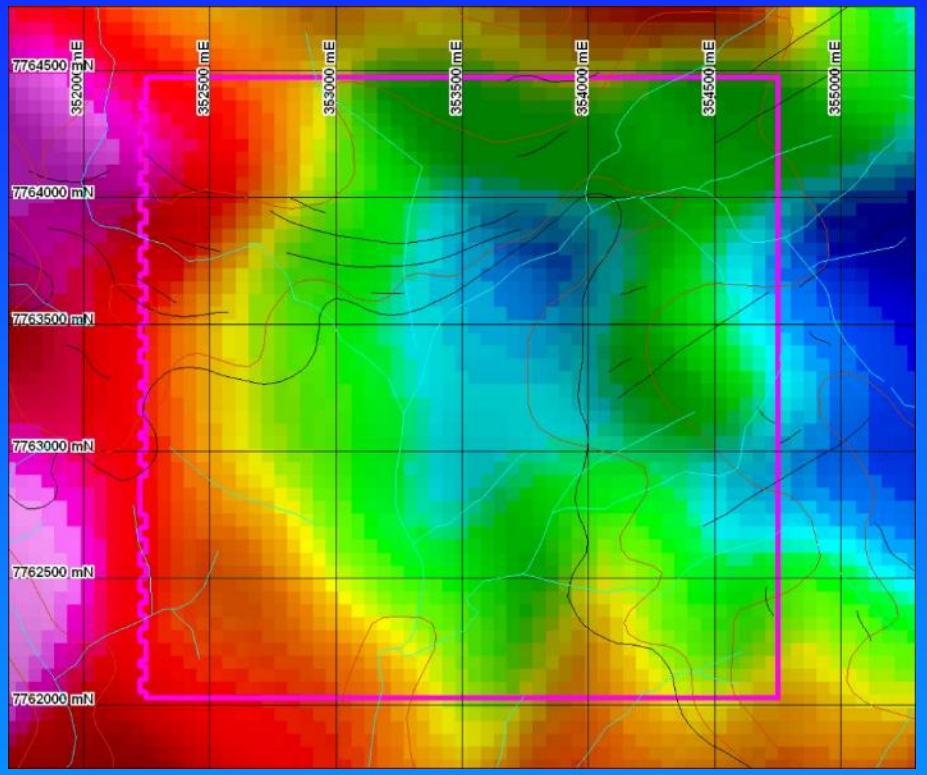
High Resolution Ground Magnetics (RTP)



