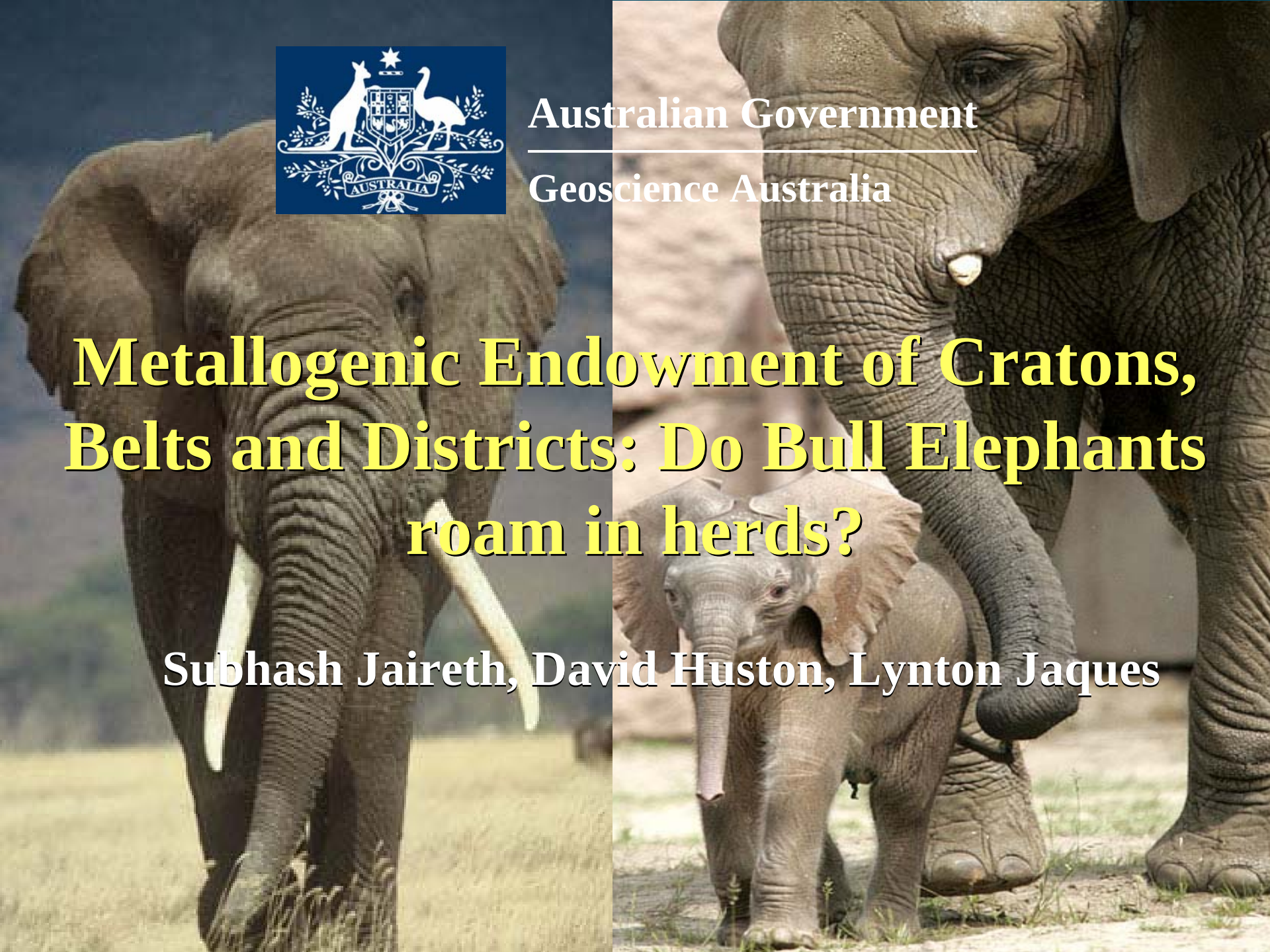


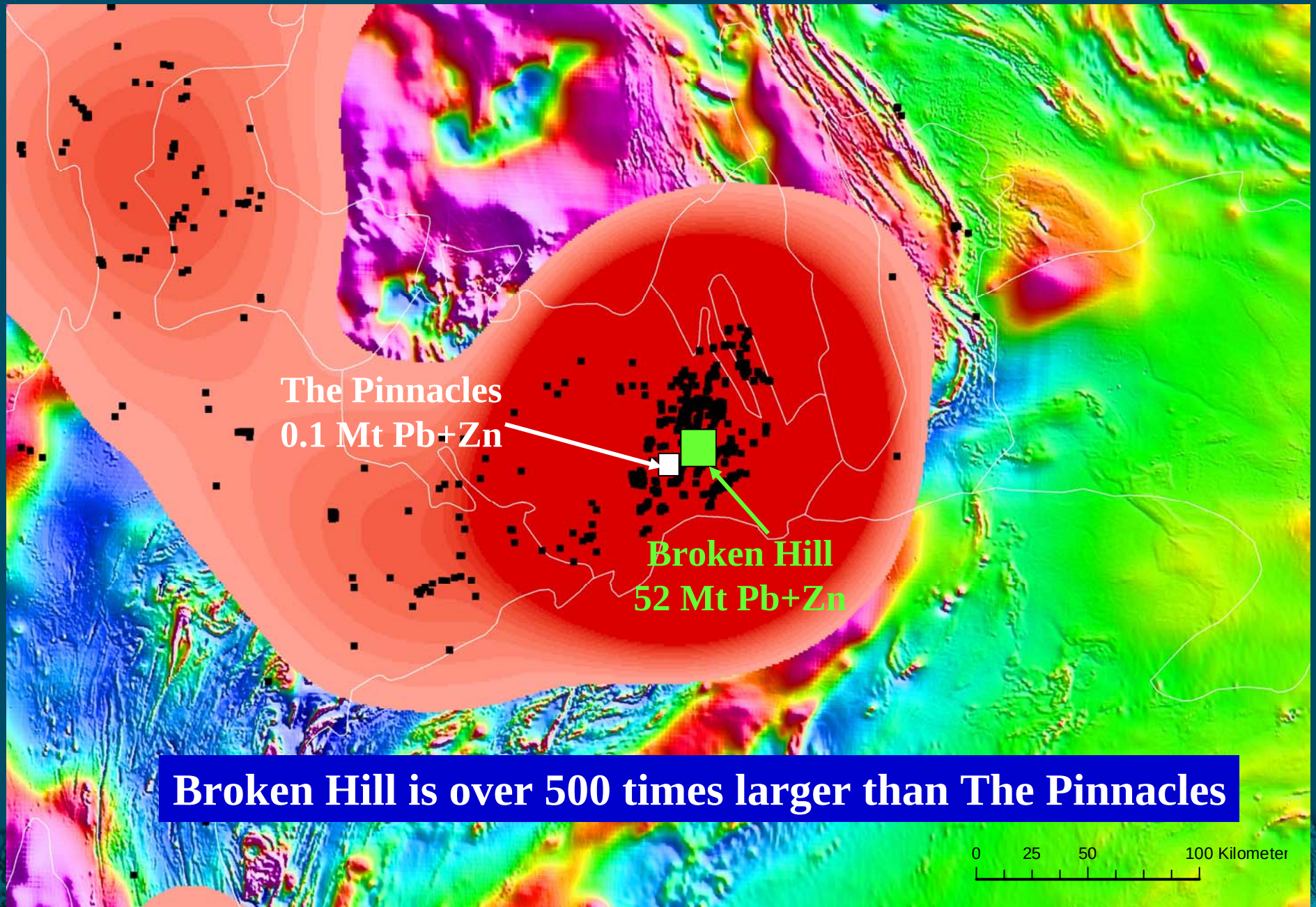
Australian Government

Geoscience Australia

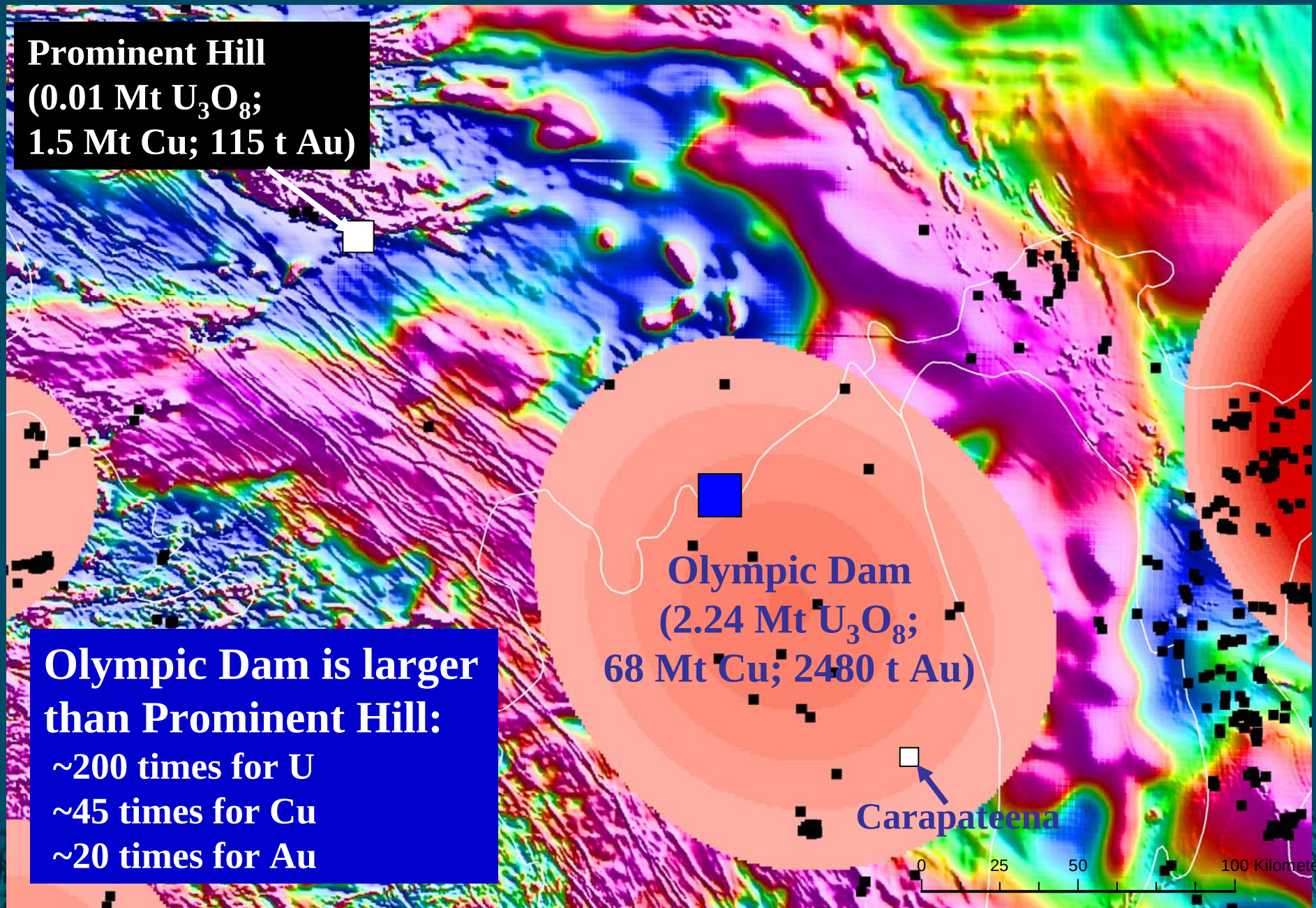
Metallogenic Endowment of Cratons, Belts and Districts: Do Bull Elephants roam in herds?

Subhash Jaireth, David Huston, Lynton Jaques

Bull Elephant 1: Broken Hill



Bull Elephant 2: Olympic Dam



Olympic Dam is larger than Prominent Hill:

- ~200 times for U
- ~45 times for Cu
- ~20 times for Au

Background

- In the past ten years terms such as ‘world-class’, ‘giant’, ‘super-giant’ deposits have been widely discussed
- Don Singer and his group:
  - used grade and tonnage data for deposits to define ‘world-class’
  - deposits with more than 100 t Gold; 2 Mt Copper, 1 Mt Lead and 1.7 Mt Zinc were considered ‘world-class’
- Richard Schodde:
  - Used a threshold value of $250 million NPV to define ‘world-class’

World-class, Giant and Super-giant?

- Deposits with more than 100 t Gold; 2 Mt Copper, 1 Mt Lead and 1.7 Mt Zinc were ‘world-class’ (largest 10% of deposits)
- Giant: 3 times bigger; Super-giant: 10 times bigger than world-class
  - Gold: 300 t (Giant); 1000 t (Super-giant)
  - Copper: 6 Mt (Giant); 20 Mt (Super-giant)
  - Lead: 3 Mt (Giant); 10 Mt (Super-giant)
  - Zinc: 5 Mt (Giant); 17 Mt (Super-giant)

Outline

- Show metal endowment data of selected deposits at craton/region, belt and district scales
- Discuss distribution of giant and super-giant deposits at different scales
- Show cumulative frequency curves (greater than curves) of total metal resources (production + remaining resources)
- Endowment curves for cratons/regions, belts and districts containing giant and super-giant deposits are different from those which do not contain them
- Discuss the need to focus on belts or districts with ‘giant’ and ‘super-giant’ deposits

