



Charters Towers Goldfield Queensland

Exploration and research indicate giant potential

Jim Morrison, Oliver Kreuzer, Brian Rusk, Kerri Whiting & Rebecca Williams.



- Queen Cross Mine, May 1903. 2,572t @ 3 oz/ton. A \$580,000 gold bar on each director's shoulder.

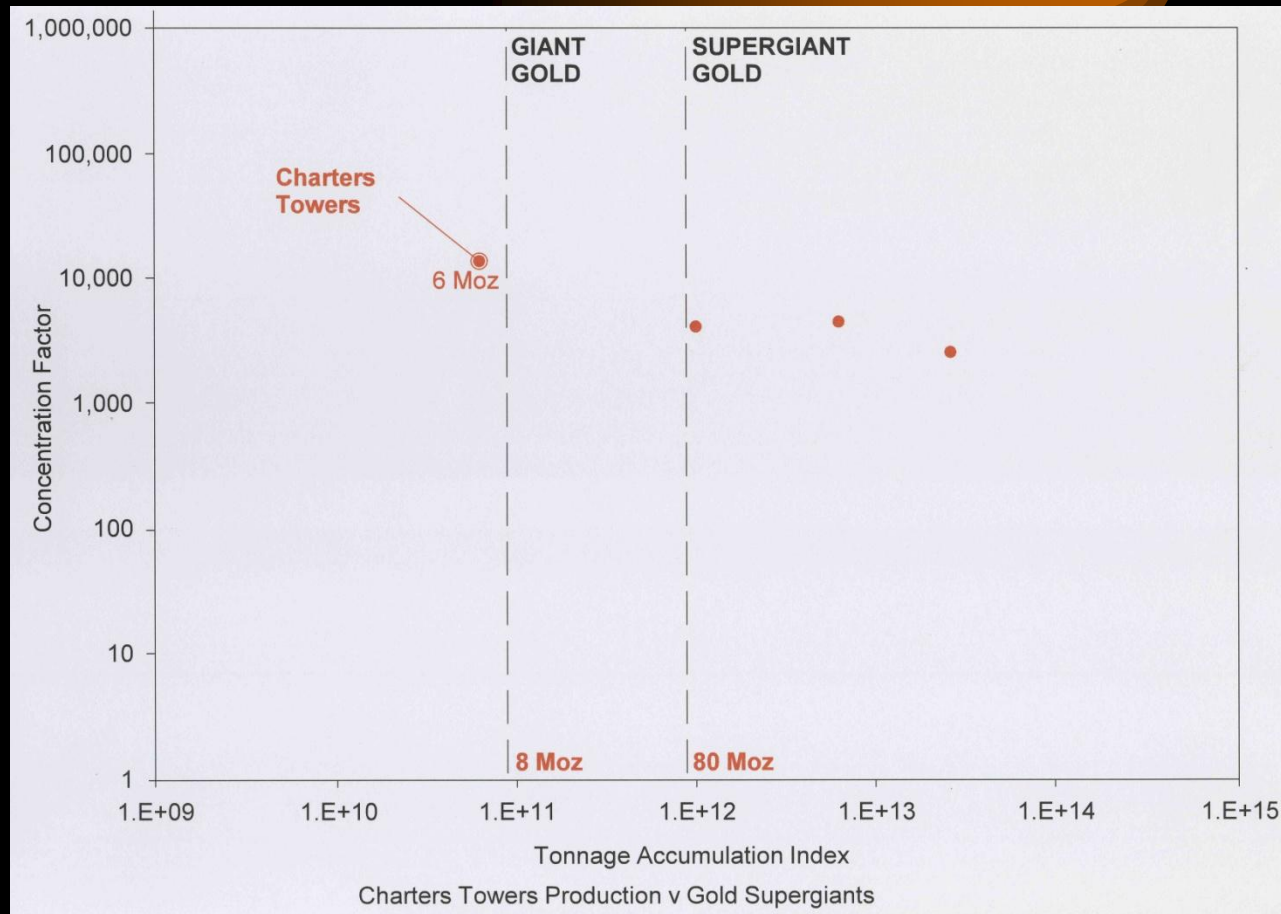
Historical Production
6.6 million oz gold
@ 34 g/t Au

In 2022 A\$ terms,

- **\$17 billion in revenue**
- **\$5 billion in dividends**

What is a gold giant? 1. Laznicka (1999)

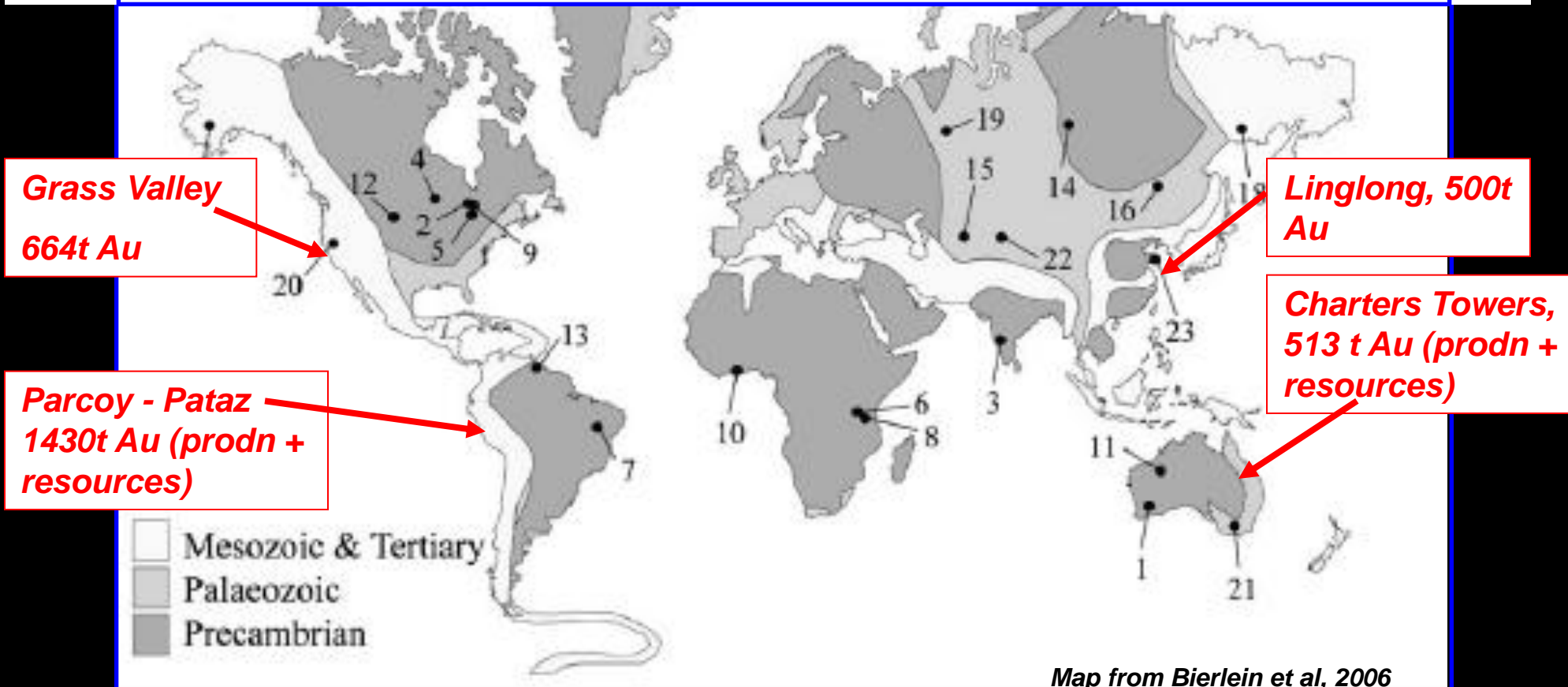
- >250t gold (> 8 Moz) geologic reserves
 - **Production + Reserves**
 - **excluding Resources**
- **Classification based on element crustal abundance**
- **Charters Towers only ~2 Moz below Giant category.**



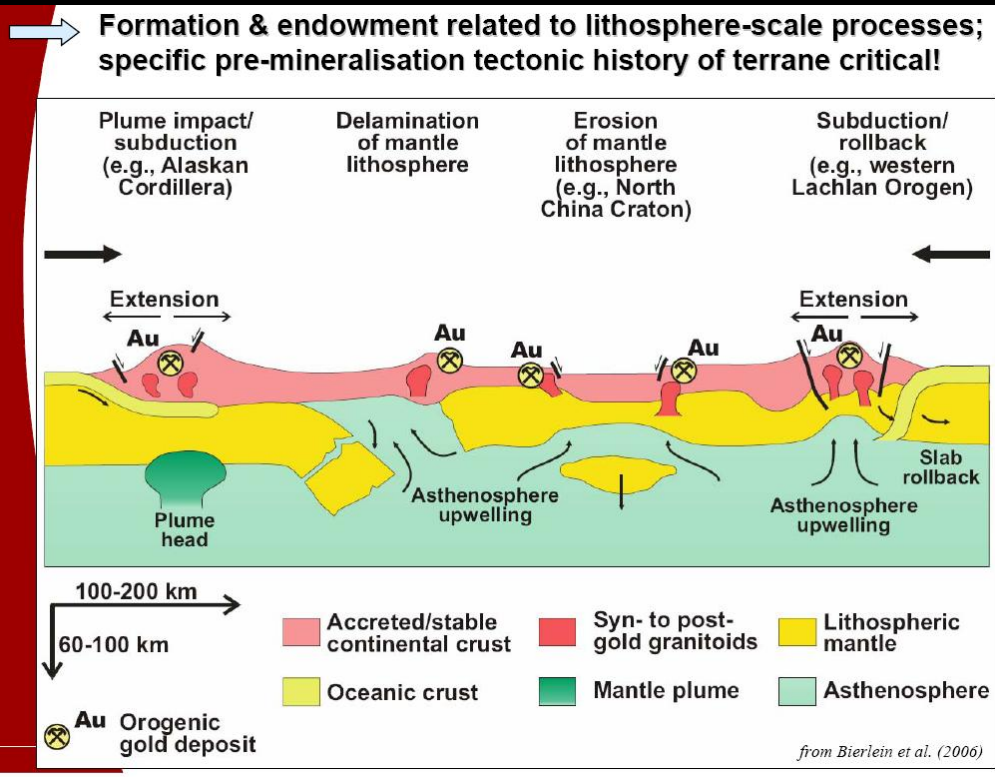
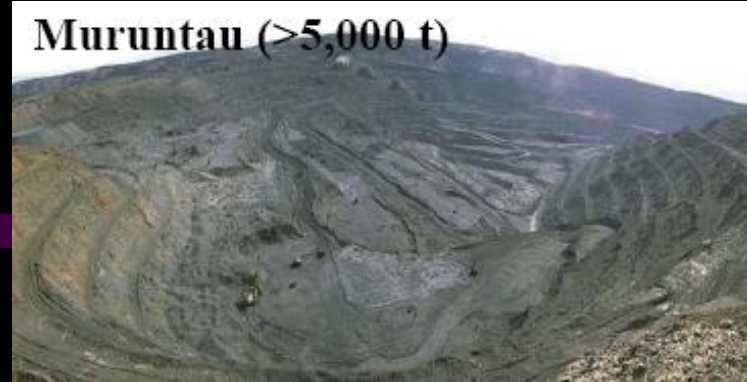
What is a gold giant? 2. Bierlein et al (2006)

- 500t Gold (Production + Resources?)
- Lithospheric controls: **rapid crust growth**, thin mafic lithosphere (source, heat), **crustal plumbing**, traps

Large base metal rich Sub-Class of Orogenic gold deposits



What is a gold giant? 2. Bierlein et al (2006)

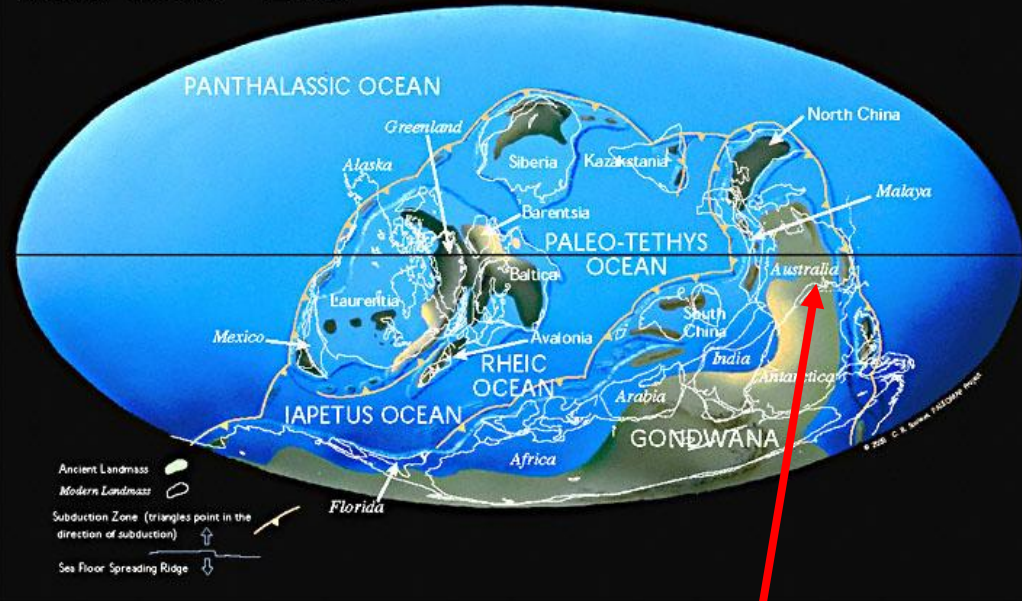


- **continental margin location** ✓
- **thin sub continental lithospheric mantle at time of gold mineralisation** ?
- **primitive oceanic crust source enriched in Au & S** ✓
- **high heat flux from the mantle to sustain crustal devolatilisation and melting.** ✓
- **large scale fluid release** ✓
- **crustal scale structures** ✓

Charters Towers: Continental Margin

• **continental margin location** ✓

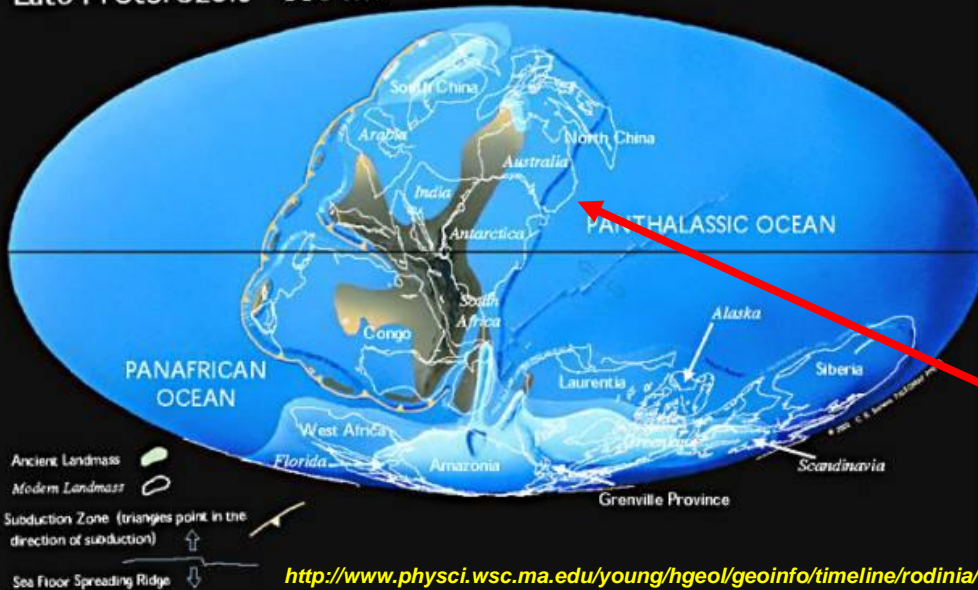
Middle Silurian 425 Ma



<http://rovicky.files.wordpress.com/2009/11/4251.jpg>

Short pre-mineralisation crustal history?