Pentland Project: Magnetic Comparison

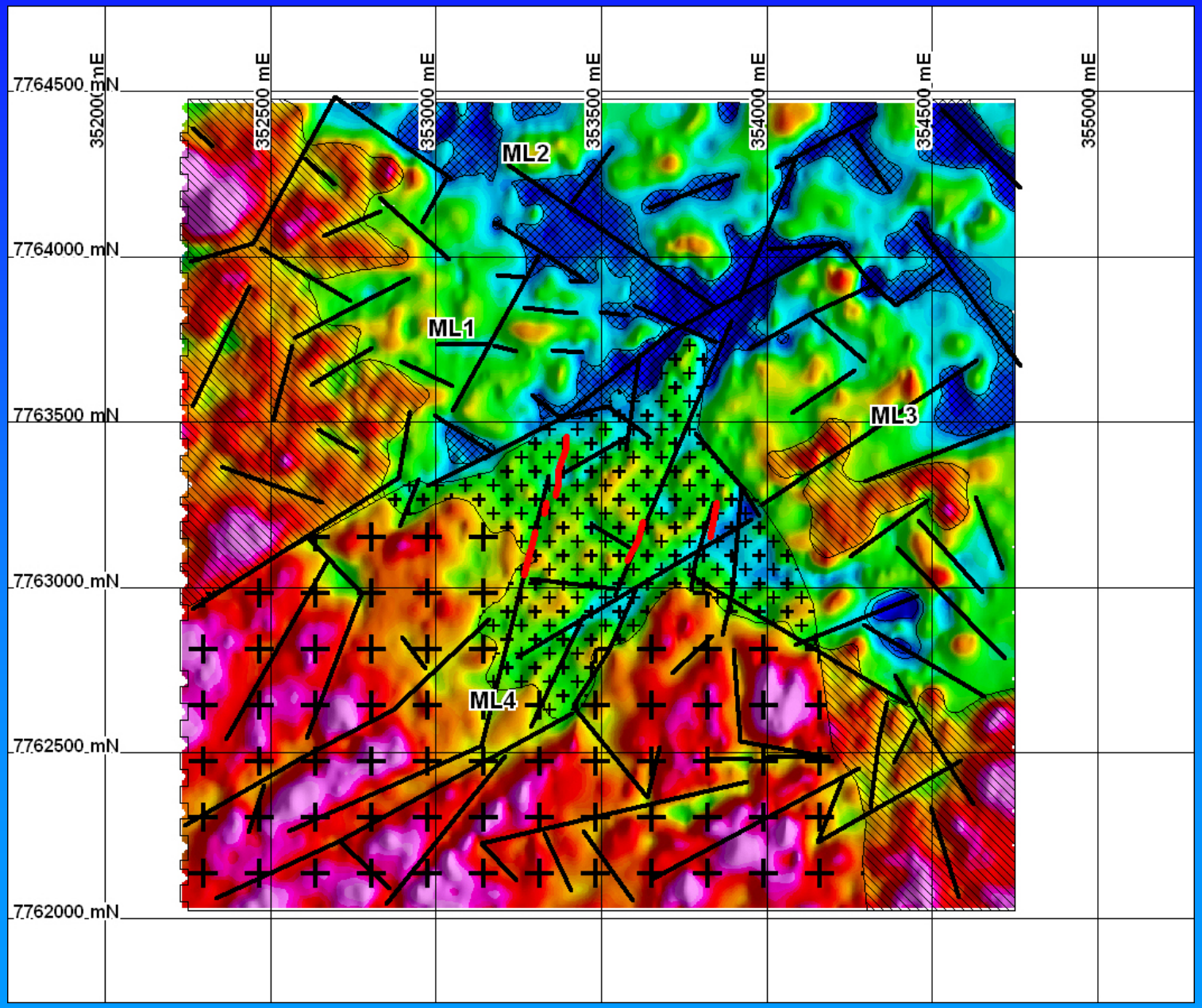


TMI – Ground Magnetics

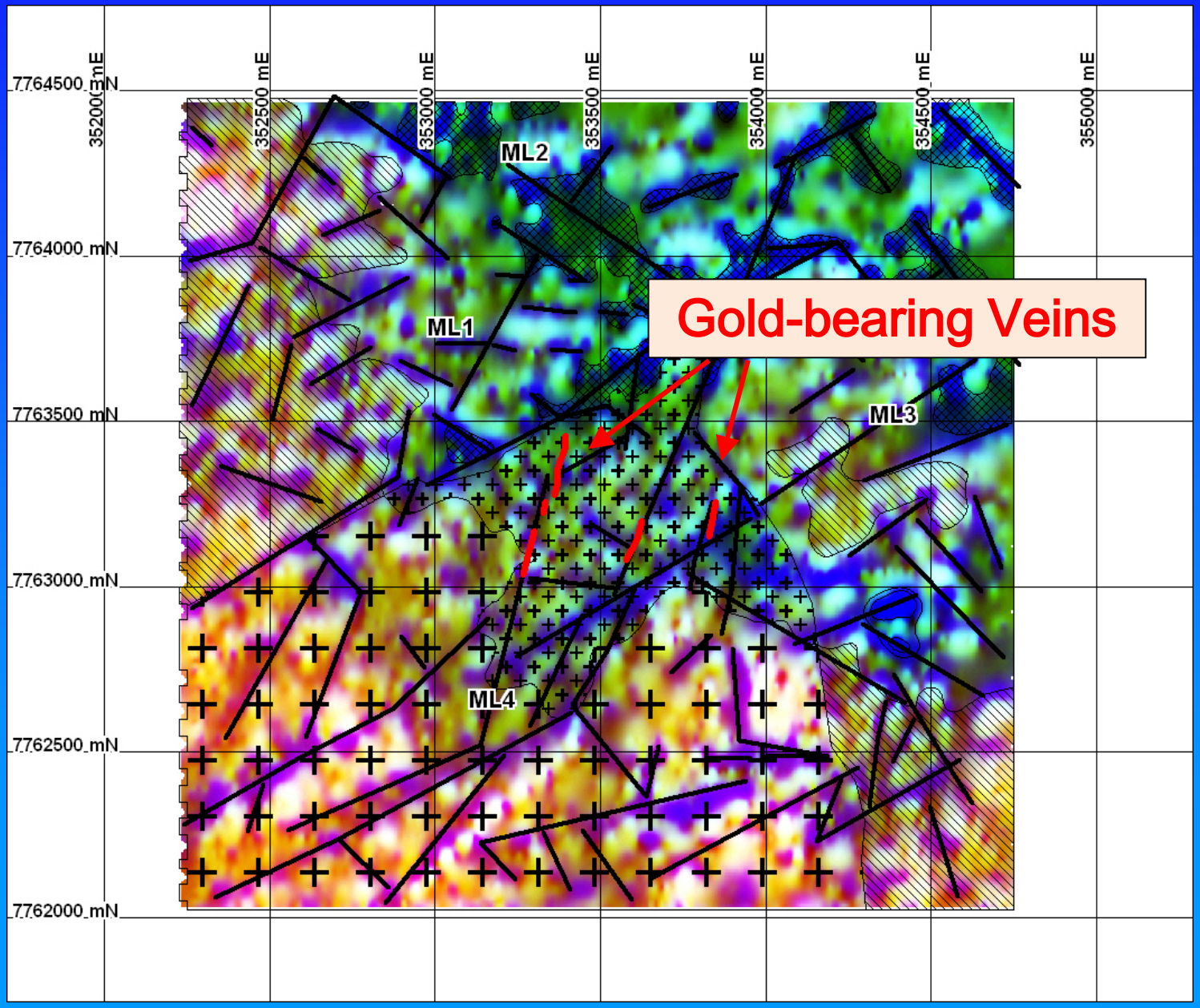