Systematic Analysis of Endowment

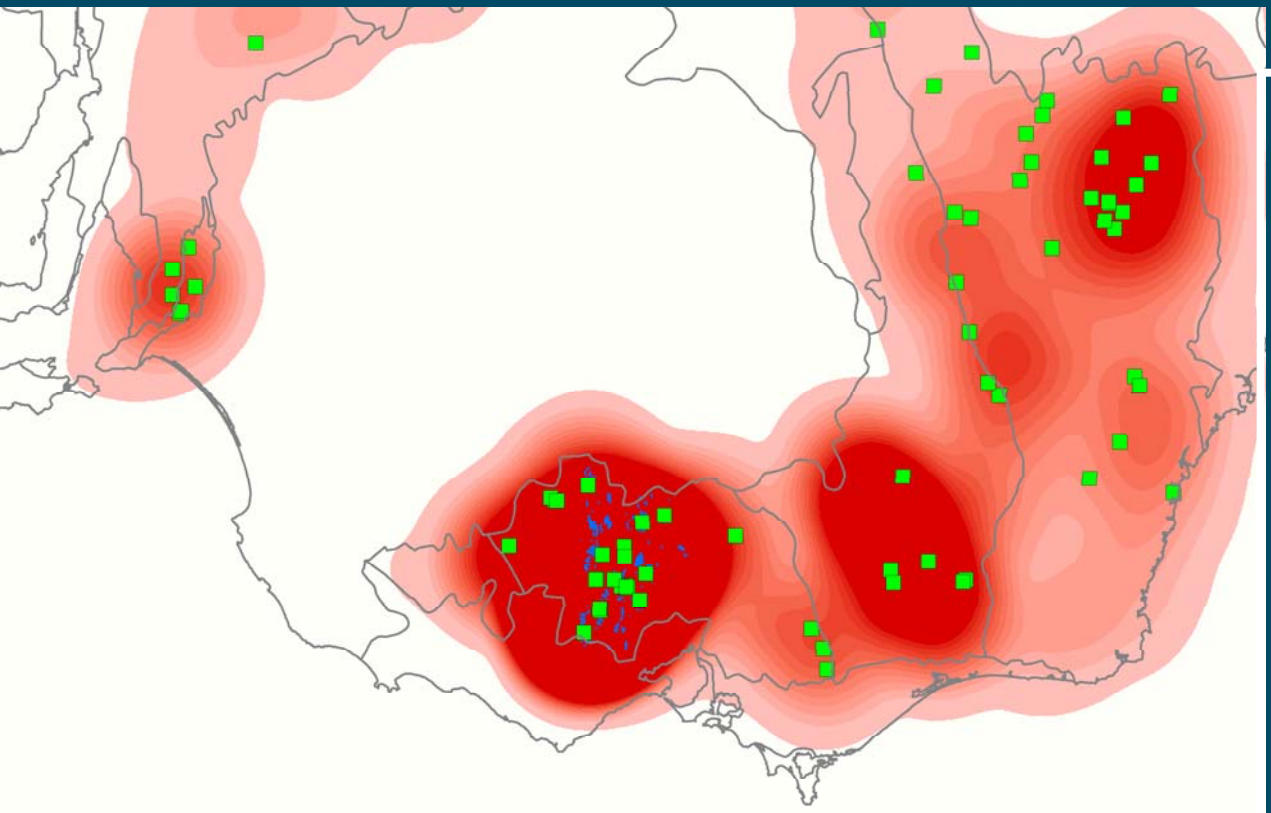
Undertaken for

- **Gold (Archaean greenstone, lode gold, epithermal, Carlin-style)**
- **Copper (porphyry, sediment-hosted copper)**
- **Lead-Zinc (VAMS, MVT, sediment-hosted stratiform or Mt Isa-style; Irish-style)**
- **Nickel (Komatiitic Ni-Cu)**
- **Uranium (Unconformity-related uranium)**
- **At craton/region, belt and district scales**

Sources of Grade and Tonnage Data

- GA's Ozmin (for Australian deposits)
- Copper deposits: USGS (Don Singer's group)
- Gold (Canadian Geological Survey)
- Lead-Zinc (David Leach)
- Nickel (Canadian Geological Survey)
- Uranium (Ozmin; Canadian Geological Survey)

Aggregation of Deposits/Resources



- Important to define what constitutes a deposit from a resource point of view
- 'Deposits' (ore zone, bodies, shoots) were aggregated using a constant distance of proximity between them

Distance used (based on proximity analysis)

- Gold: 1.6 Kms
- Copper: 2 Kms
- Nickel, Lead-Zinc: 1 Km
- Uranium: 600 m

Archaean Greenstone Gold (Kalgoorlie Terrane)

- Tonnage of Total metal (Log axis) vs Cumulative proportion of deposits sorted from smallest to largest
- Using the mean and standard deviation of the data, a curve is fitted to these data

90% deposits > 1 tonnes

50% deposits > 15 tonnes

10% deposits > 196 tonnes

Kalgoorlie (64)

Saint Ives

Super Pit

Quantile (%)