Late Proterozoic 650 Ma



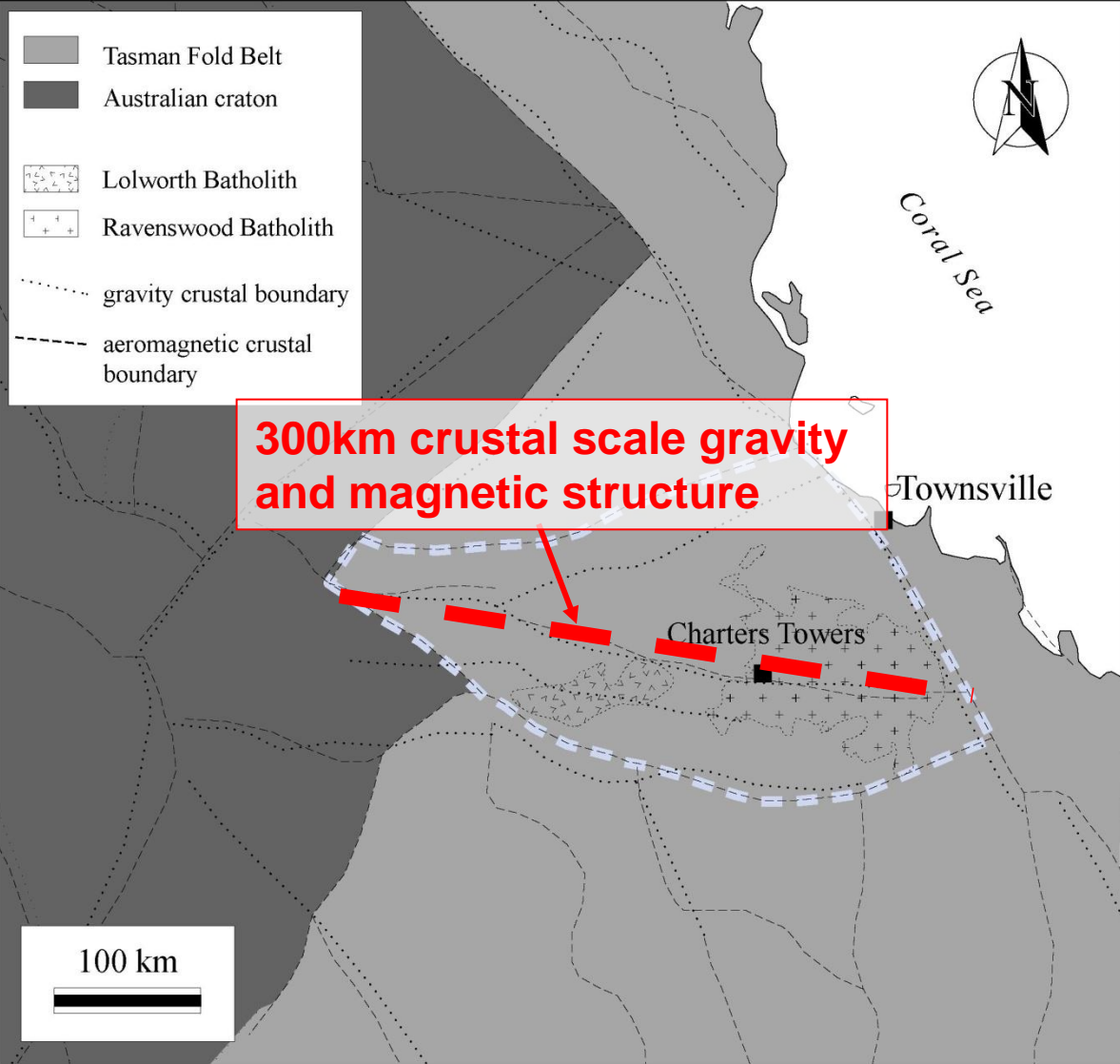
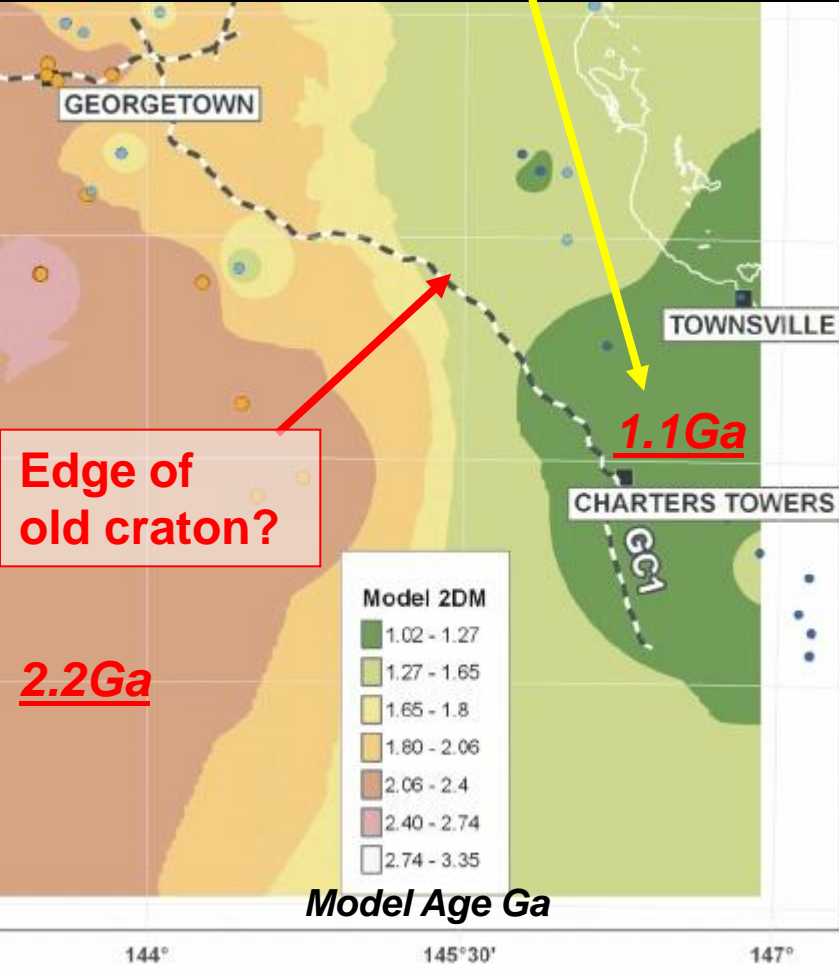
<http://www.physci.wsc.ma.edu/young/hgeol/geoinfo/timeline/rodinia/esm.html>

Rapid growth of continental crust?

Tectonic setting:

Source and channelways?

- Sm-Nd isotopic data model ages (Henson et al 2009)
- Formation of juvenile crust? Au source?

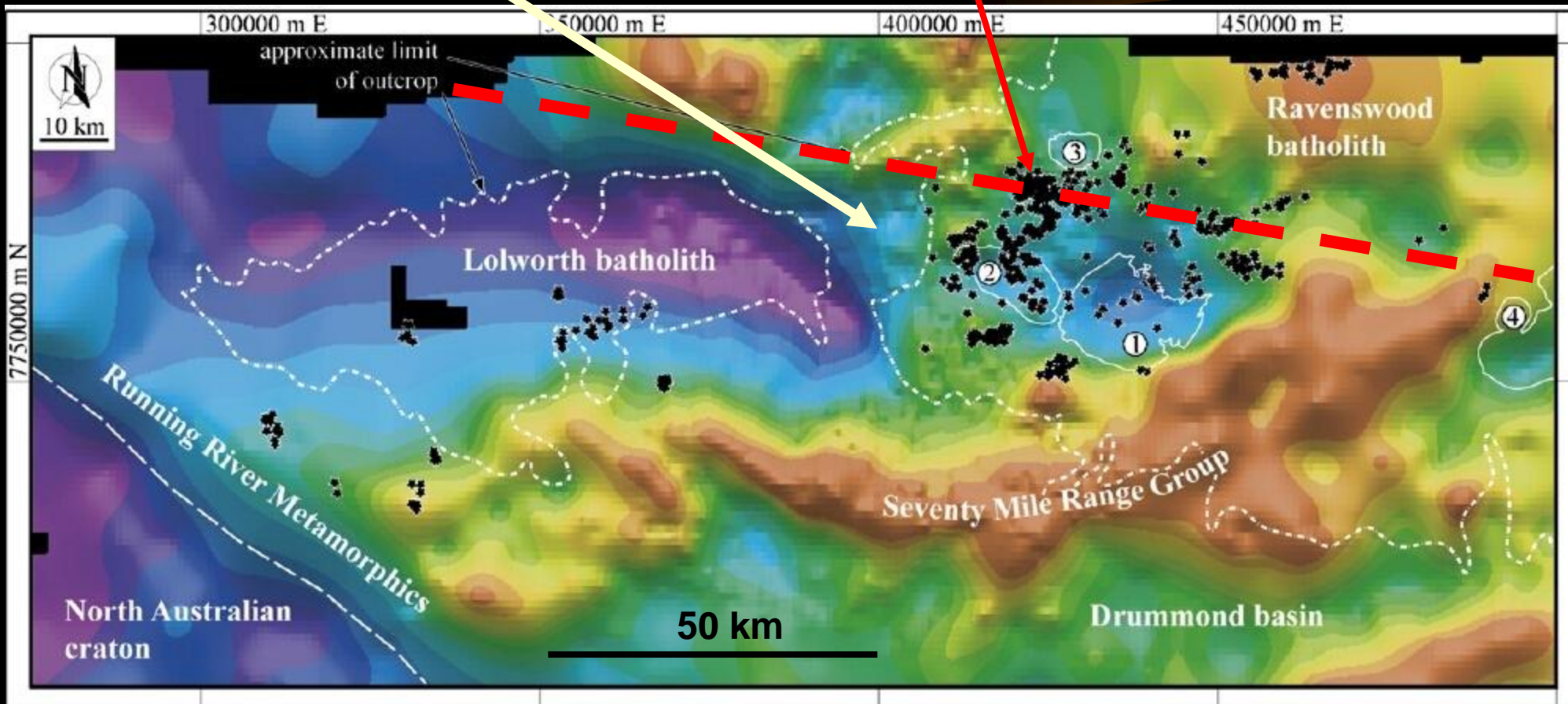


Based on Geoscience Australia / Geol. Survey of Qld data
http://www.ga.gov.au/image_cache/GA14872.pdf

Regional Setting: Gravity & Gold Occurrences

- Single district wide ~406Ma gold event
- Large scale fluid release
- Gold at margins of gravity lows
- Possible extension under cover to west

Charters Towers – more intersecting fractures, fluid focus?

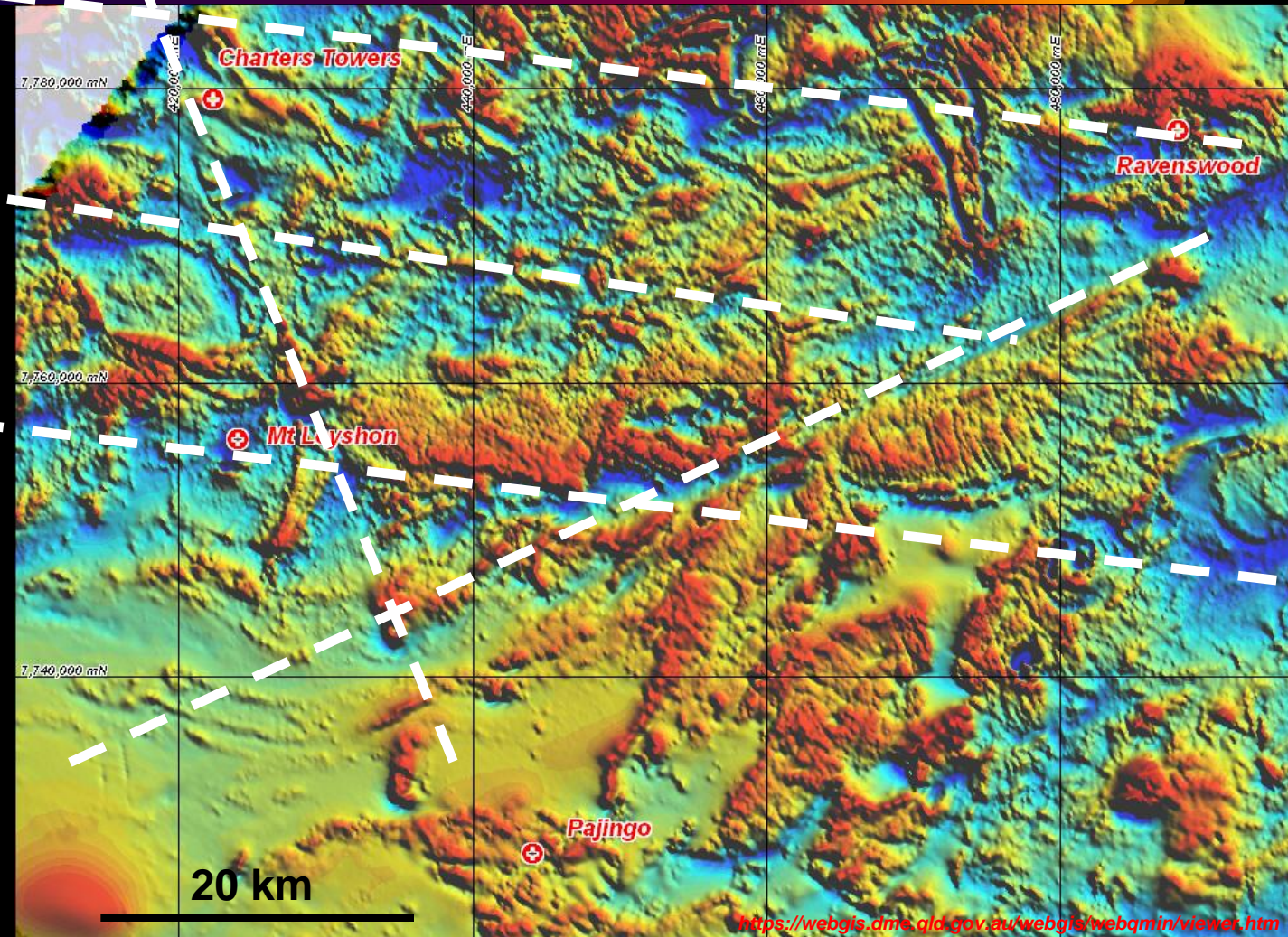


Regional Magnetics: showing architecture

Charters Towers – Ravenswood

Lineament (Mosgardies)

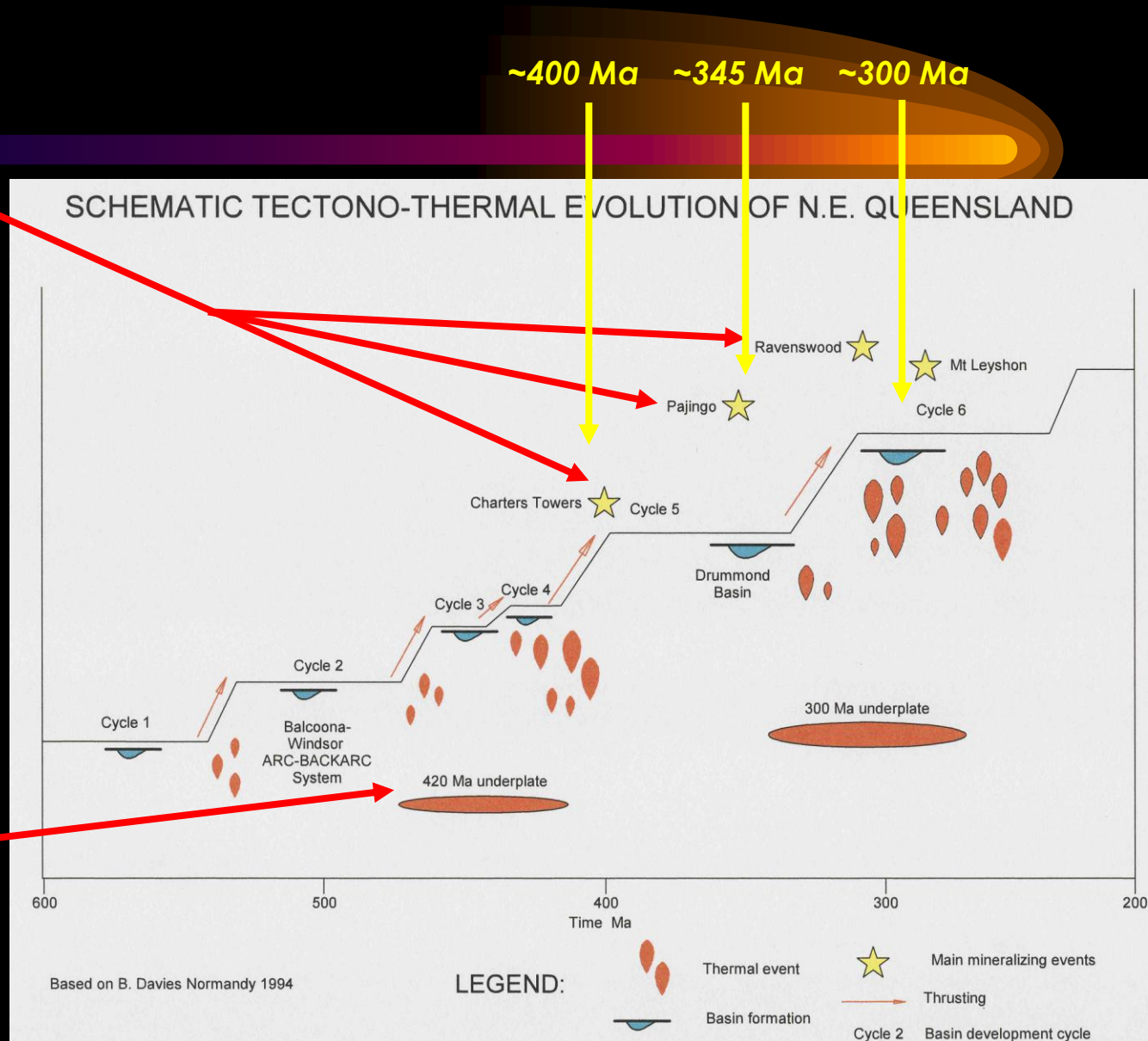
- Charters Towers & >3Moz gold deposits
- Hosted in fractured central Ravenswood Batholith
- **Gold assoc with change of direction of crustal compression from N to NE**
- Ore formed between 5 & 15km depth