TMI –Aeromagnetics

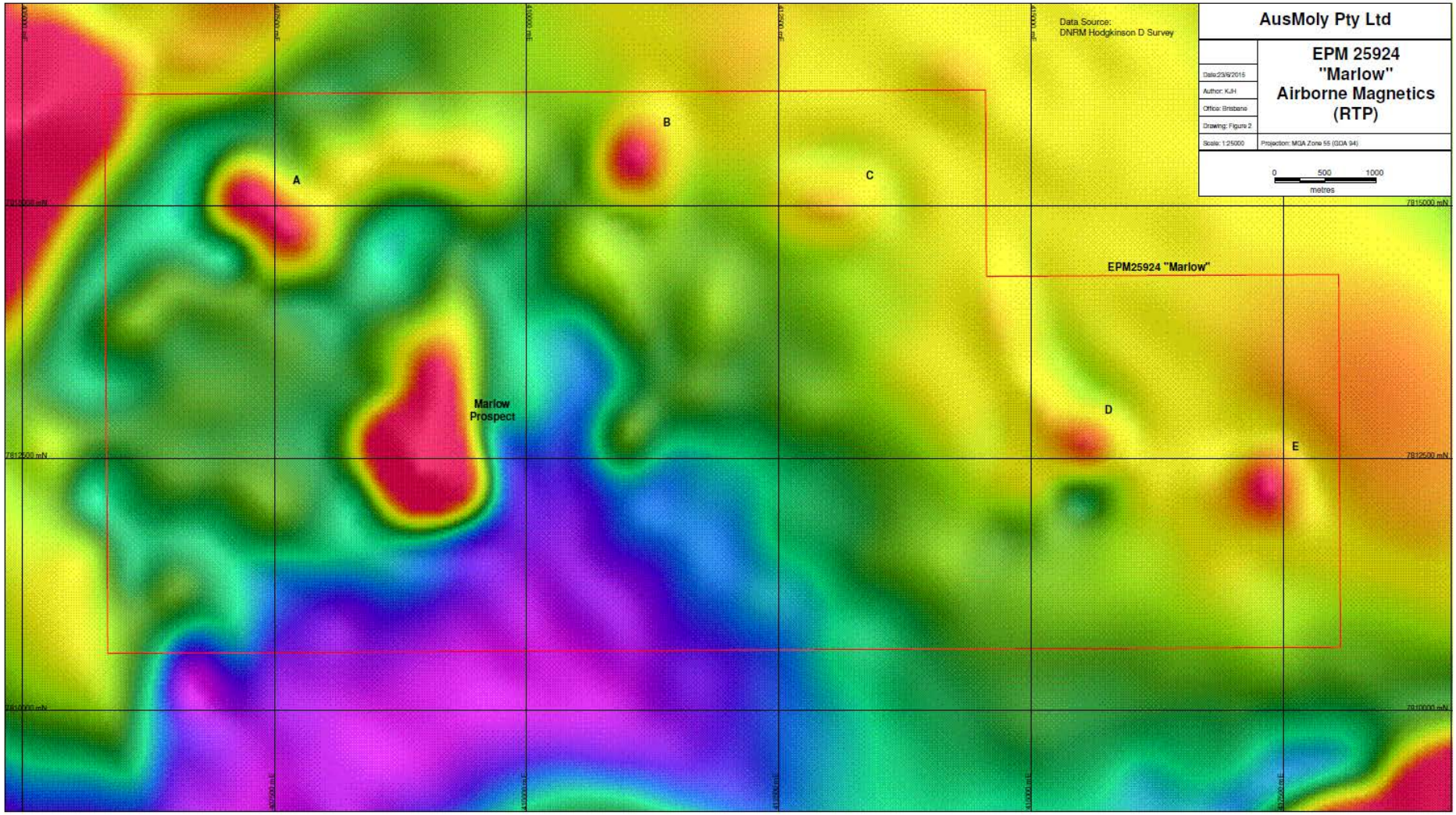
Pentland Project: RTP, Domains and Linears