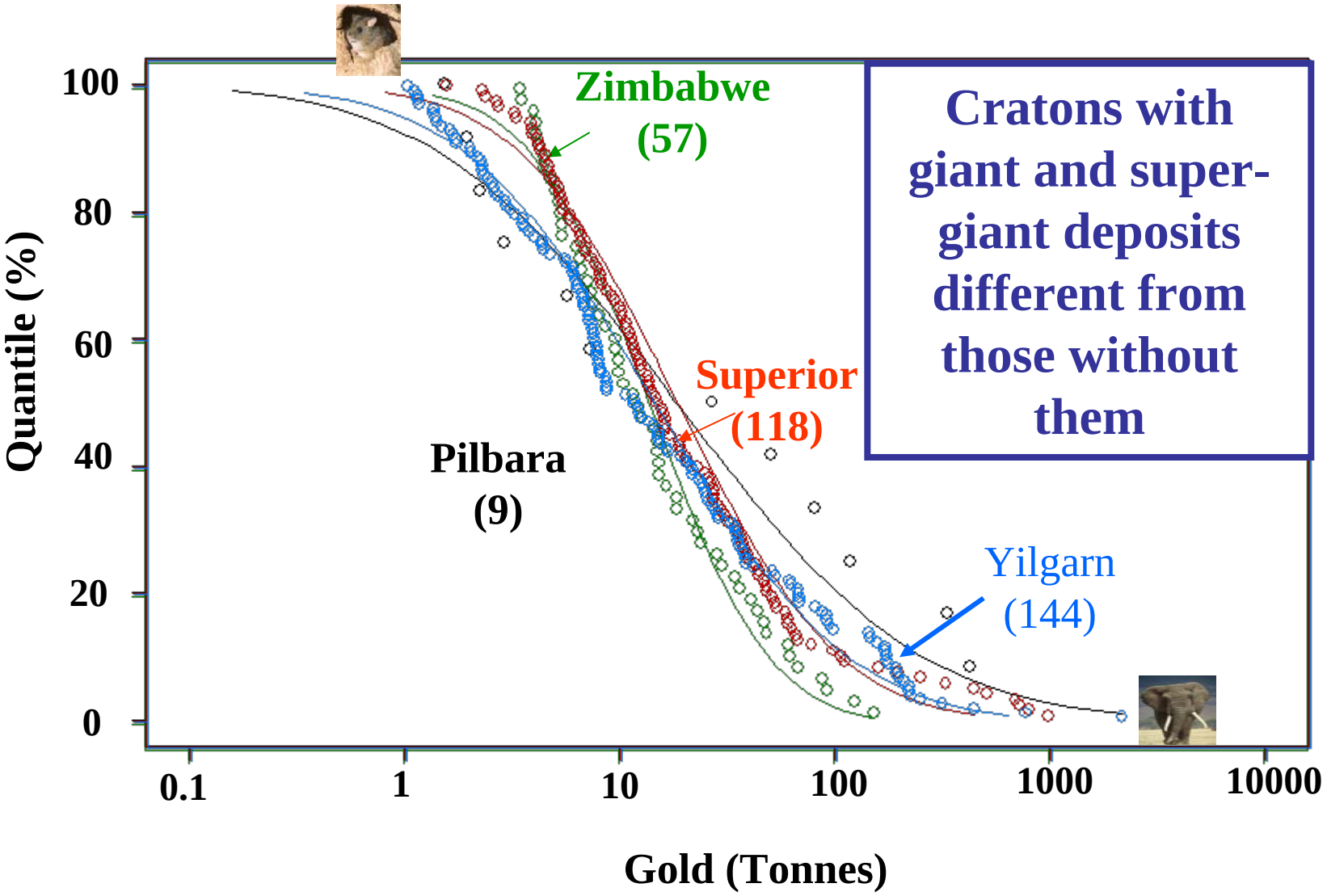
100
80
60
40
20
0

0.01
0.1
1
10
100
1000
10000

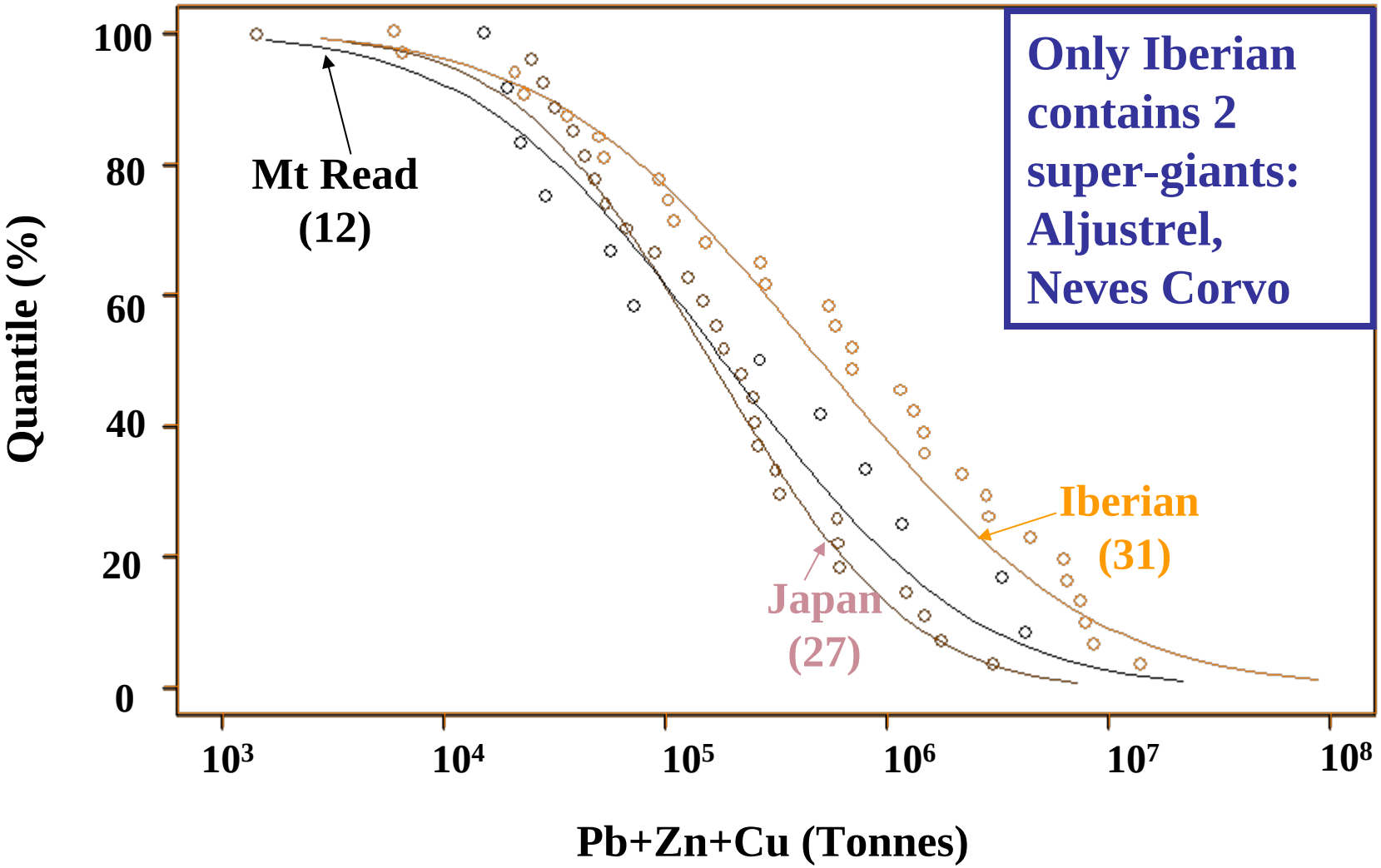
Gold (Tonnes)