Map source: Qld Mines & Energy
Airborne magnetic and radiometric
images 2009

Regional Thermal fluid flow drivers

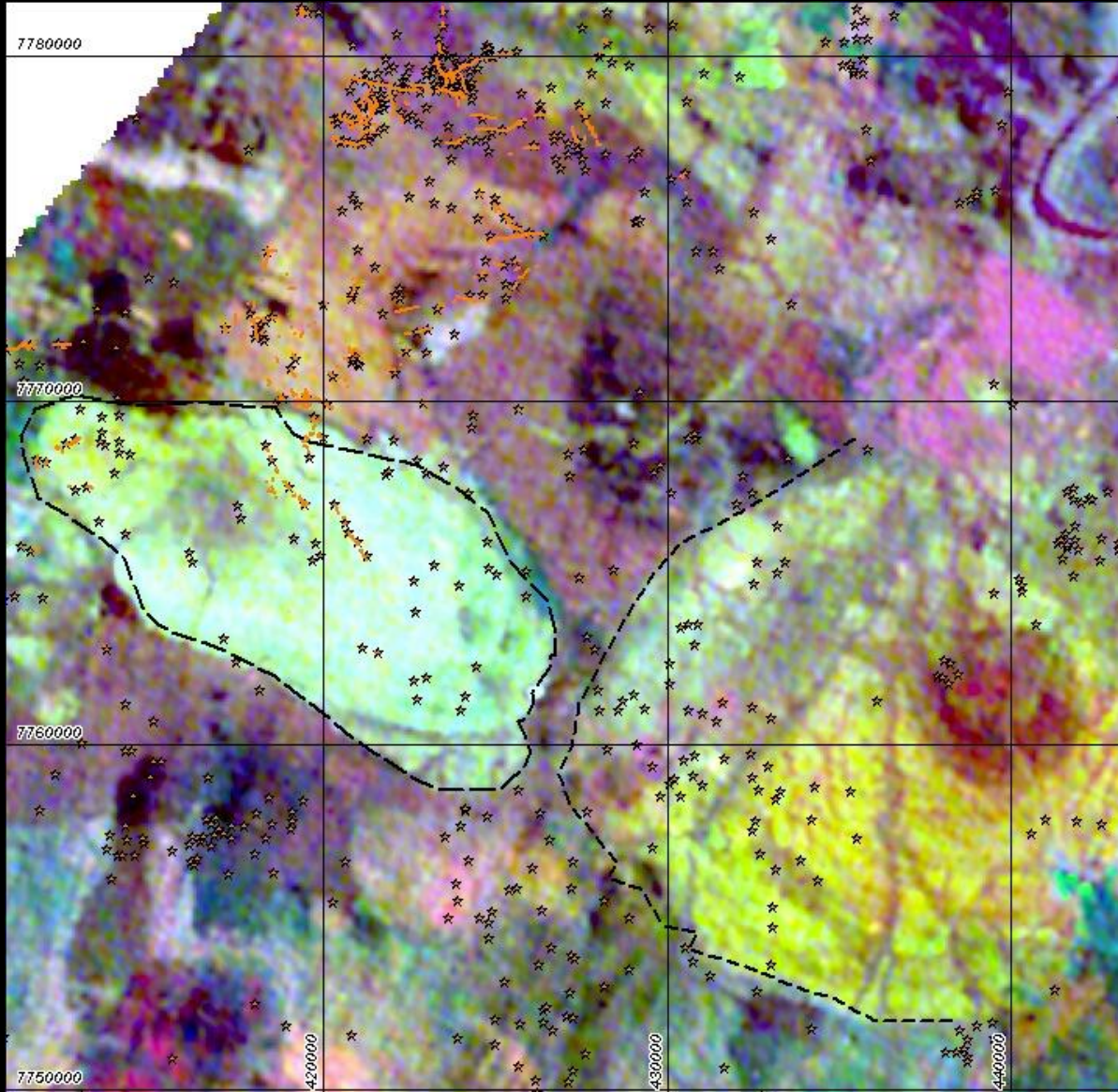
- Repeated >3 M oz gold events
- Au enriched source rocks
- Mafic underplating model heat
- Alternative is crustal thickening heat
- high heat flux from the mantle to sustain crustal devolatilisation and melting.



2010 Interpretation: District scale

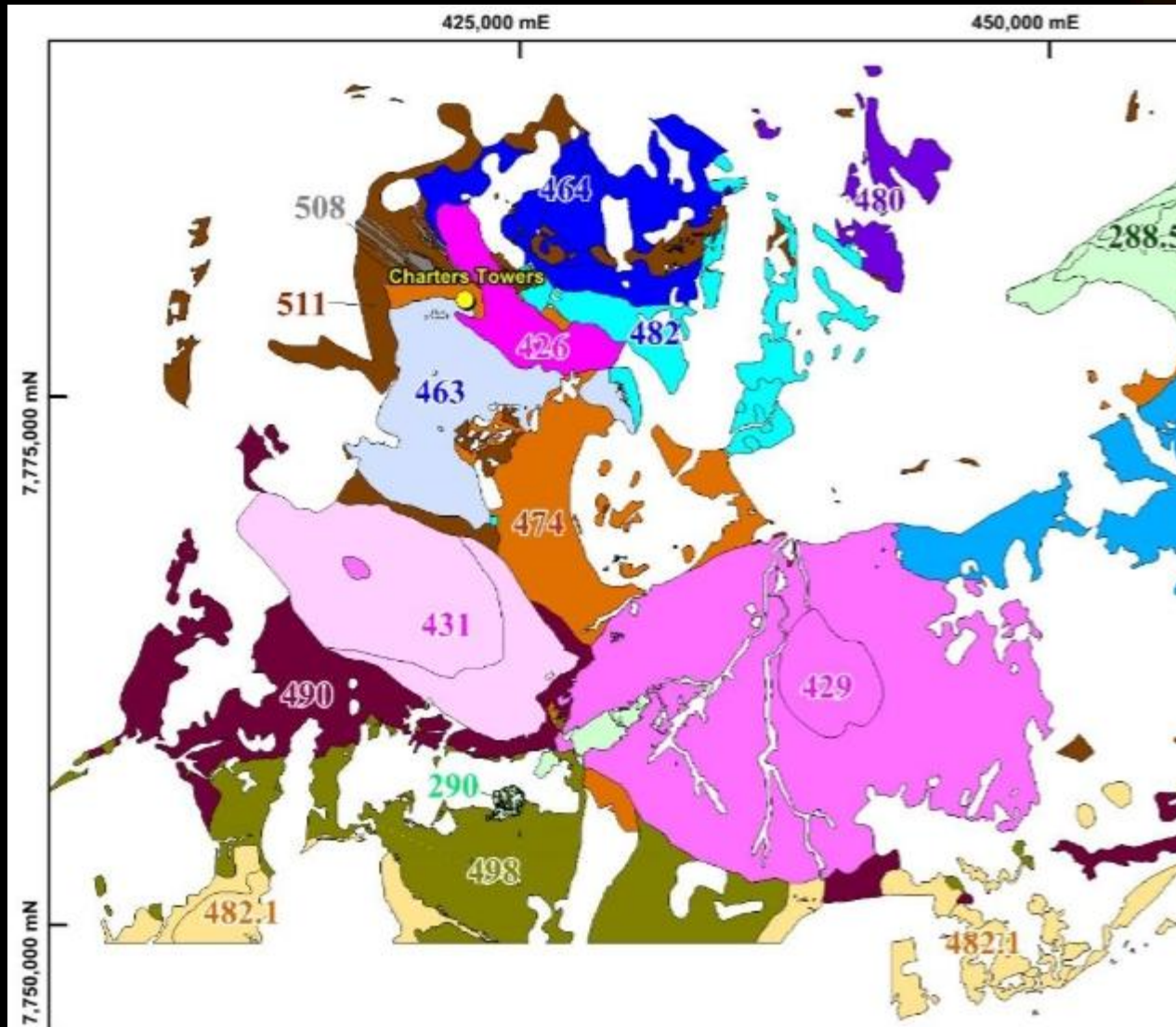
Anomalous Siluro-Devonian Granites

K = red, U = blue, Th = green
Magn. Lows = black



- 405-409Ma zoned granodiorites south of Charters Towers (Hutton & Rienks, 1997)
- High Th Broughton River Granodiorite (West)
- Deane Granodiorite with trondjemite core (East).
- Formed by crustal melting not fractionation.
- Main 400-405Ma gold bearing in NW (orange).
- Grid = 10km

Since 2010: New Interpretation based on U-Pb zircon dates:



Broughton and Deane Granodiorites dating now corrected

From 406 – 411 Ma to 429-431 Ma (Beams et al 2016).

Now ~ 25 Ma older than the gold mineralisation.

Deposition: Quartz reef District scale

- Extensive ~400Ma reefs cut granites, mafics & metamorphics

- Pre-ore dyke swarm and pegmatite-aplites

- Main workings over ~5 sq.km.

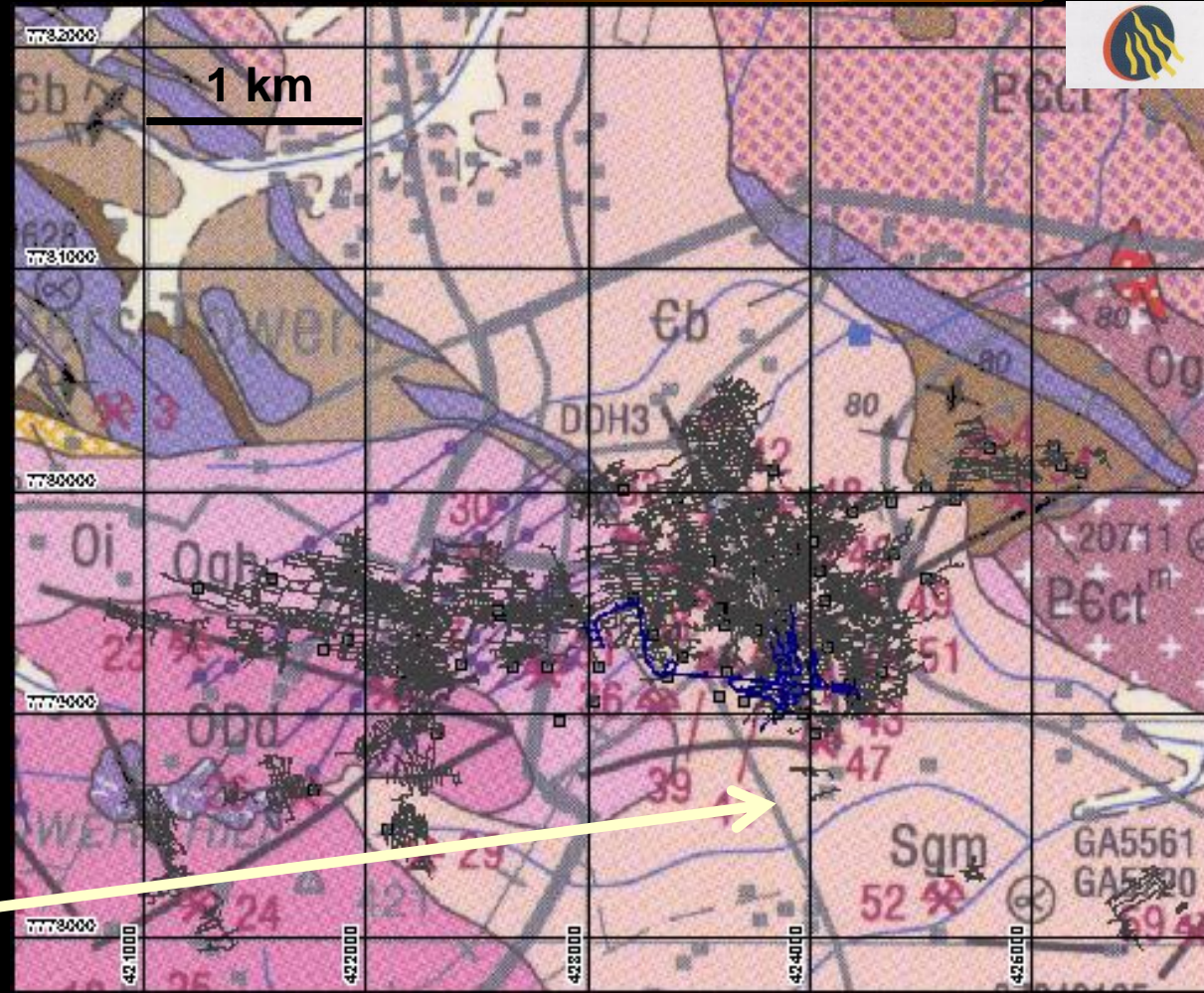
- Zoned sericitic to propylitic alteration

- NOT standard Orogenic gold

- High S, Fe, Pb, Zn, +/-Cu
- High salinity Ca brines
- Lack of CO₂ inclusions
- I-type granite main host.

- Major host brittle 425 Ma Millchester Creek Tonalite.

Source: Geol. Survey of Qld (Hutton et al 1996)

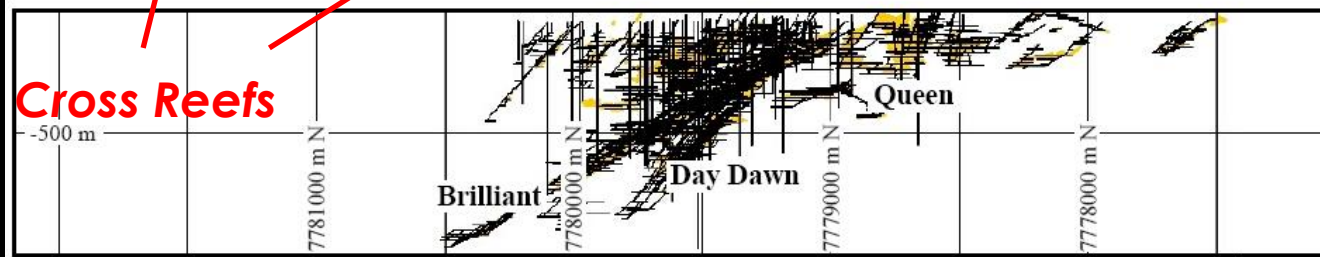
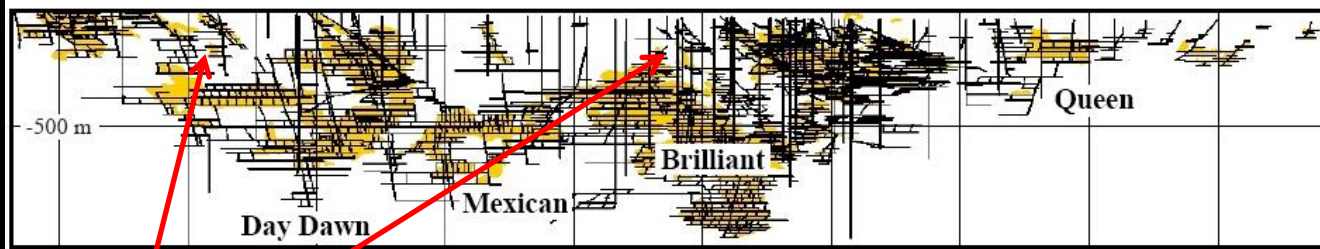
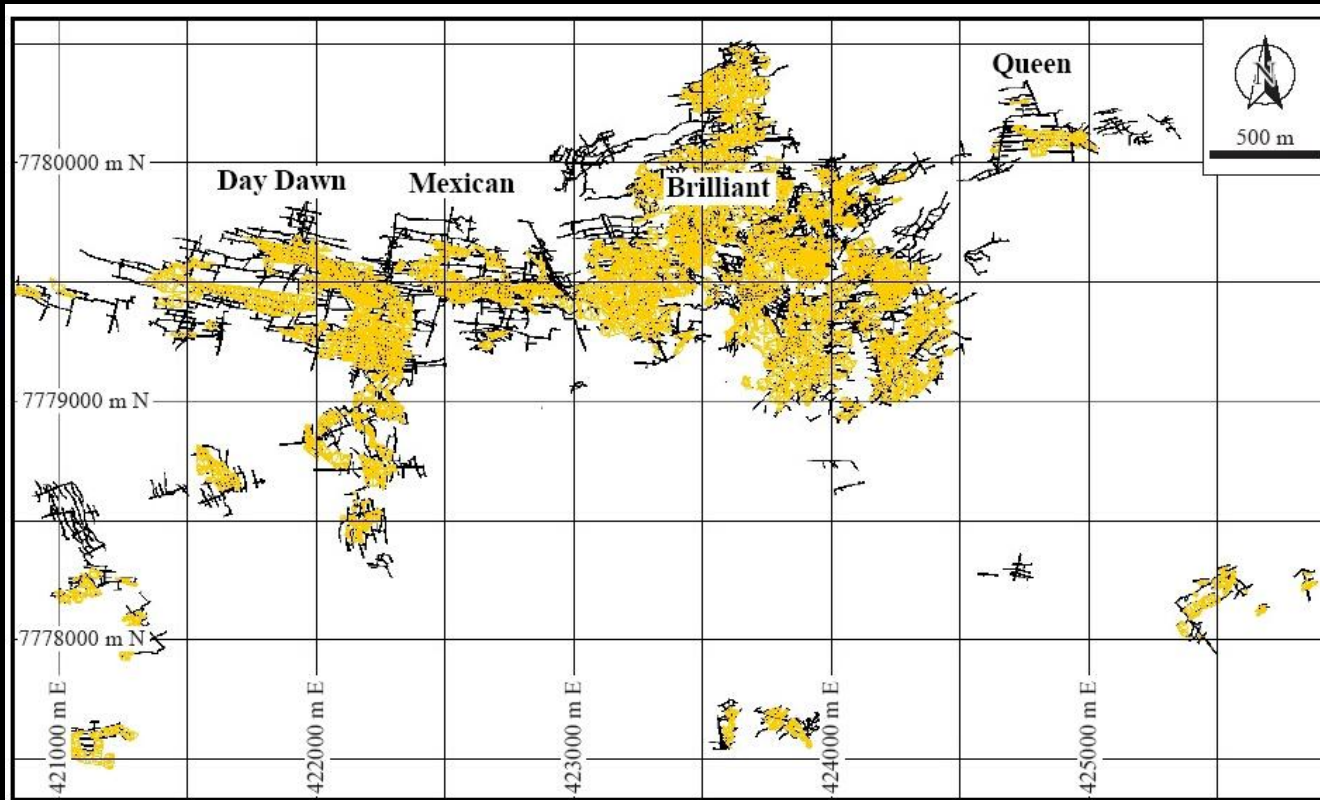