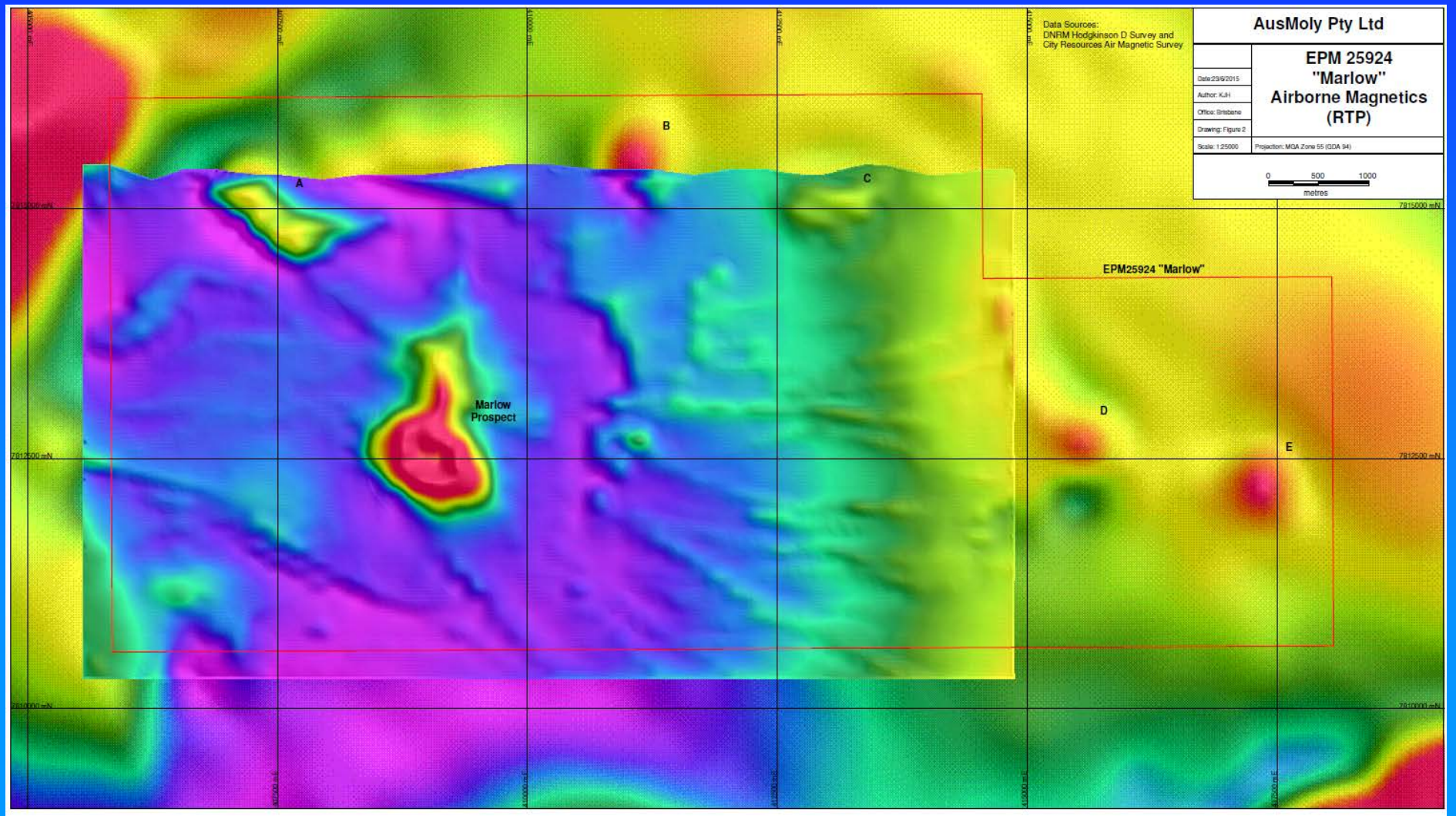
Pentland Project: Combined 1VD AS RTP, Domains and Linears