Comparison of Regions/Cratons

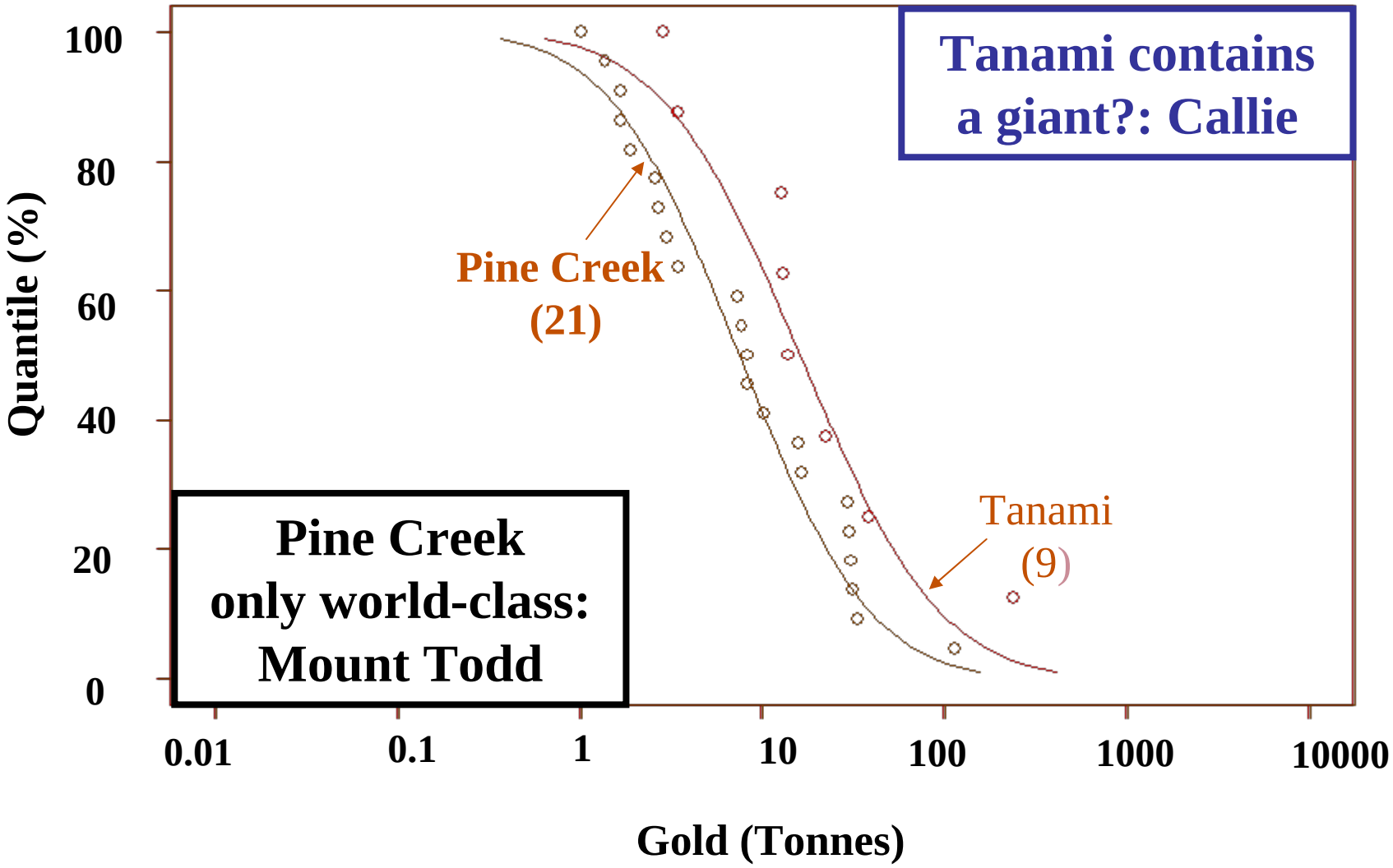
Archaean Greenstone Gold



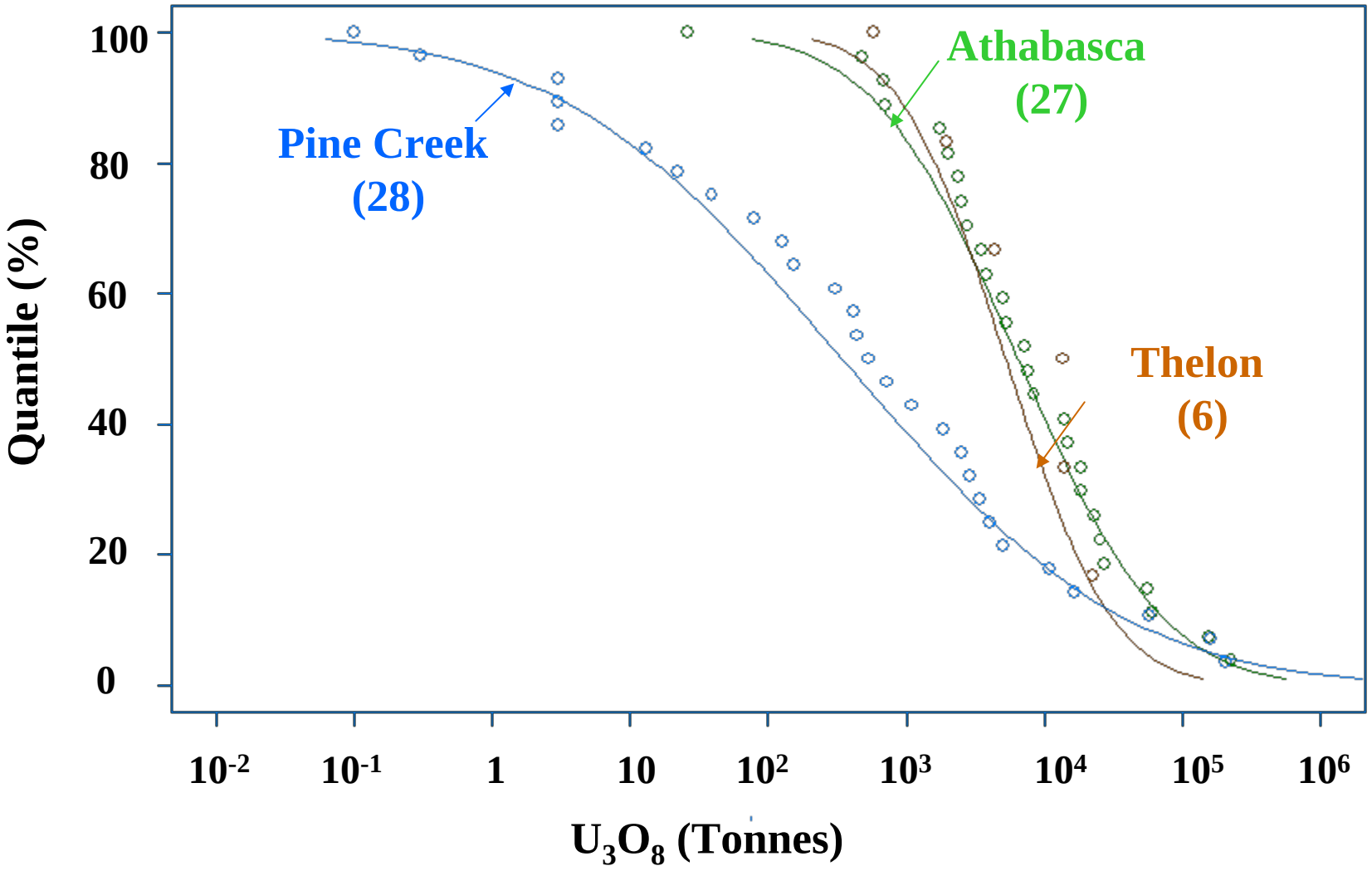
Volcanic-Associated Massive Sulphide



Lode Gold Deposits (Proterozoic, Australia)