Charters Towers: Ore Mined

Plan 5 x 3 km

E Section

S Section

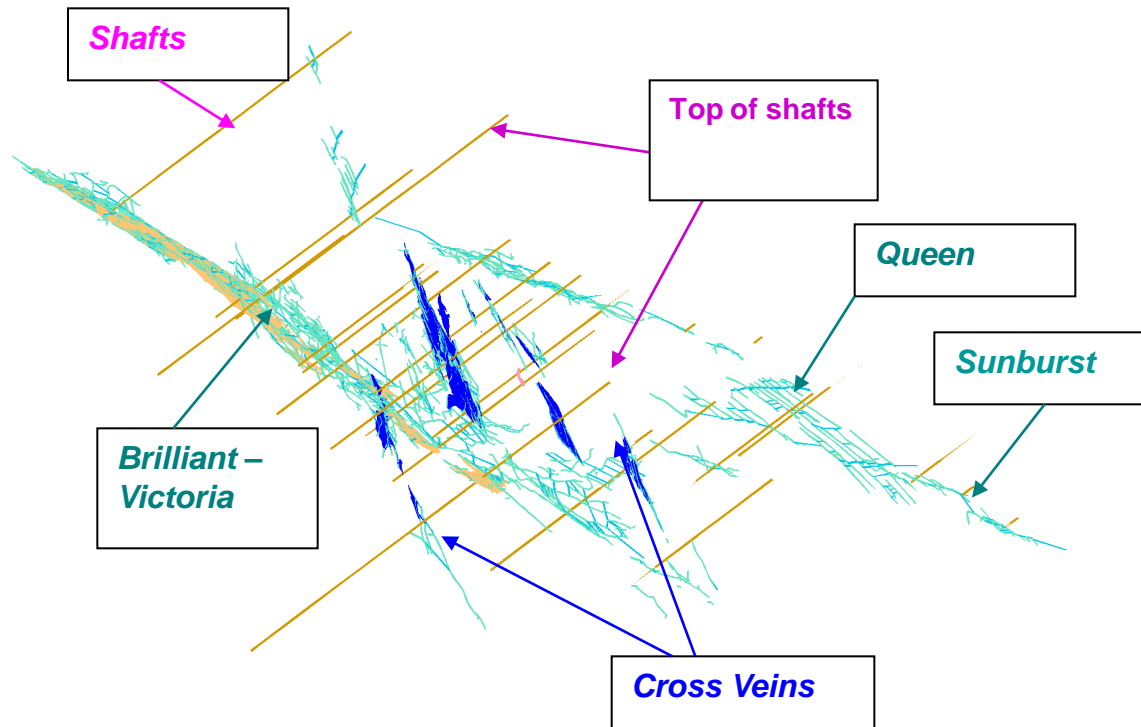


W

N

Cross Reefs

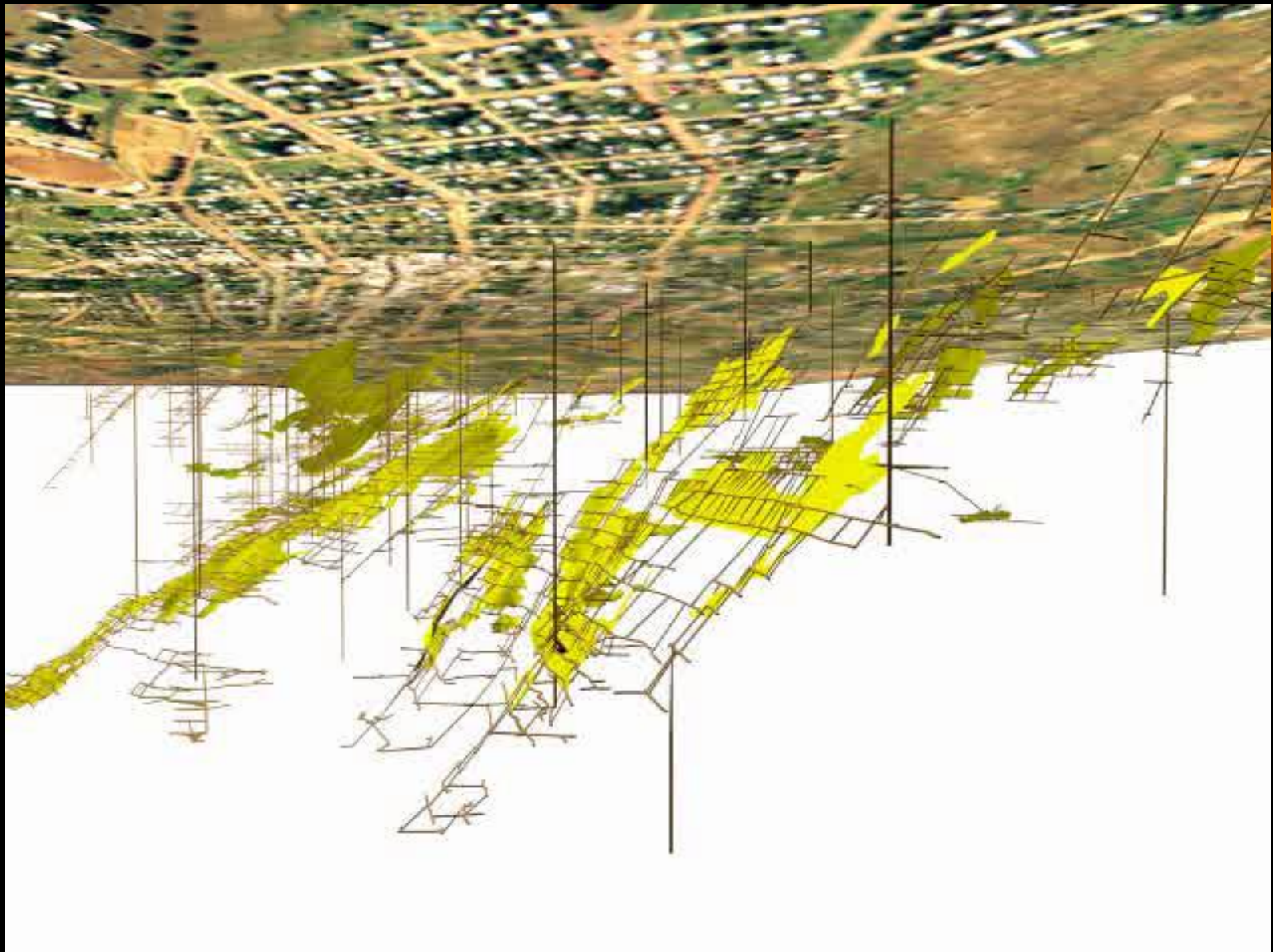
Charters Towers: Oblique view structural continuity



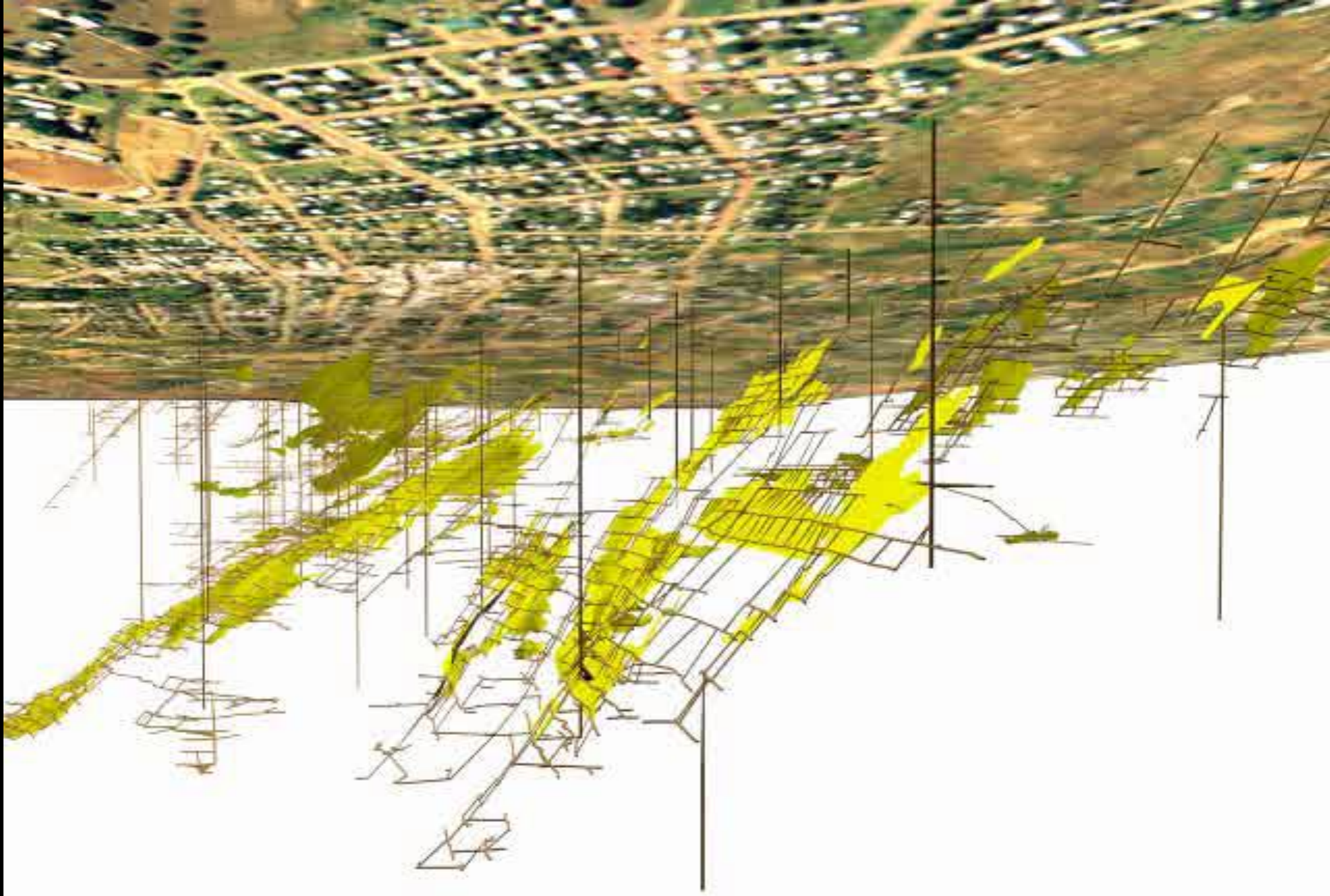
Sunburst Project Sublease
Looking down plunge to the North East

- Oblique 3D view of eastern lodes looking down plunge (2 km strike)
- Good continuity of large planar sheet-like lode structures

CHARTERS TOWERS WORKINGS FROM -300m



- *kilometre scale planar lodes on which oreshoots repeat*
- *E-W & NNW parallel structures through district*



Charters Towers: Quartz reef gold 1

- Shallow dipping (20°-50°) pyritic quartz reefs
- Width av. 0.1 to 1.2m (max. 15m)
- Within sericitic hydrothermal alteration
- Mostly granite hosted
- Single phase gold mineralisation



Charters Towers: Quartz reef gold 2

- **Reactivation of old fractures with N and ENE dip**
- **Channelways are trap sites**
 - Reverse faulting gave dilation
 - 20%-50% payability on lodes
- **Narrow quartz vein ore**
 - Shear hosted ore rare
 - ~1:1 Au:Ag (Ag in galena)



Golden Alexandra reef, Washington open pit, 1999.

Charters Towers: Other Styles

- 1. Shear hosted
 - Stockholm W1



- 2. Sheeted quartz veins
 - e.g. DDH BD4, 1250m



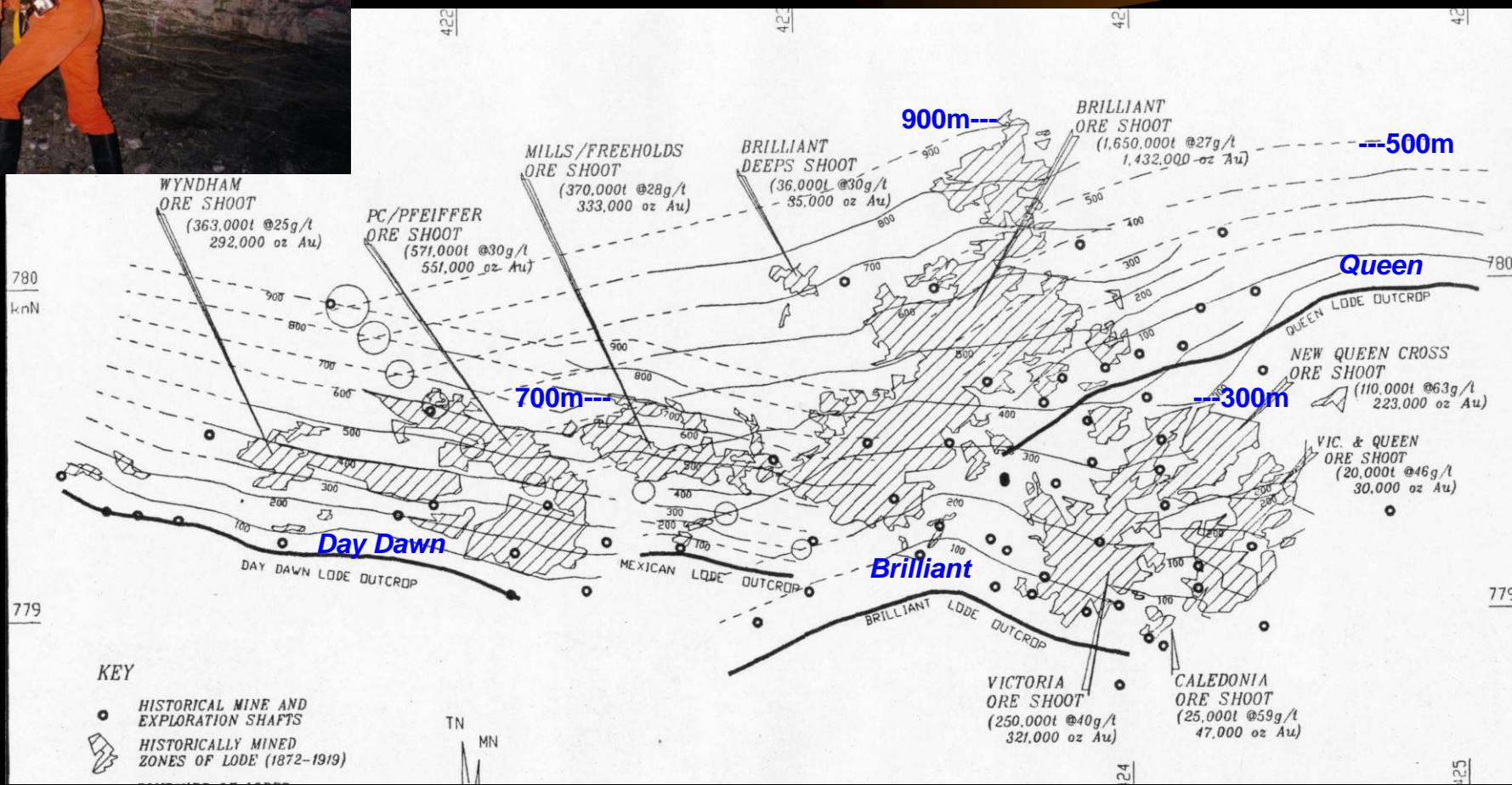
- 3. Metamorphic hosted
 - Great Britain