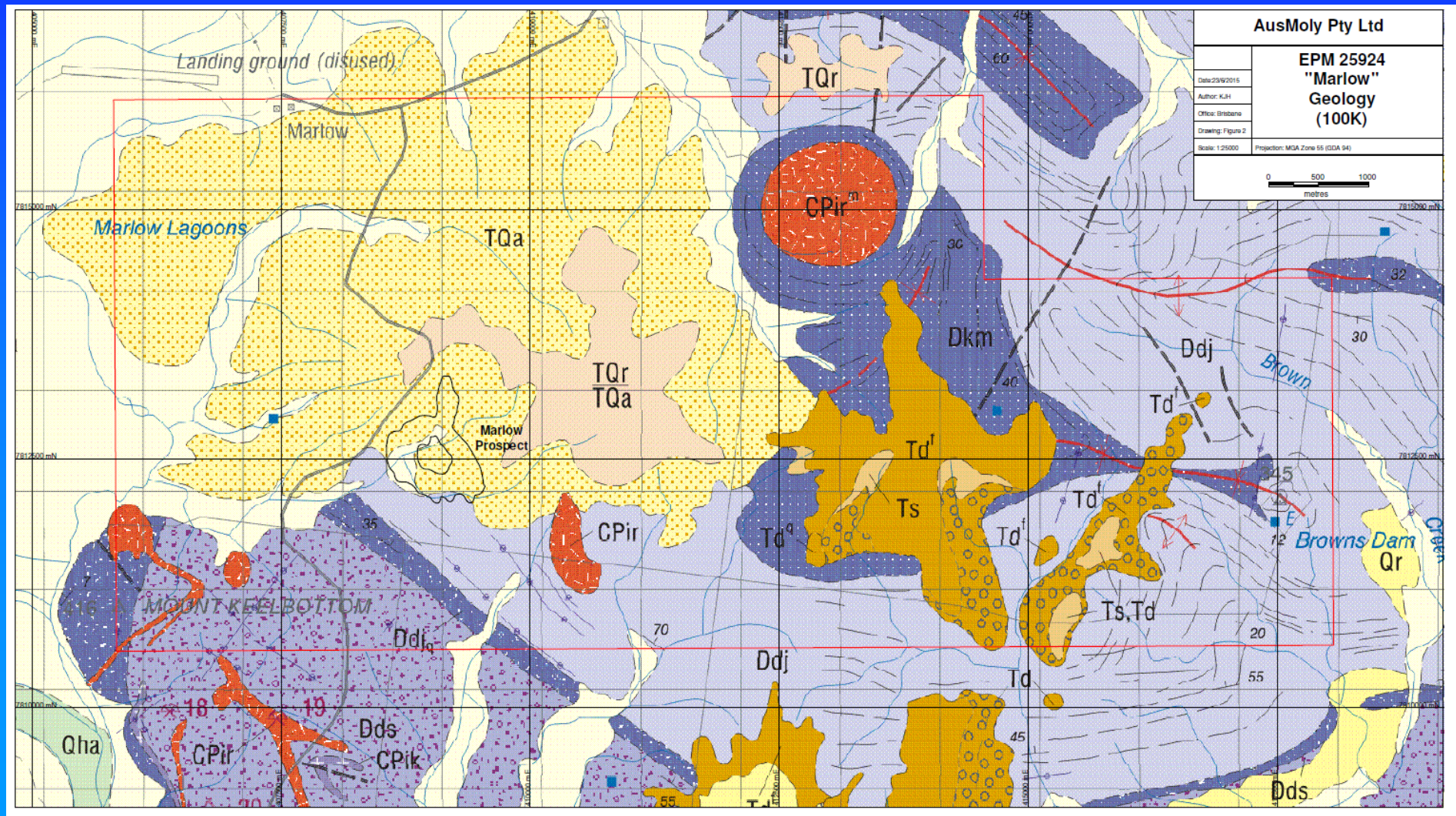
Marlow Prospect: GSQ Aeromag RTP

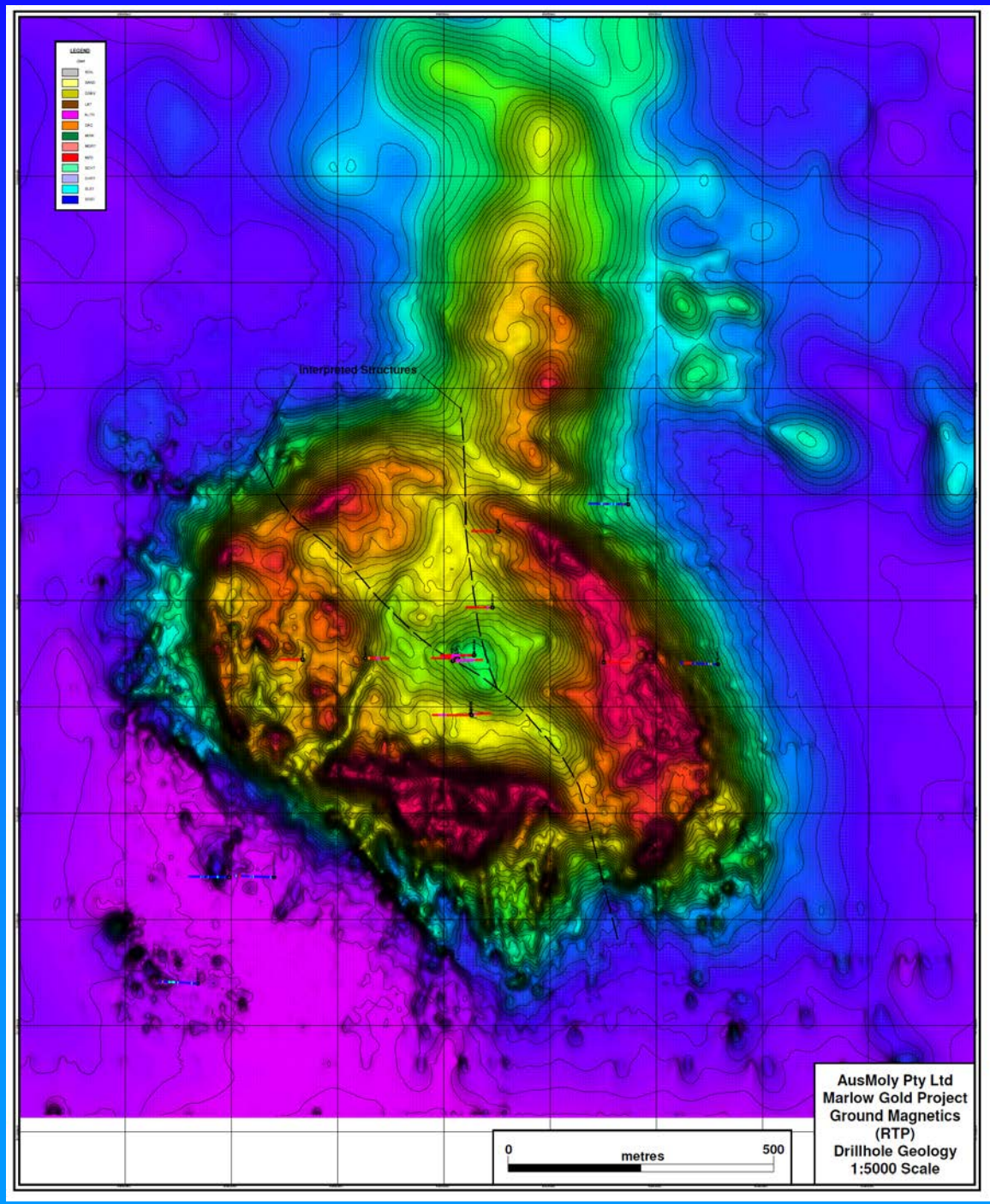


Marlow Prospect:
City Resources (1987) Aeromag RTP



Marlow Prospect:
GSQ Geology Dotswood 100k sheet





Marlow Prospect:

High Resolution Ground magnetics AusMoly

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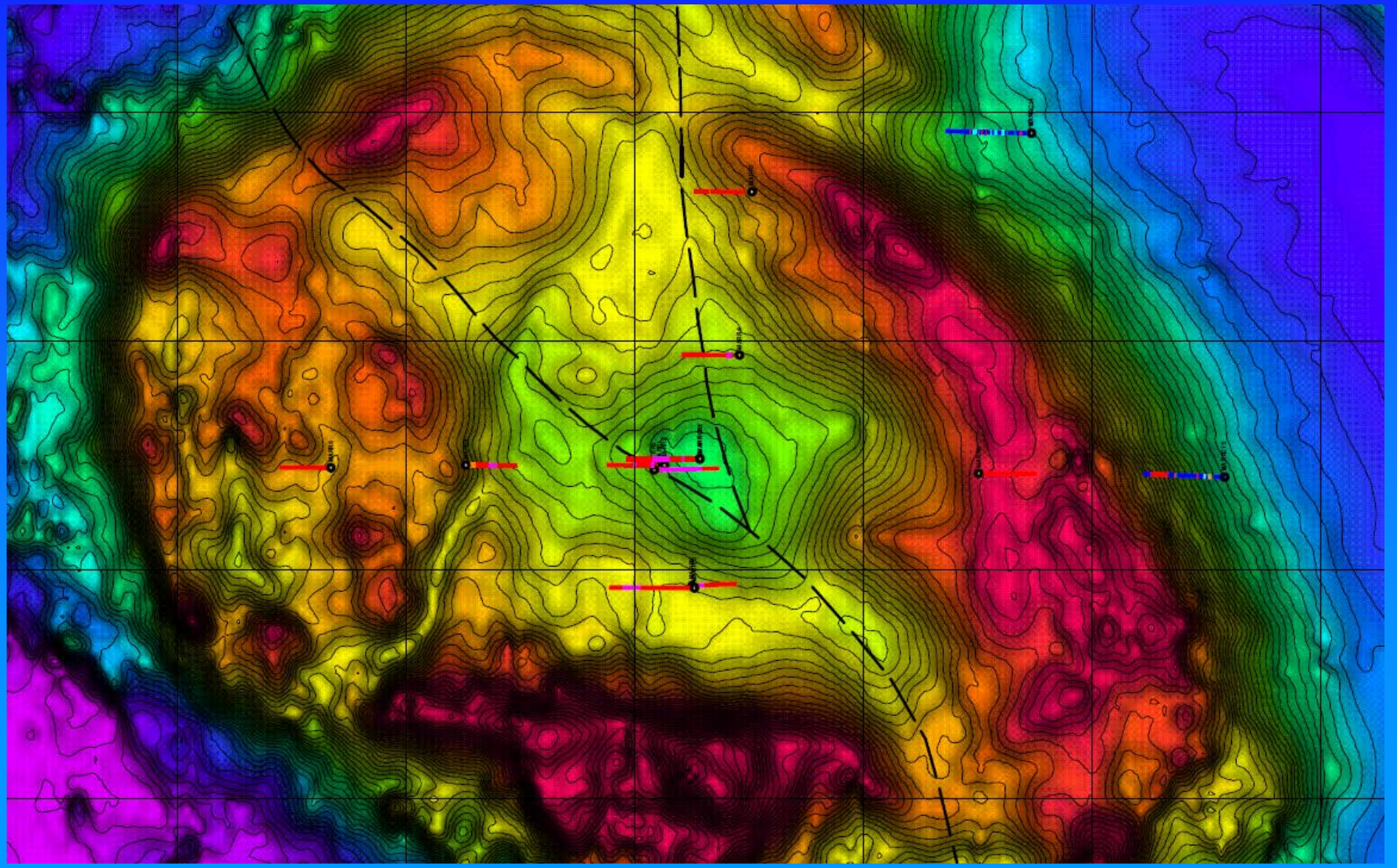
High Resolution Ground magnetics AusMoly



Marlow Prospect:

Drill Results include 2m @ 85g/t Au With visible gold, elevated copper.