Unconformity-Related Uranium

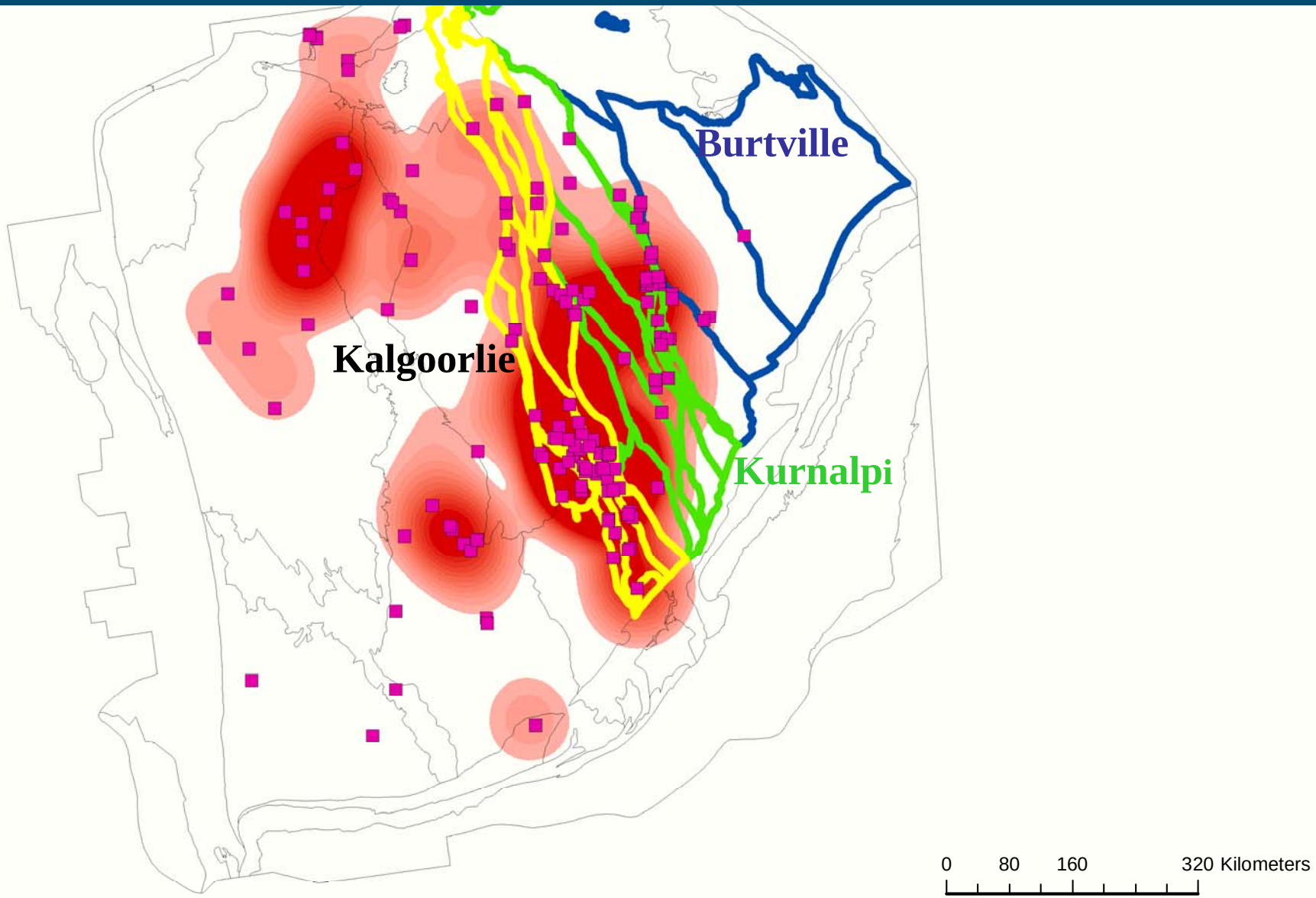


Conclusions Part I

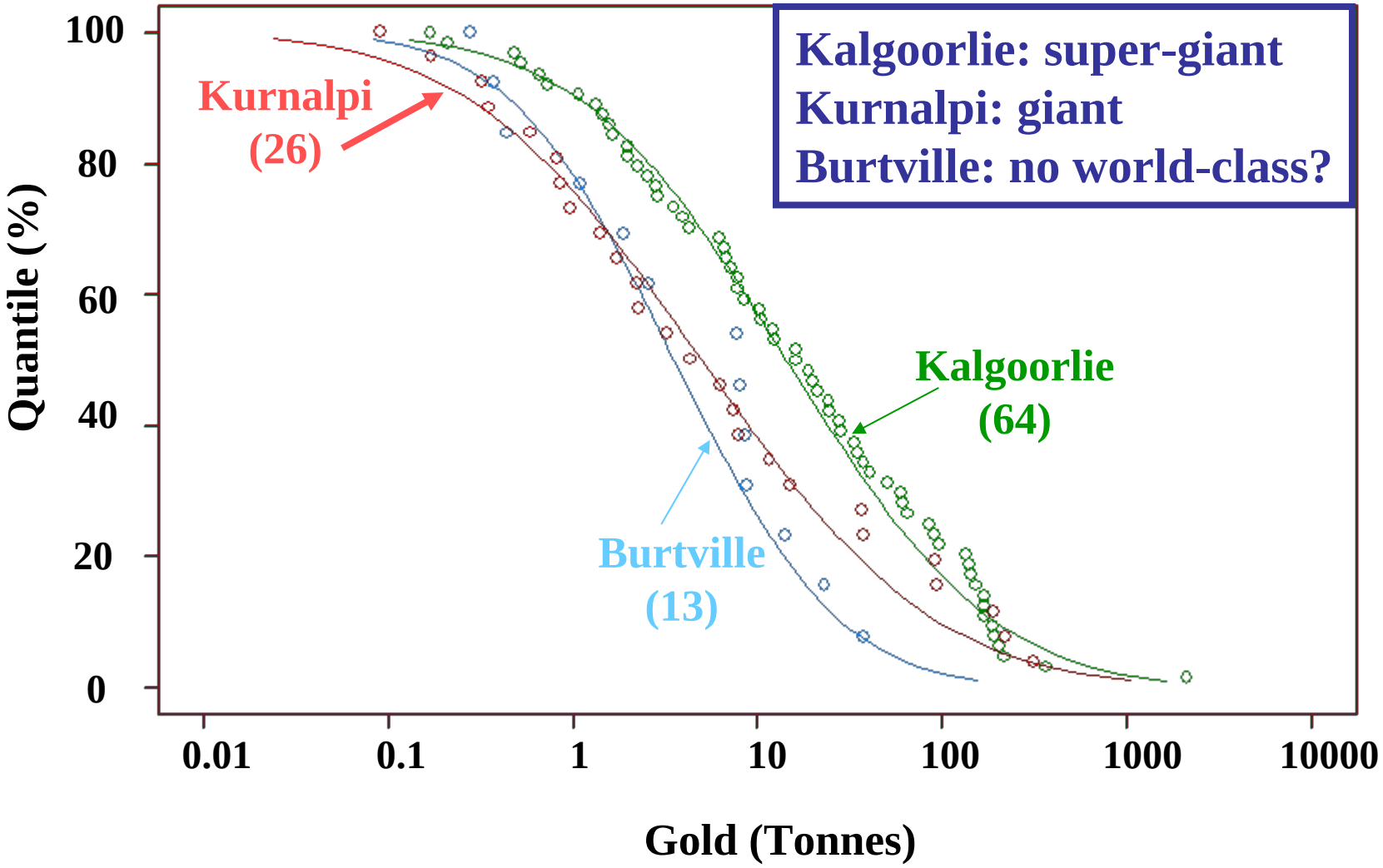
- **'Bull elephants' do exist**
- **Endowment curves can distinguish large areas (cratons/regions) with different endowment (with and without giant and super-giant deposits)**
- **In most regions/cratons the Largest Deposit is 2 or 5 to 10 times larger than the 2nd Largest**

Comparison of Belts and Districts

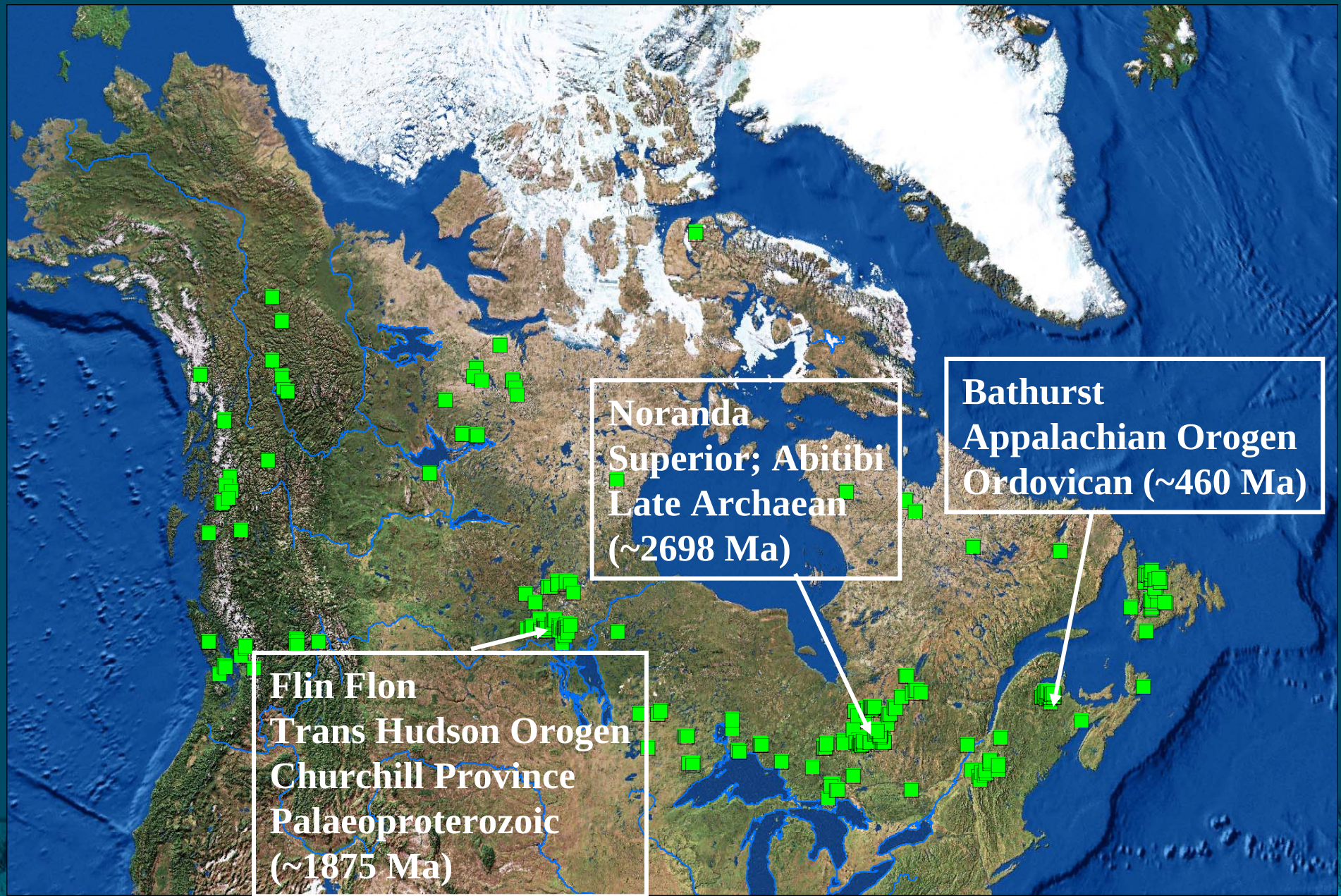
Archaean Greenstone Gold (Eastern Goldfields)