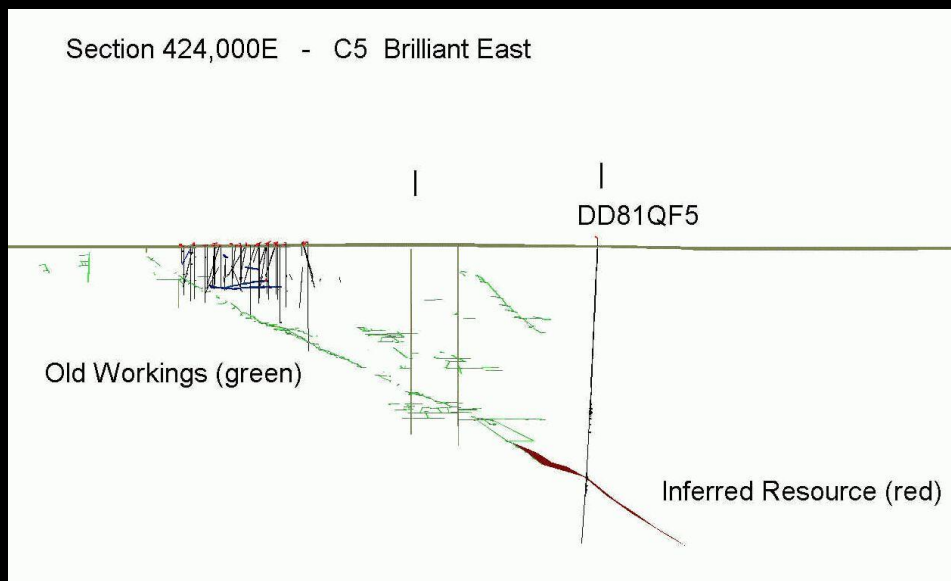
- 4. Alluvials

Ore Shoots

- Mined to 300 to max.~900m v.d.
- ~20% to >50% of fissures stoped
- Oreshoots 200-700m long (max. 1.6km) 70-200m wide
- Repeated at 200->300m intervals
- Subtle structural control on shallower dipping sections

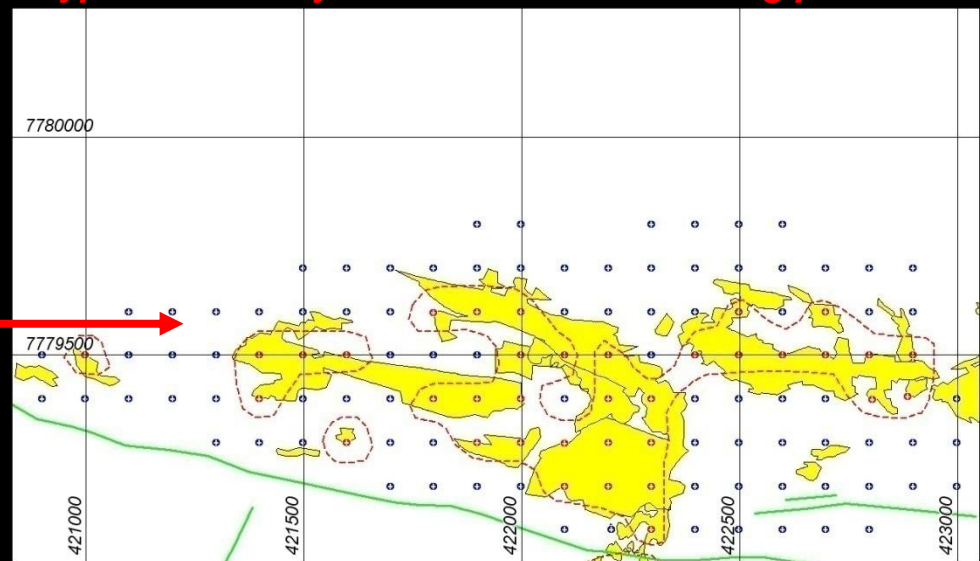


Known patterns of repetition of ore shoots

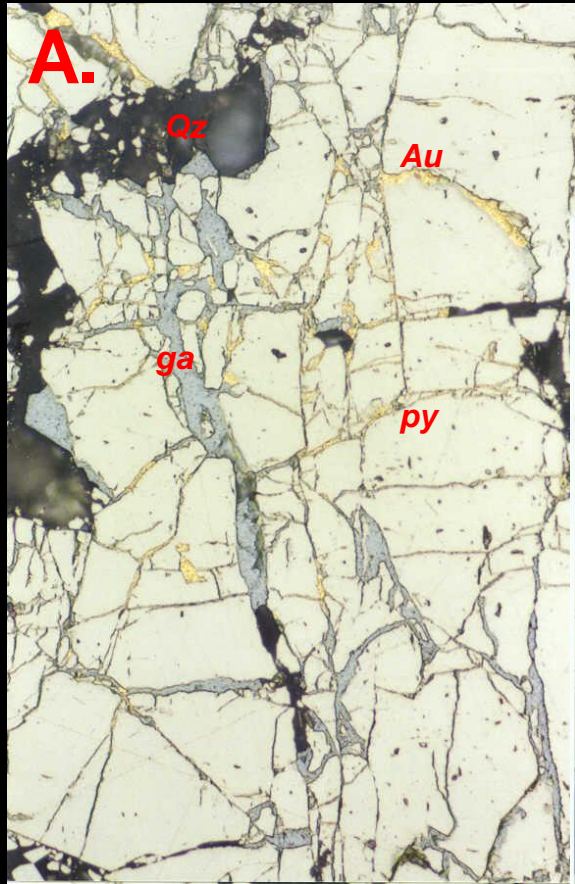


- Sparse current drilling pattern
- *Day Dawn*: <100m pattern required to outline ore
- 20% to 50% payability on lodes

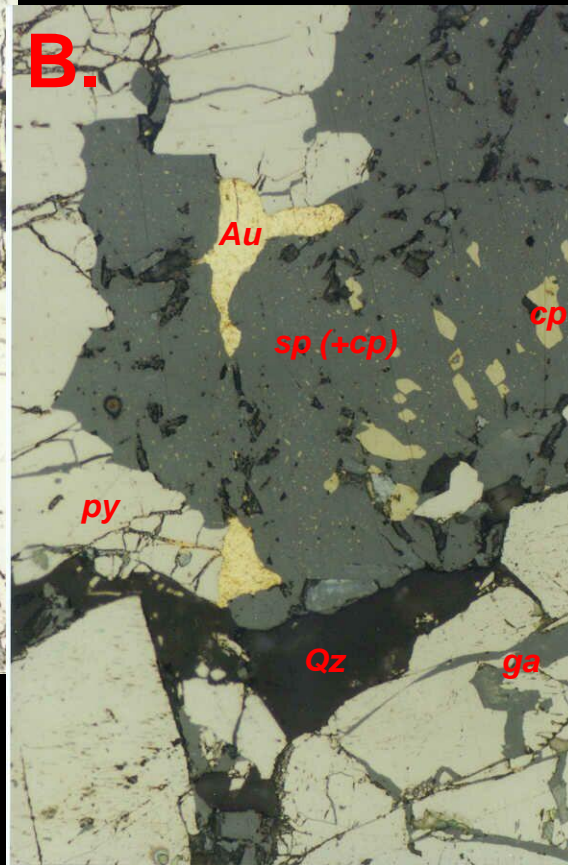
Hypothetical Day Dawn 100 x 100m drilling pattern



Charters Towers Gold Deposits – Most gold in the sulphides



0.0 mm 0.1



Stockholm Mine ore

Photos: Oliver Kreuzer

- **A.** Fine gold with galena and late quartz in fractured pyrite
- **B.** Coarser gold on pyrite / sphalerite contacts
- ~90% of gold in and on pyrite
- ~70% of the gold is on fine fractures in pyrite
- efficient chemisorption deposition process likely
- historic **visual** grade control based on gold correlation with sulphides

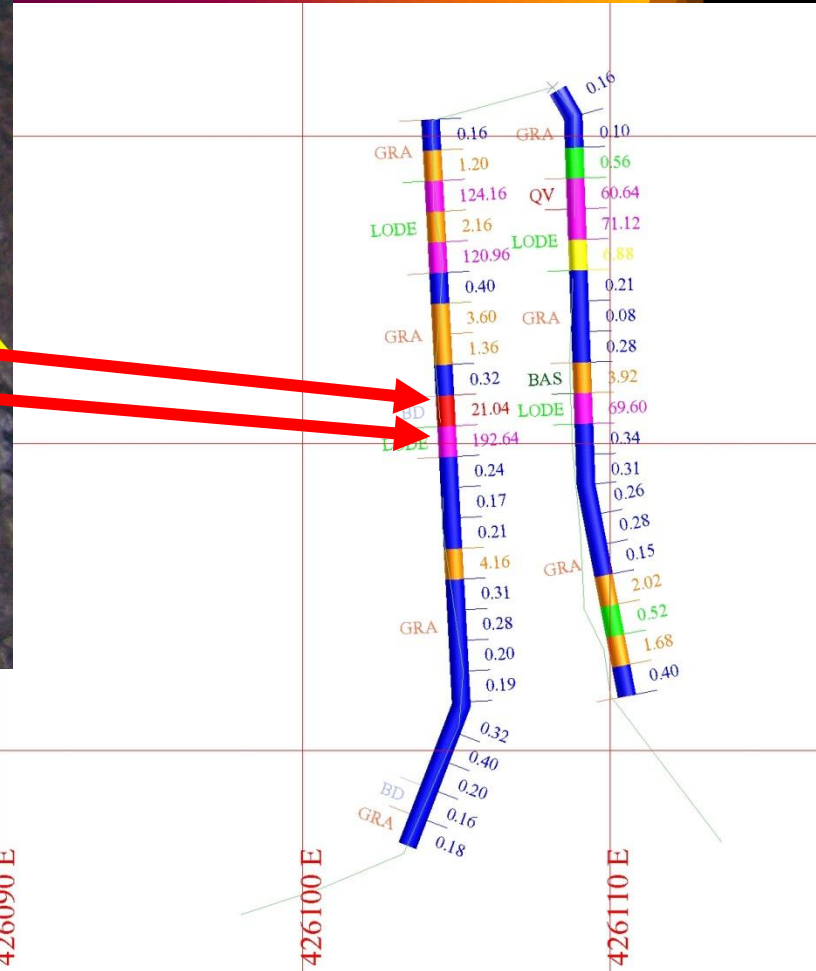
Charters Towers: Paragenesis

Paragenesis *(Roger Taylor):*

1. early barren white quartz reef
2. in-reef refracturing with grey quartz +/- pyrite deposition
3. refracturing with galena-Au and sphalerite +/- quartz deposition
4. refracturing with carbonate +/- quartz deposition.