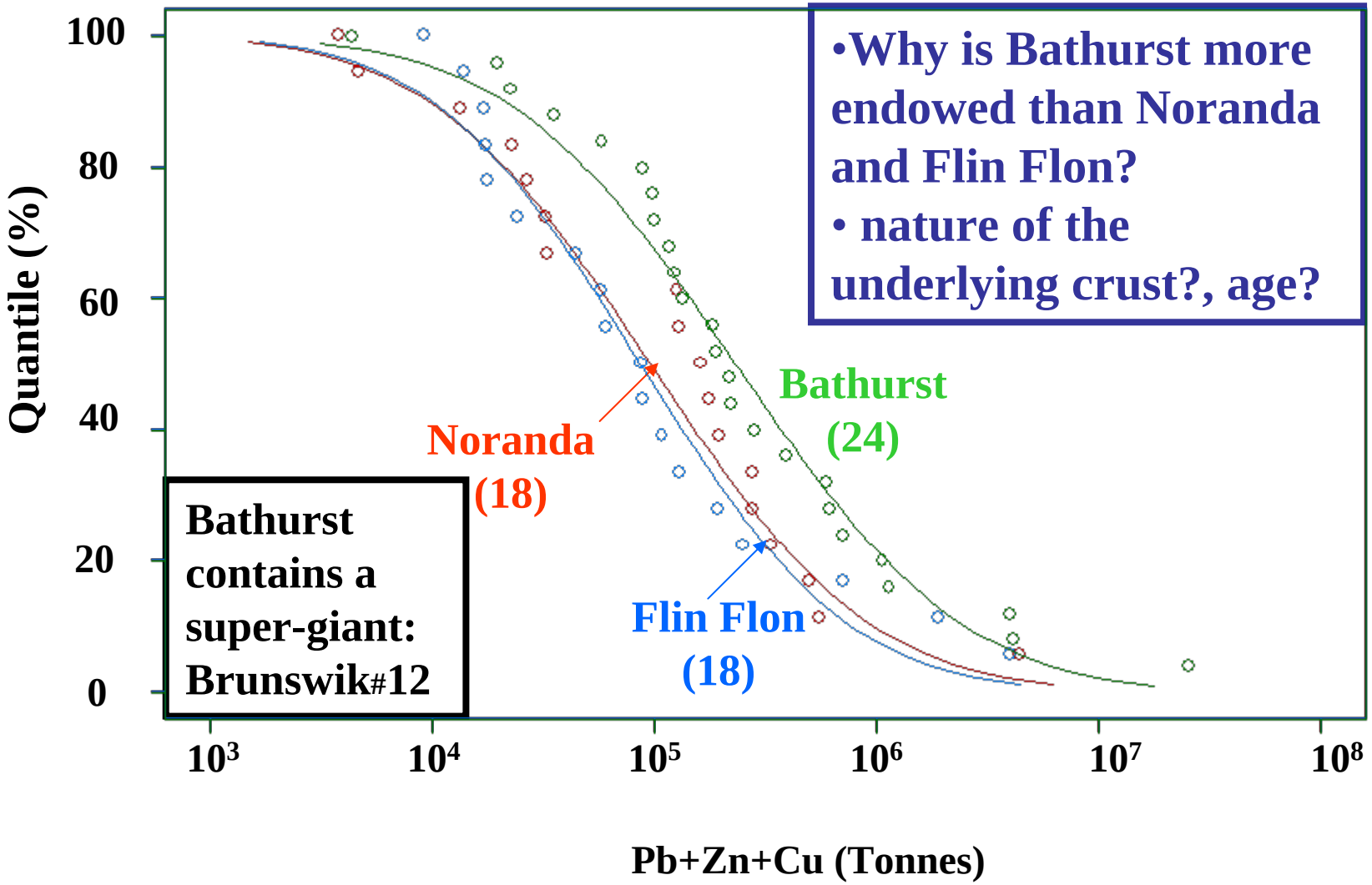
Archaean Greenstone Gold (Eastern Goldfields)