Structural Control: high grade ore, 830m XC Warrior East



774930 N

426090 E

426100 E

426110 E

- Shear/fracture control on high-grade pyritic and quartz reef ore

Charters Towers: Grade continuity

CV2 Stope, 890 Level
85% Nugget Effect
8m Max. Range

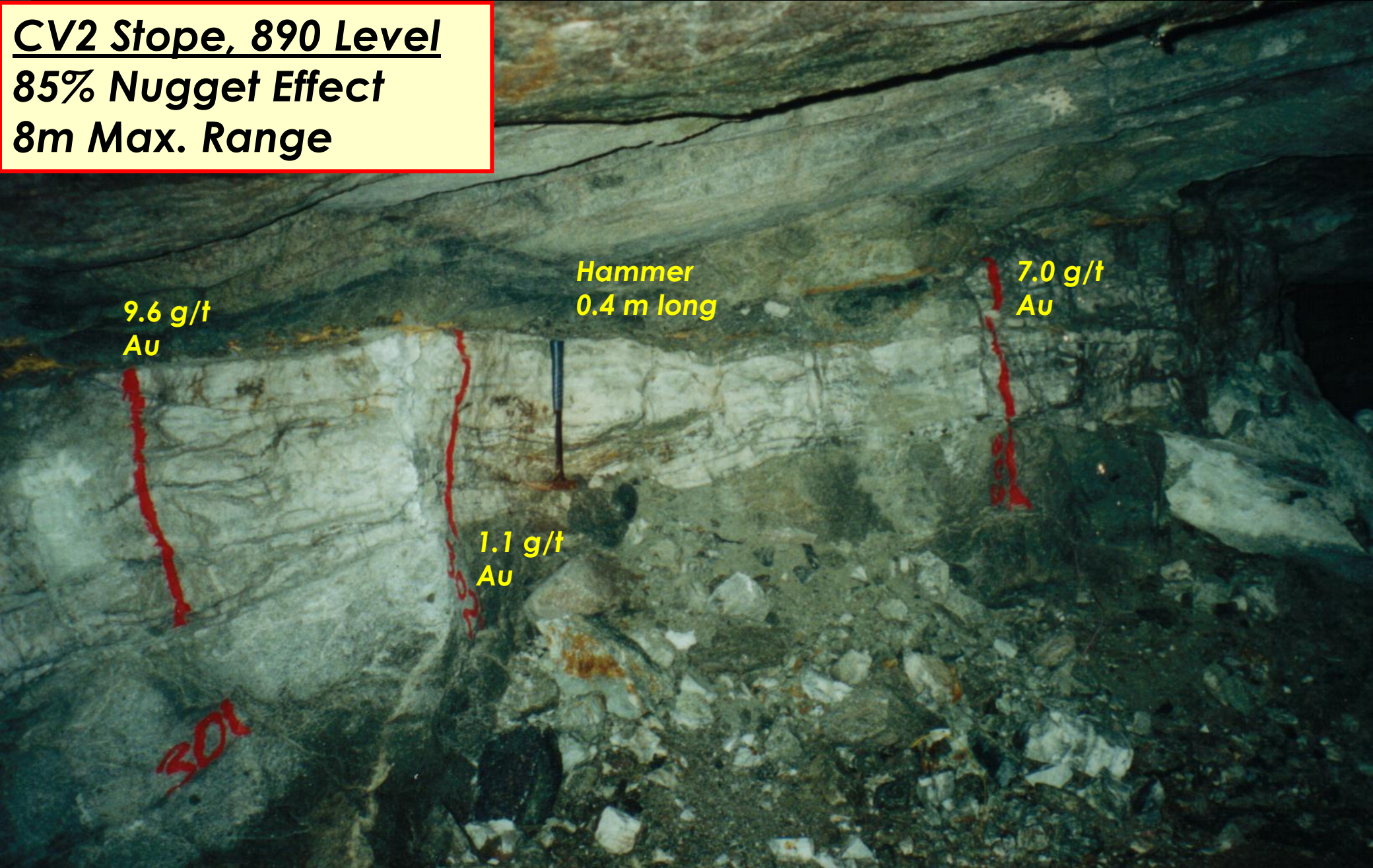
9.6 g/t
Au

Hammer
0.4 m long

7.0 g/t
Au

1.1 g/t
Au

301

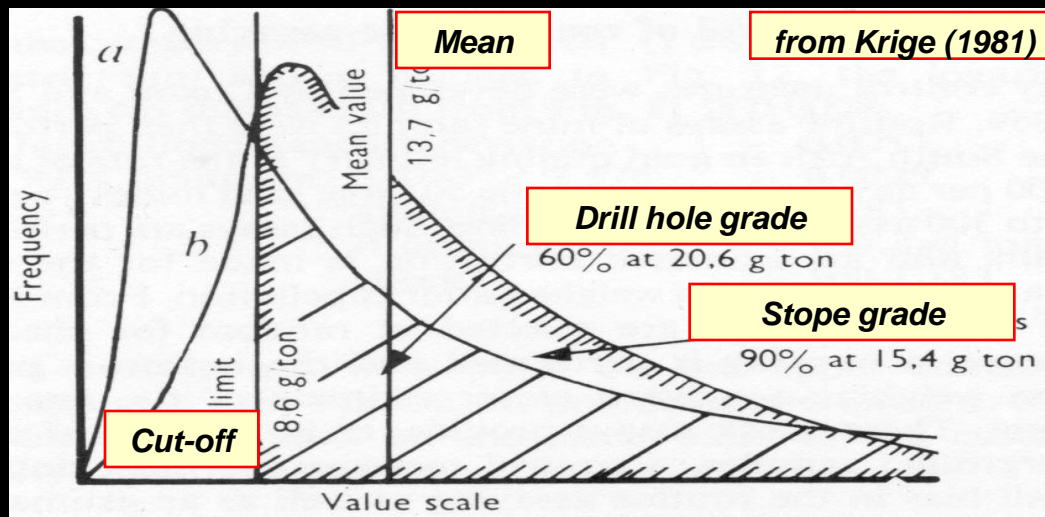


Charters Towers: Drill Intersection grade distribution



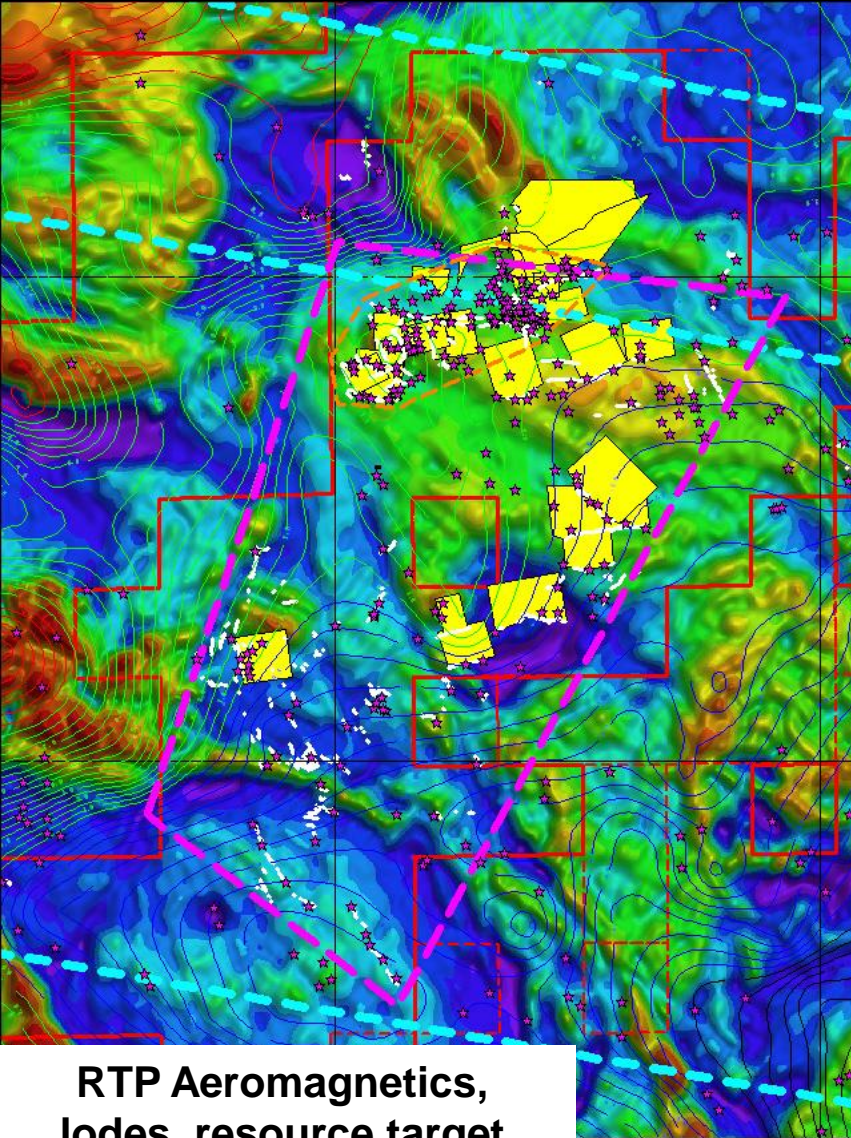
CT5010, 1.9m ETW

@ 8.8 g/t Au



- Drill hole grade distribution is highly skewed
 - Most hits are lower grade than the mean
 - Need to persevere
- Requires delineation by
 - Close spaced drilling
 - On-lode development
- Drill for structure; Drive for grade.

Charters Towers: Resource target areas



RTP Aeromagnetics,
lodes, resource target
blocks

- 2010 Inferred Resources were 10 Moz gold **23 Mt @ 14 g/t Au** (*yellow outlines on geology map to left*)
- 50 strike-km of lodes mostly undrilled or not tested at depth.

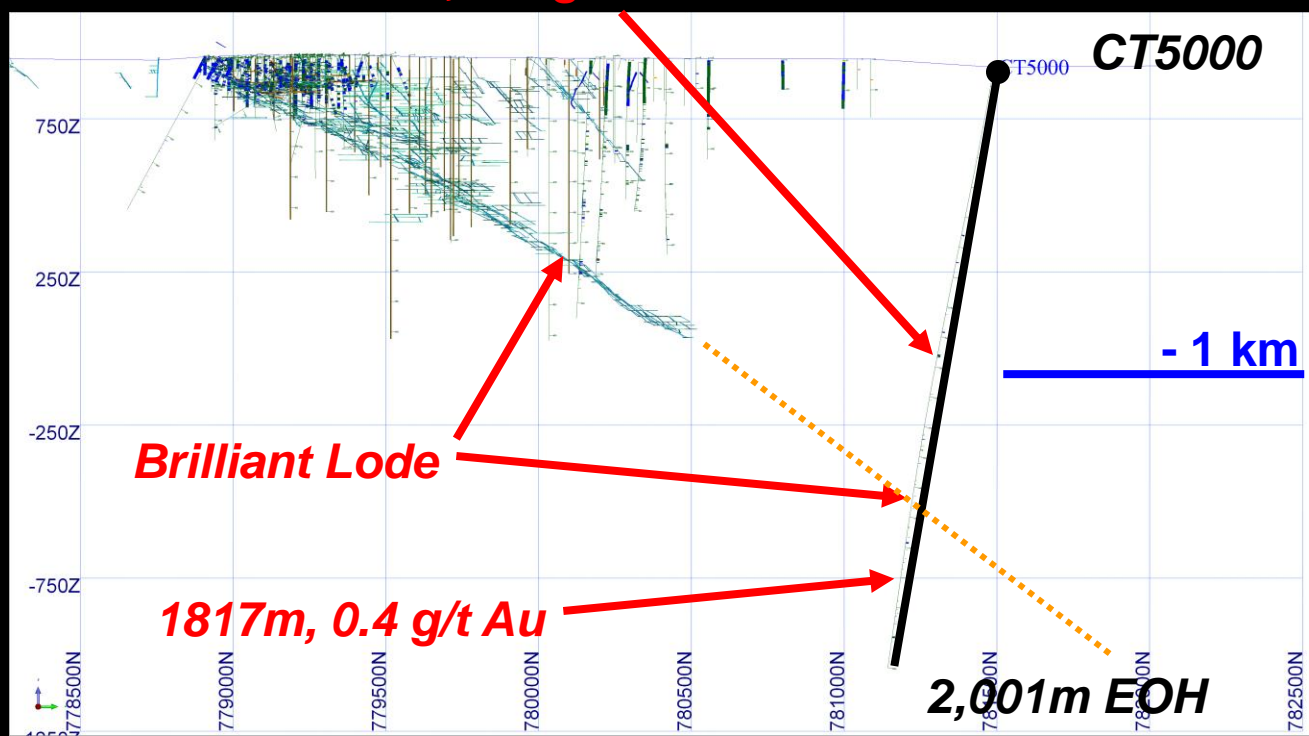
Geological Research: Queensland Govt. Collaborative Drilling Initiative



- **DDH CT 5000 in 2008**
 - in different hosts >1km from mines
 - extended known reefs to ~2,000m

960m, 1.9 g/t Au

- 0.2m @ 1.9 g/t Au at 960m (33 g/t Ag, 0.5%Pb)
- 0.6 g/t Au @ 1430m;
Brilliant Lode?
- Deepest intersection 0.1m @ 0.4 g/t Au at 1817m.
- Granites upper 1km,
Monzo-diorite lower 1km



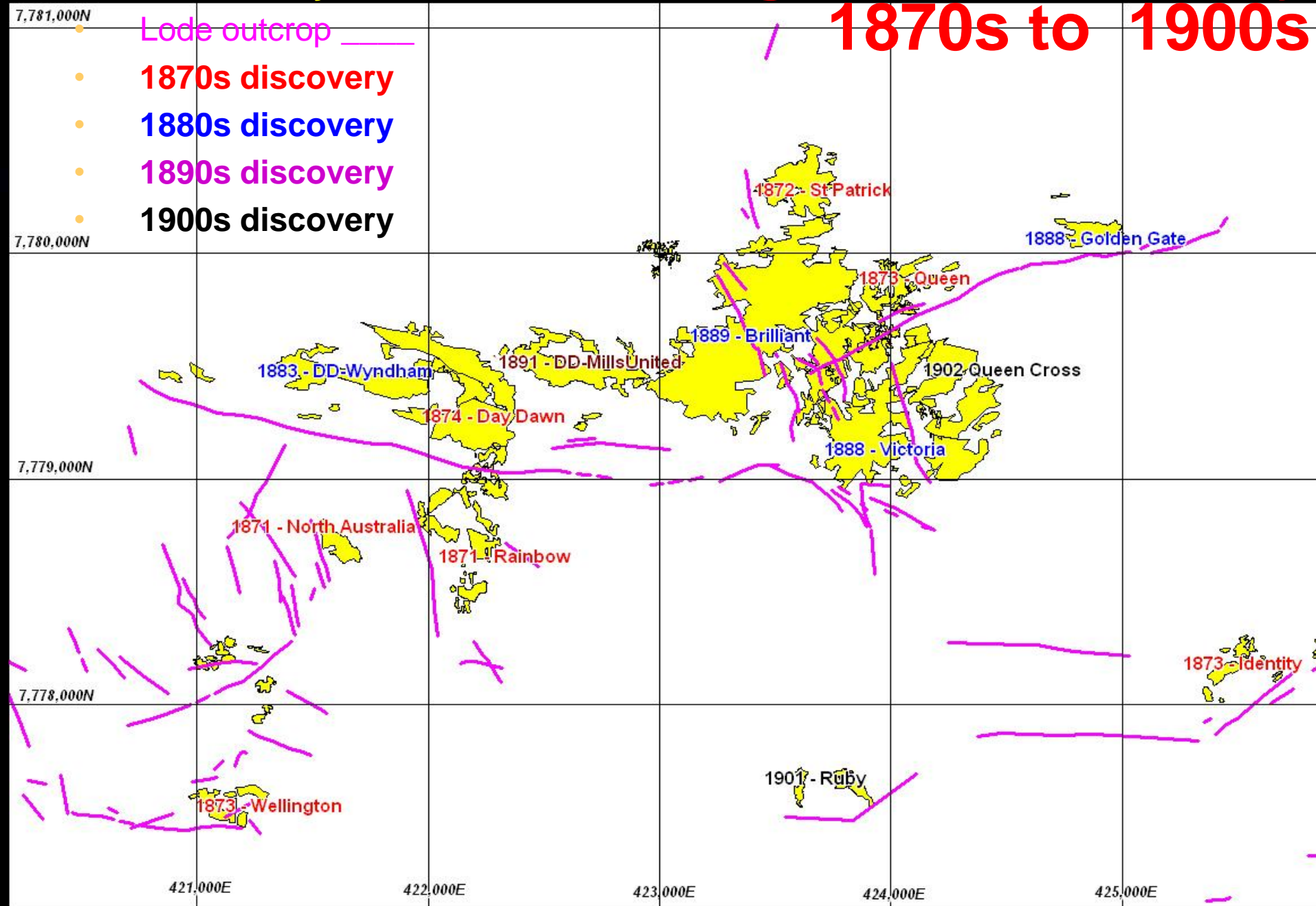
Locating ore shoots: City

• Oreshoots yellow

1870s to 1900s

7,781,000N
7,780,000N
7,779,000N
7,778,000N

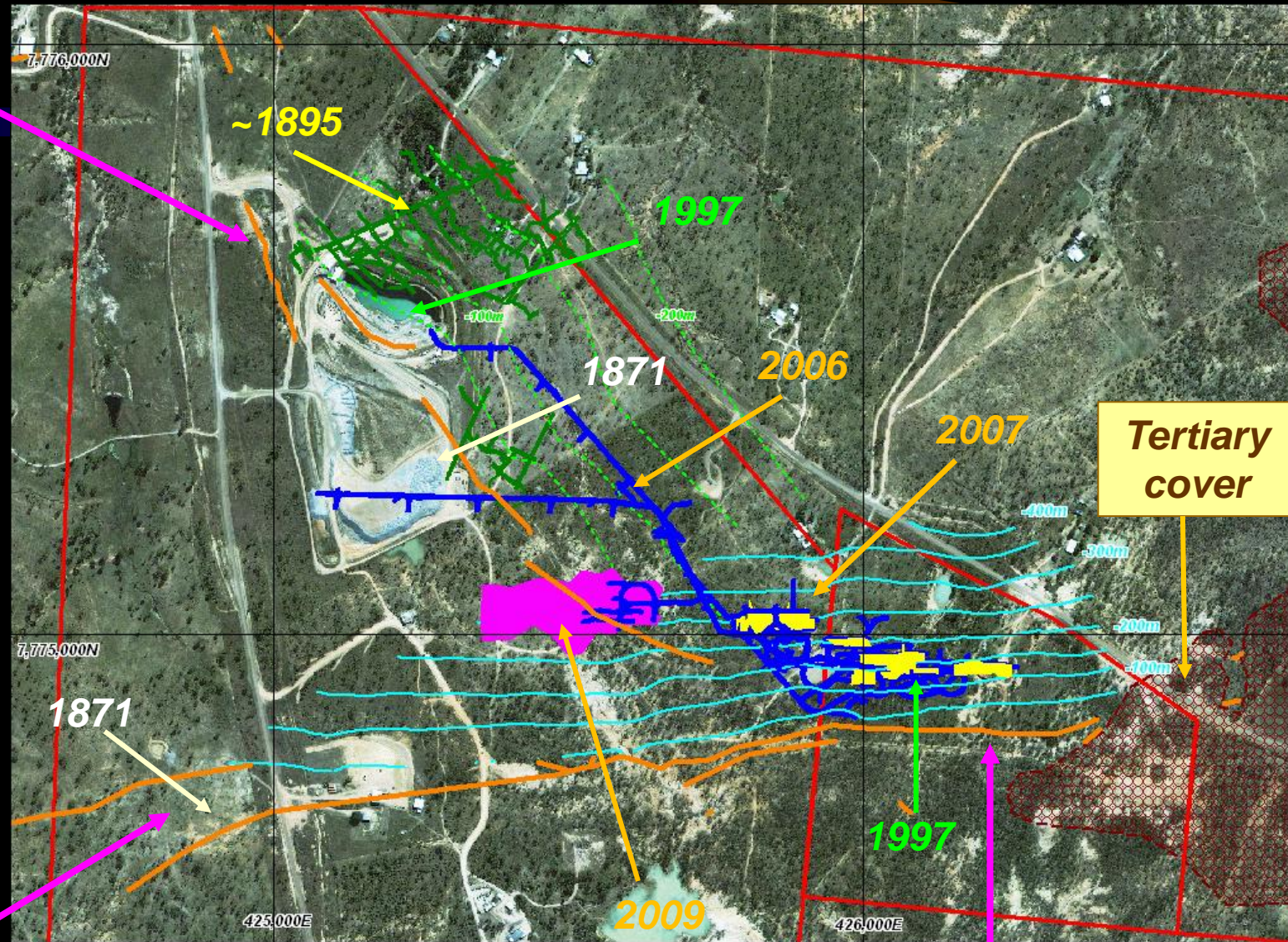
- Lode outcrop _____
- 1870s discovery
- 1880s discovery
- 1890s discovery
- 1900s discovery



Continuing discovery: Warrior

Golden Alexandra -
Washington - Sons
of Freedom lodes

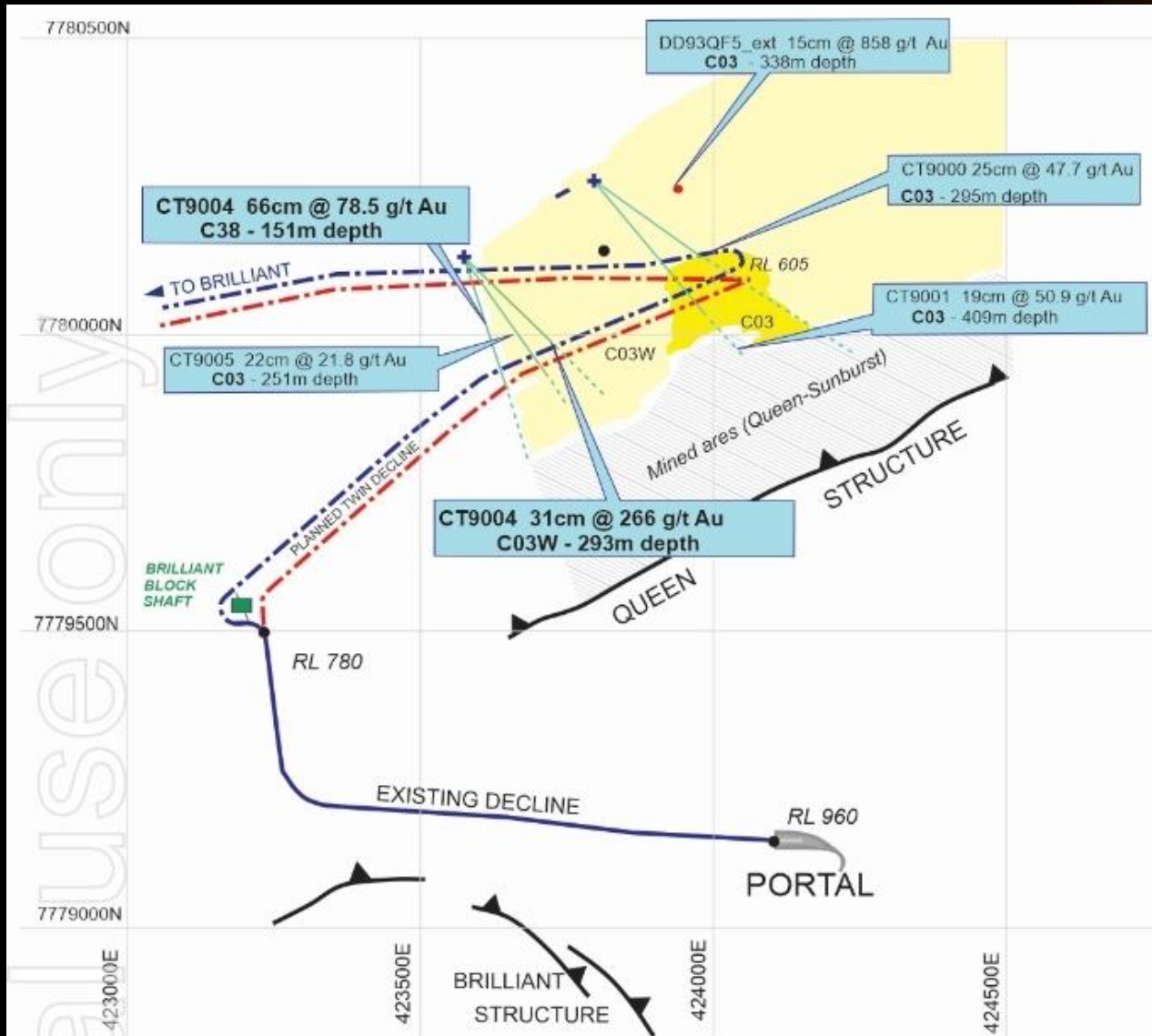
- 1870s prospecting
- 1890s underground
- 1990s RC drilling
- 2006 underground development
- 2007-2009 diamond drilling



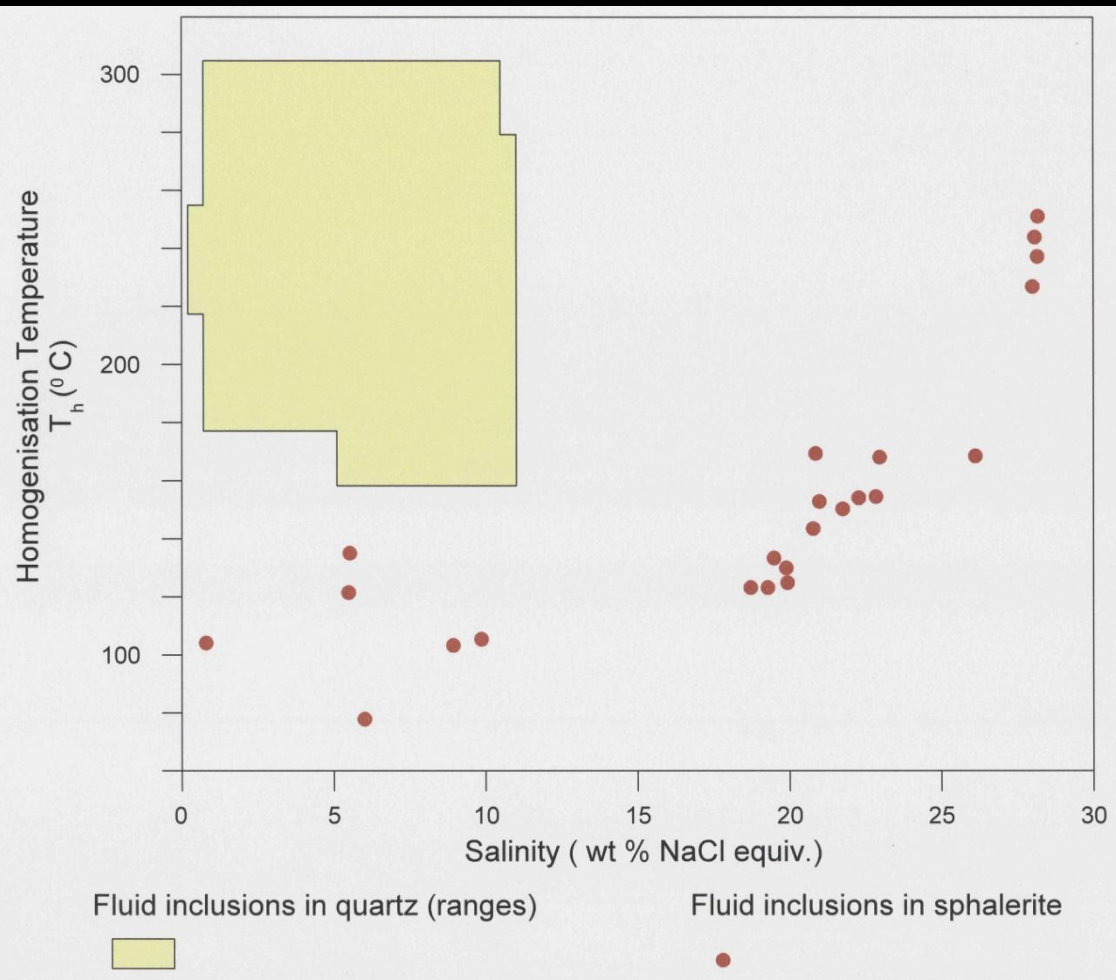
Warrior West

Warrior East

2010s: New Queen Lode Intersections



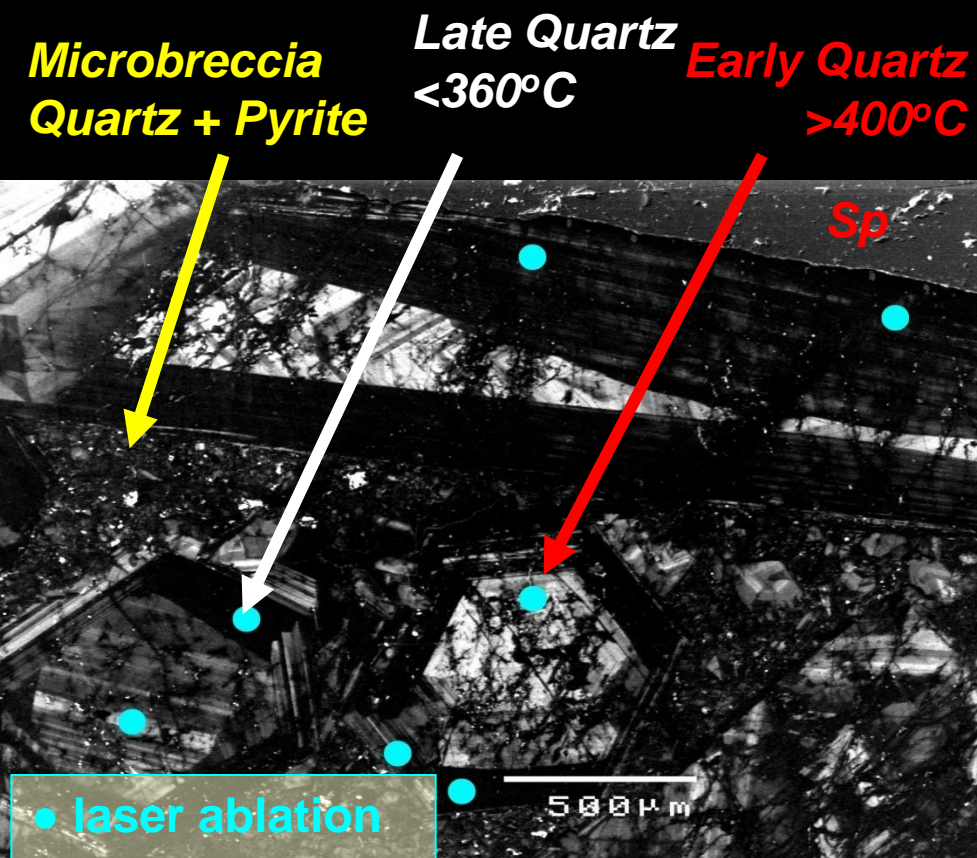
Research: Fluid inclusions models



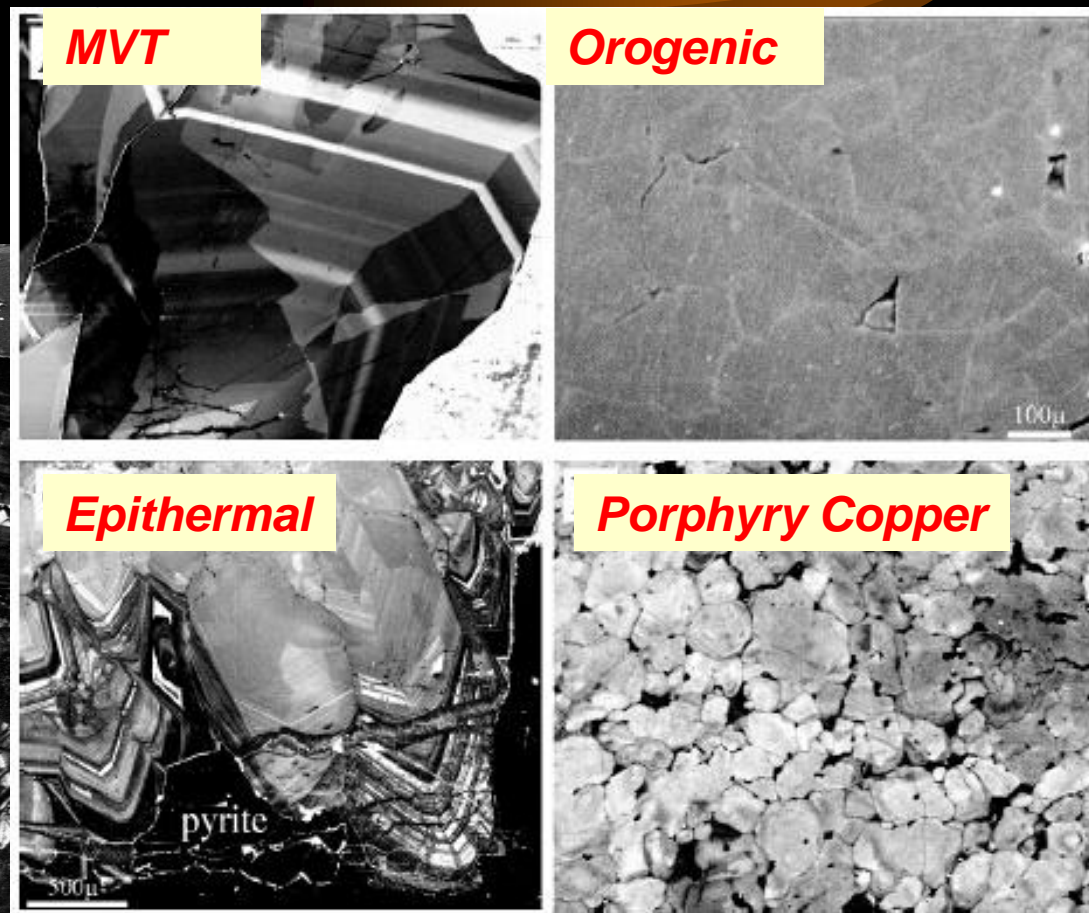
- **Some depositional models:**
 - **Fluid mixing of deep sourced saline fluids with cooler dilute higher level fluids (likely)**
 - **Structurally controlled pressure drop (likely)**
 - **Fluid mixing with reduced mantle methane (NOT Charters Towers)**

Research: SEM-Cathodoluminescence (CL)

- Charters Towers quartz veins not typical orogenic texture
- Oscillatory zoning in open brittle fractures
- Similarities to epithermal rather than orogenic or porphyry.



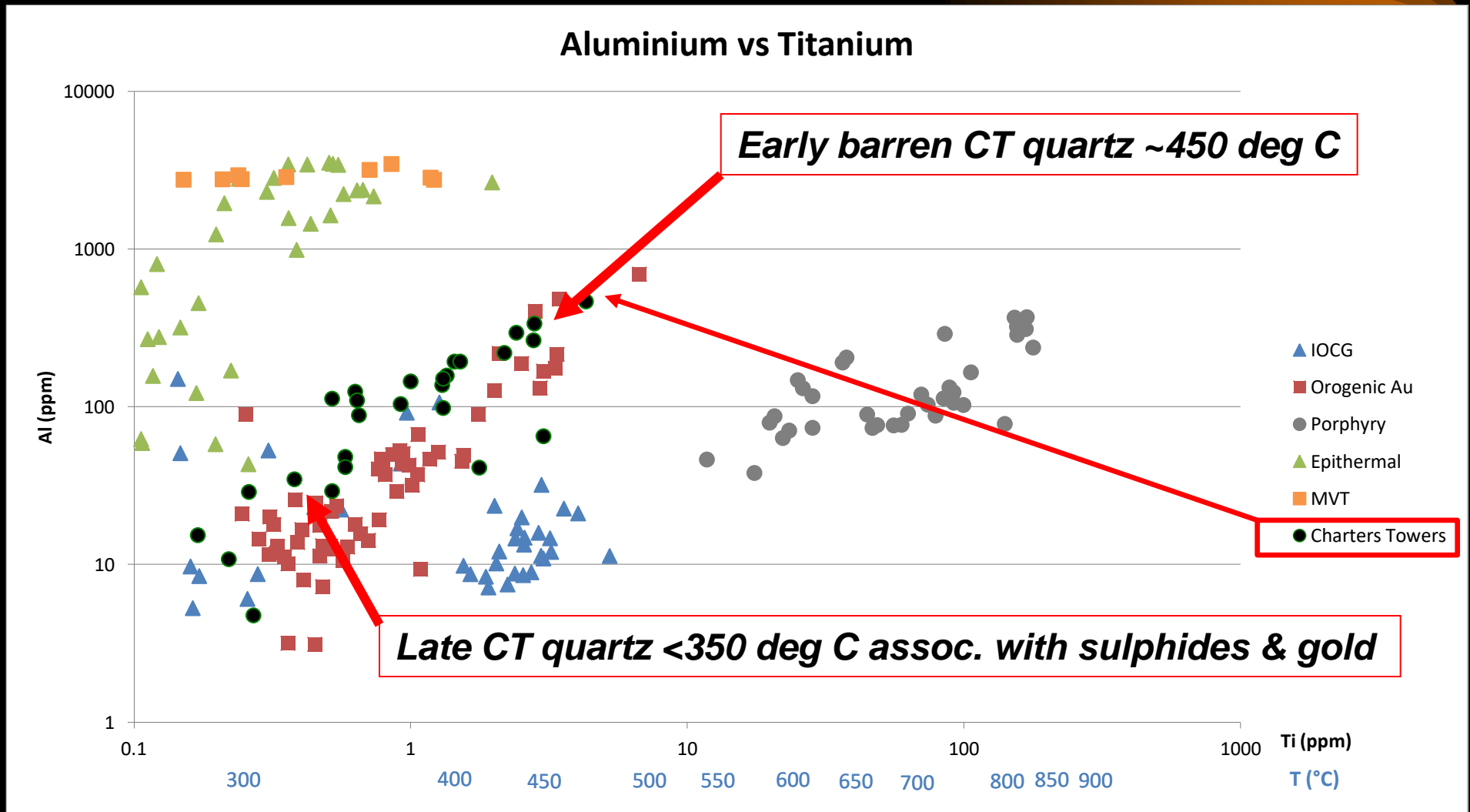
SEM-CL – Warrior East ore (Whiting, 2010)



SEM-CL quartz vein styles (Rusk, 2009)

Geological Research: LA ICP-MS - Ti v. Al

- Similar Ti:Al ratios to Orogenic gold
- fluid cooling +/- mixing?



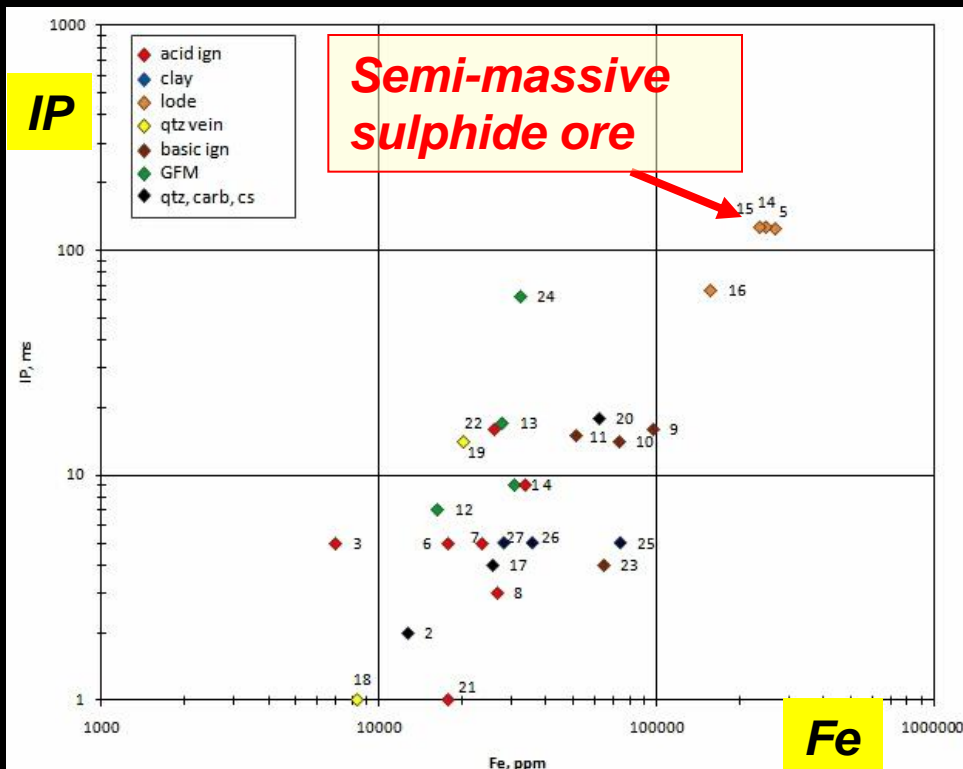
Geophysical Research: Petrophysical testwork

High grade pyritic ore:

- Conductor; EM target
- IP target
- Strong radar reflector

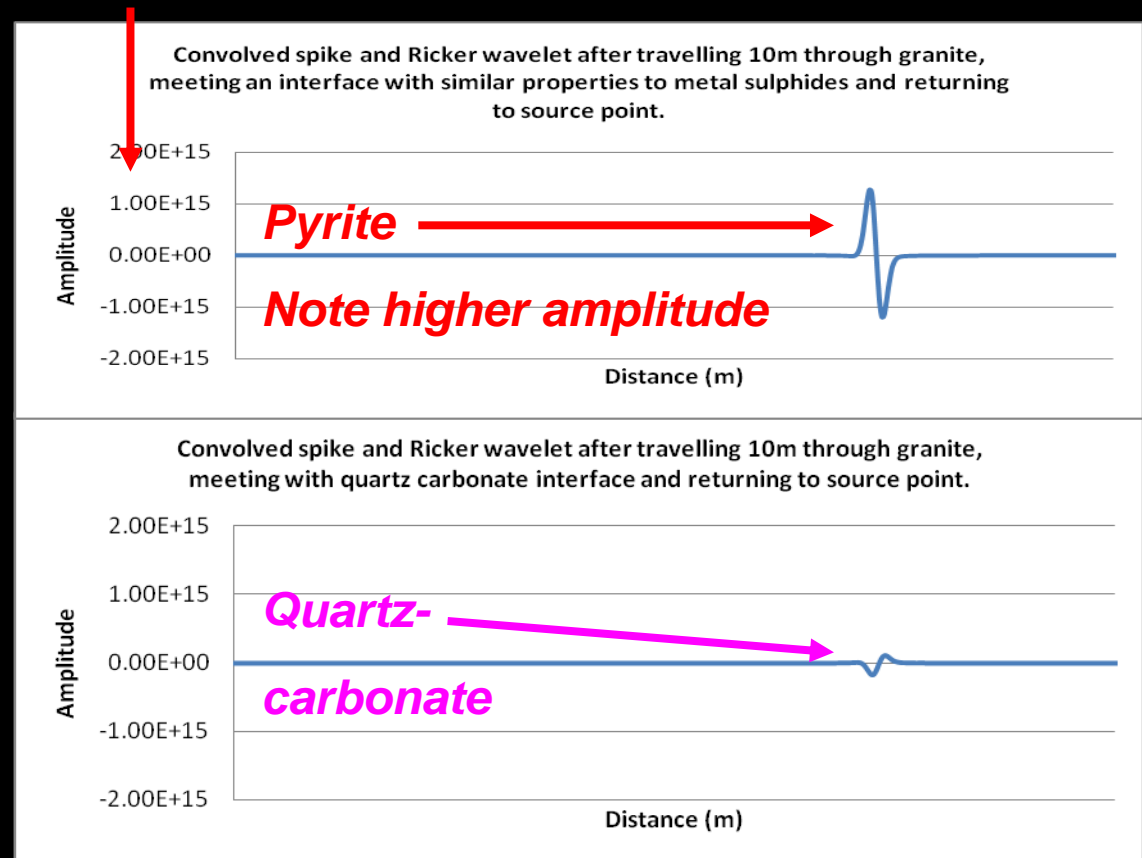
Lode structures & low grade gold:

- Low resistivity; IP conductivity target
- Galena is radar reflector
- Clay alteration radar absorber
- Magnetite destructive alteration



Geophysical Research– Geomole radar trials

- Lode parallel drilling trial
- Borehole radar can “see” out to ~50m in unaltered granite
- Forward modelling shows theoretical Radar reflections of interface types.
- Pyrite reflects better than quartz/carbonate

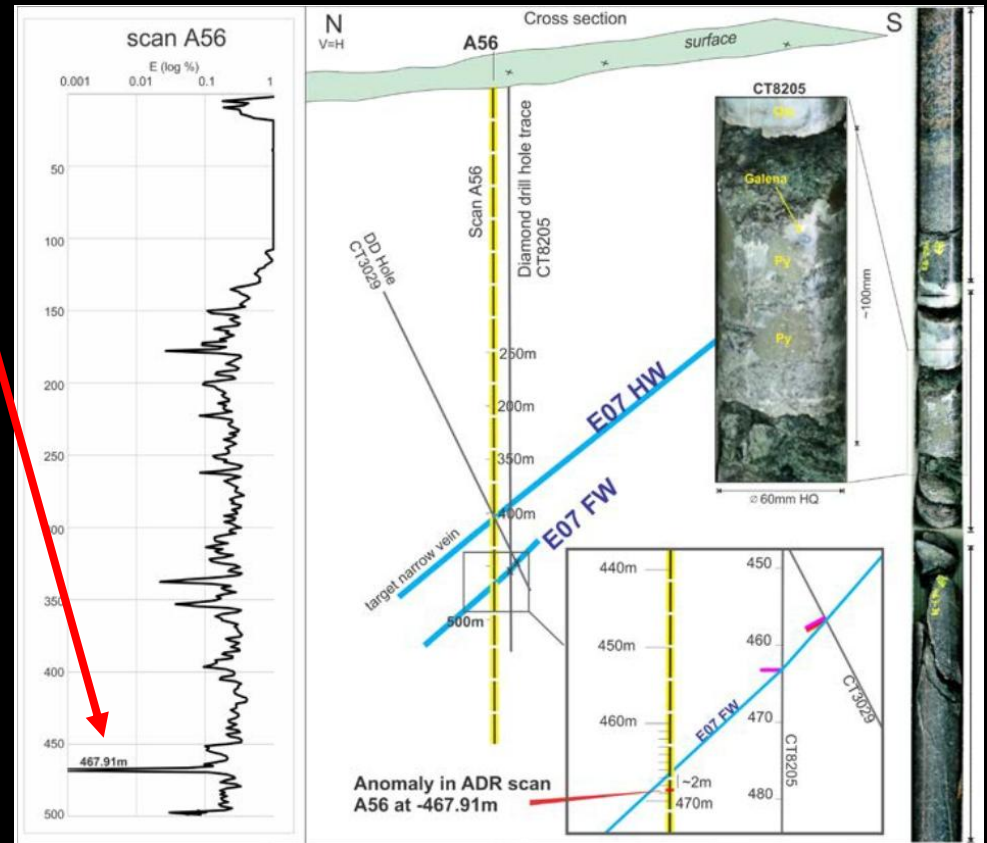


Post 2010 Geophysical Research: Atomic Dielectric Resonance (ADR)

- In contrast to borehole radar, ADR is a focussed radio frequency method.
- In reflectivity energy mode **reflections** from relative dielectric permittivity contrasts (ease with which a material is polarised by an electric field) are revealed.
- ADR can “see” out to > 1km



ADR field survey Warrior area.



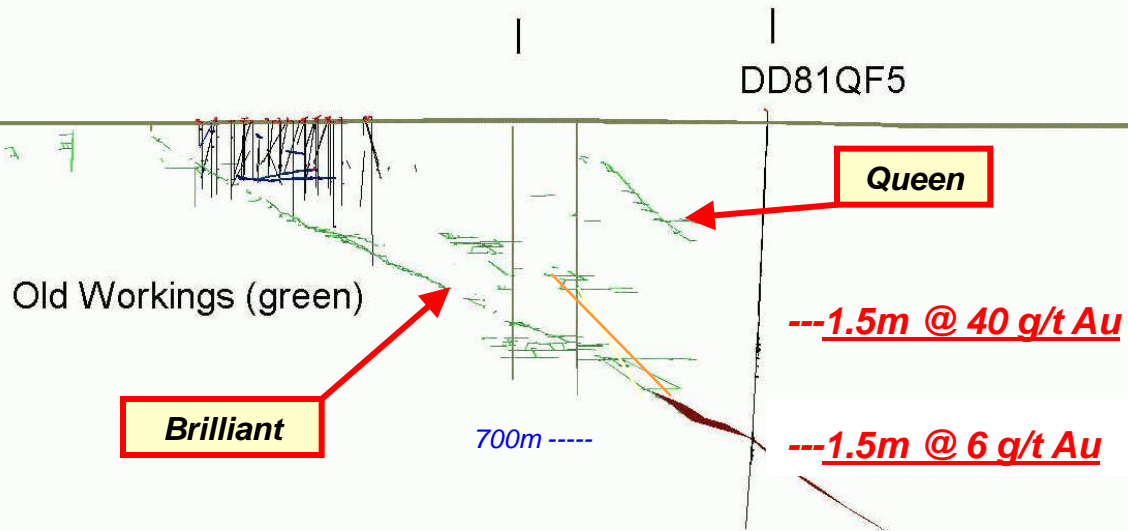
Summary

Charters Towers Goldfield:

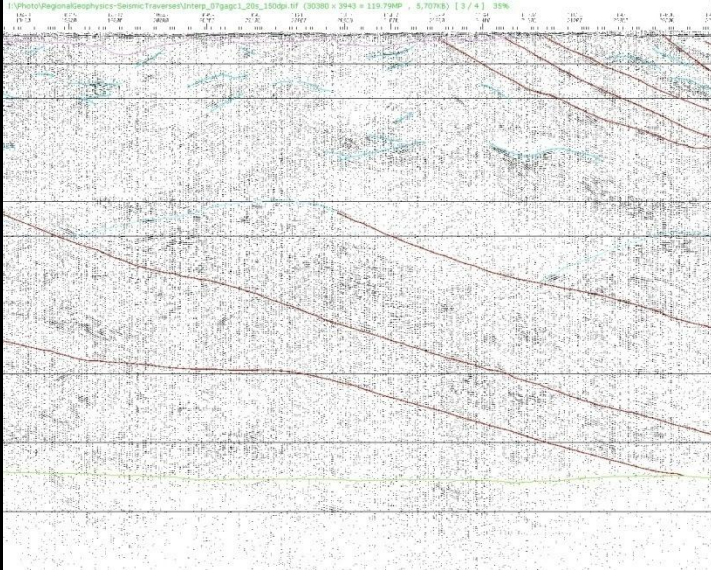
- 6 M oz gold production, + 10 M oz Exploration Targets & Inferred Resources (>500t Au)
- Has lithospheric characteristics required for a giant goldfield
- Geological research showing differences to standard Orogenic gold model
- Many lodes only sparsely tested
- Drilling continues to outline new gold oreshoots
- Down-hole IP, EM & radar targeting high grade ore
- Has potential to be a giant goldfield (>8 M oz production + reserves)

ANY QUESTIONS ?

Section 424,000E - C5 Brilliant East

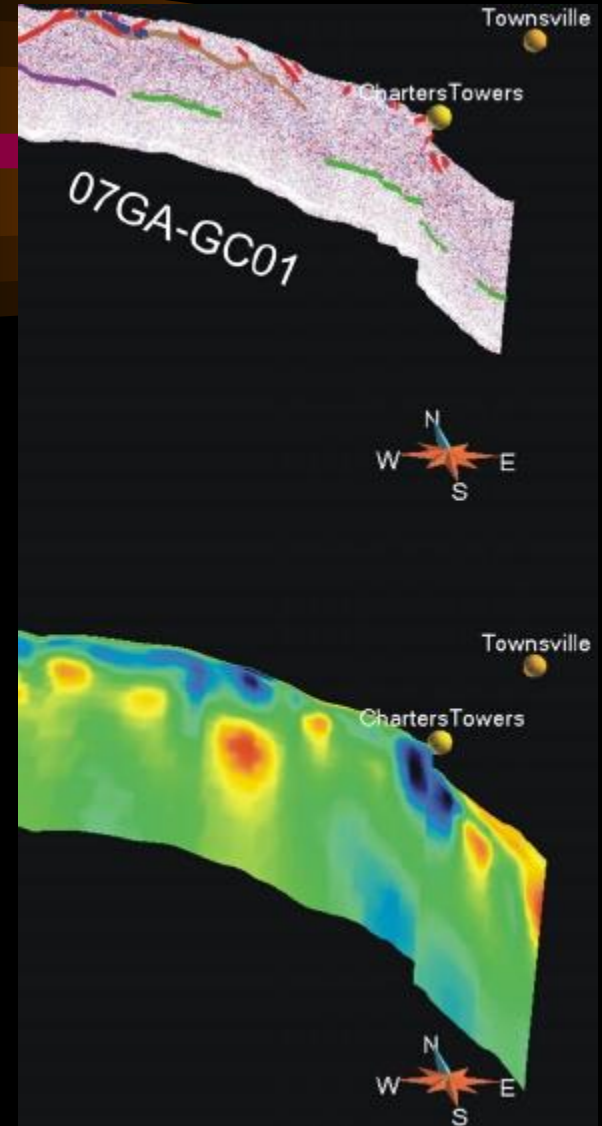


Geophysical Research: Seismic and MT



Based on Geoscience Australia data

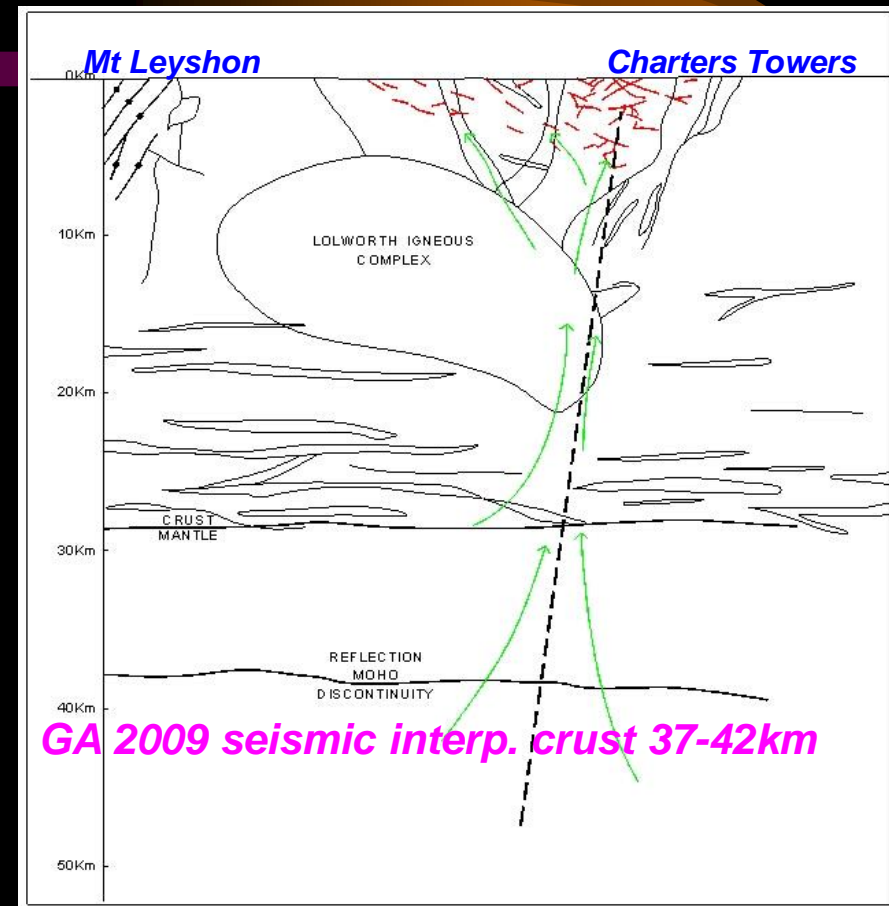
- ~60km depth seismic reflection traverse(above)
- ~80km depth magnetotellurics (below) showing resistive units below Charters Towers both shallow and at depth.



Giant base metal rich orogenic gold deposits (>500t Au): Charters Towers

• **Critical factors in Bierlein et al (2006) giant goldfield model include:**

- **continental margin location** ✓
- **thin sub continental lithospheric mantle at time of gold mineralisation** ?
- **primitive oceanic crust source enriched in Au & S** ?
- **high heat flux from the mantle to sustain crustal devolatilisation and melting.** ✓
- **large scale fluid release** ✓
- **crustal scale structures** ✓



Charters Towers cross section pre-2009 seismic data (looking west) with schematic mafic underplating