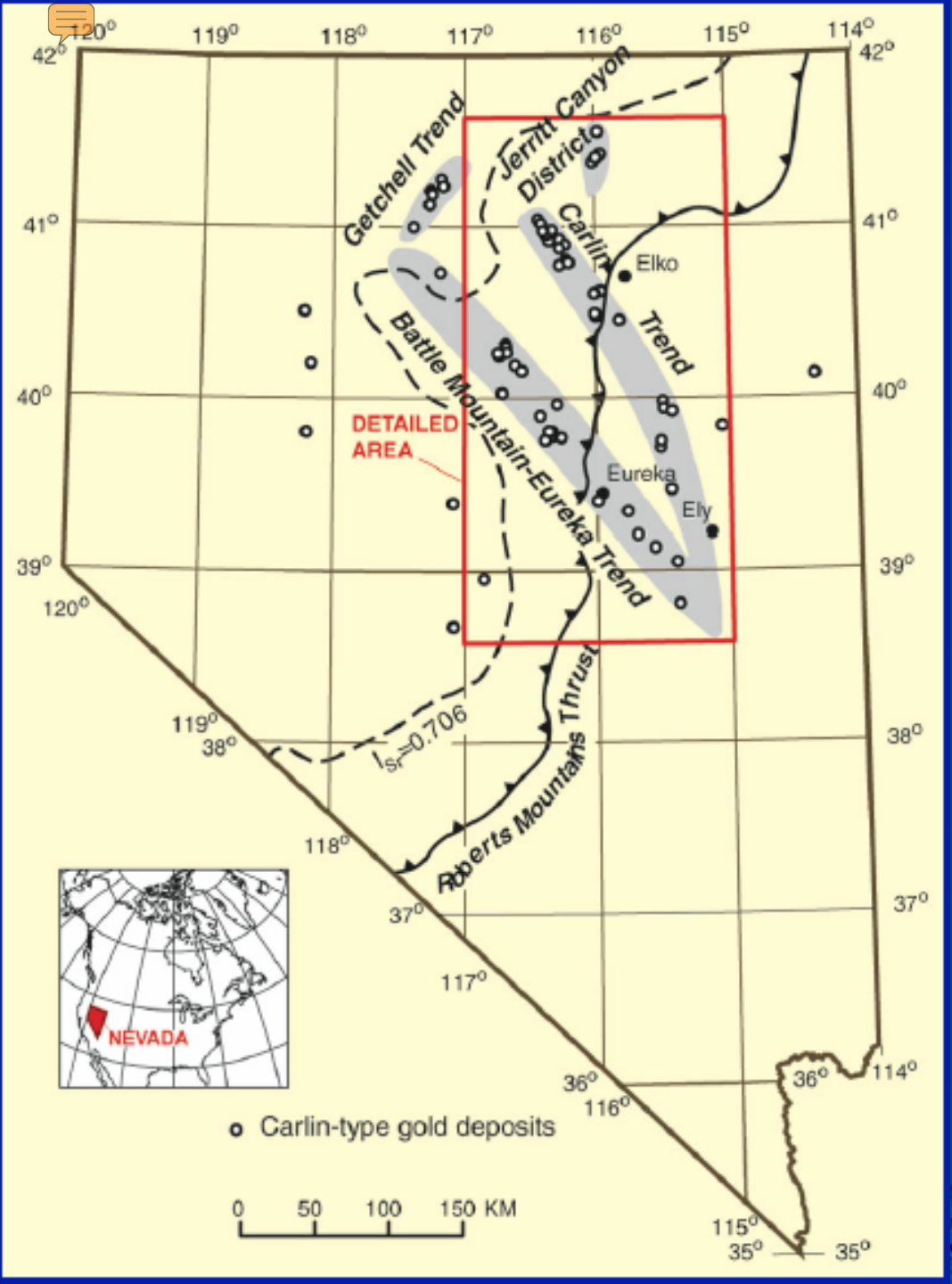


Volcanic-Associated Massive Sulphide: Canada



Volcanic-Associated Massive Sulphide: Canada





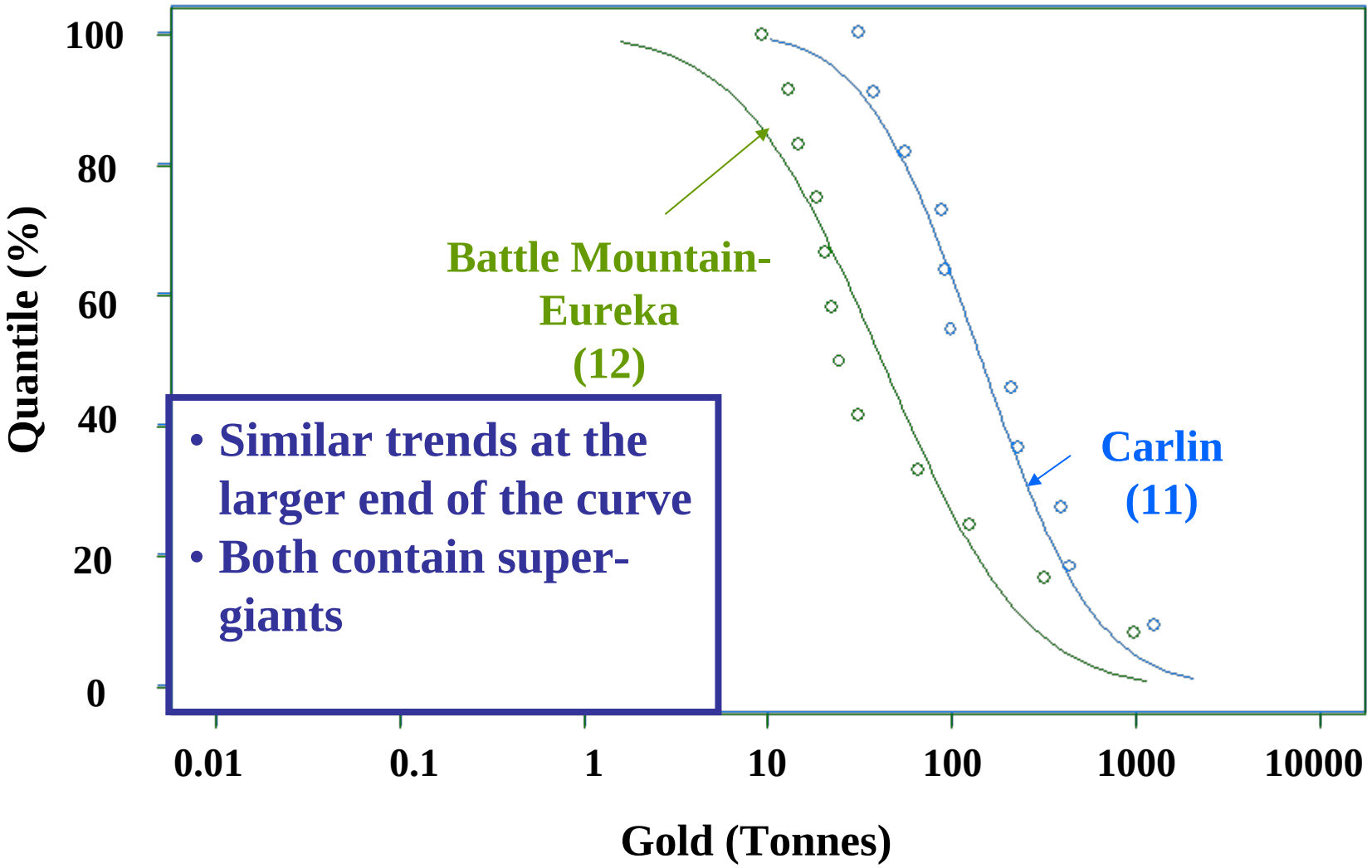
Carlin-Type Gold Deposits in Nevada

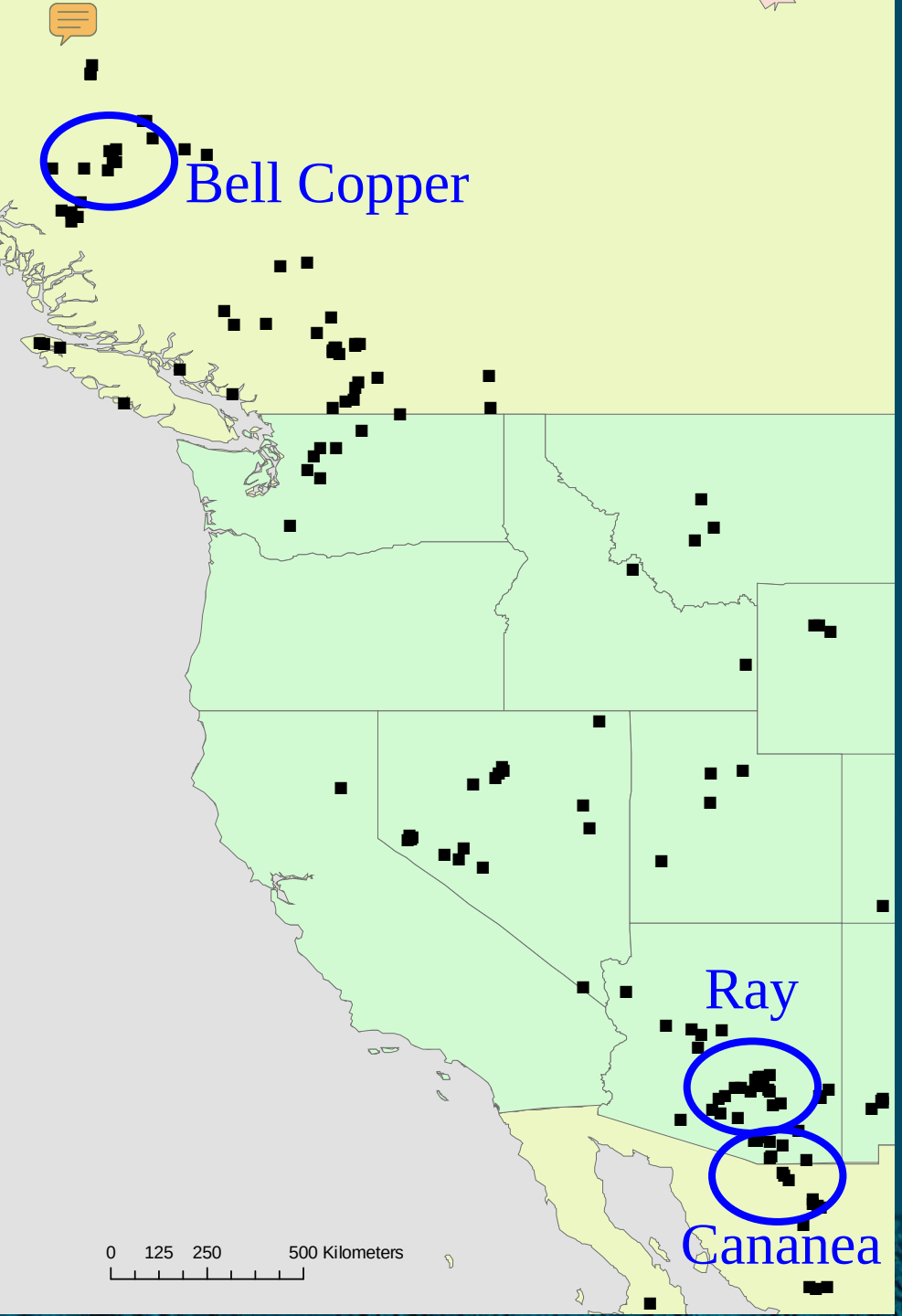
USGS, 2005

V. Berger, T. Theodore

GEOSCIENCE AUSTRALIA

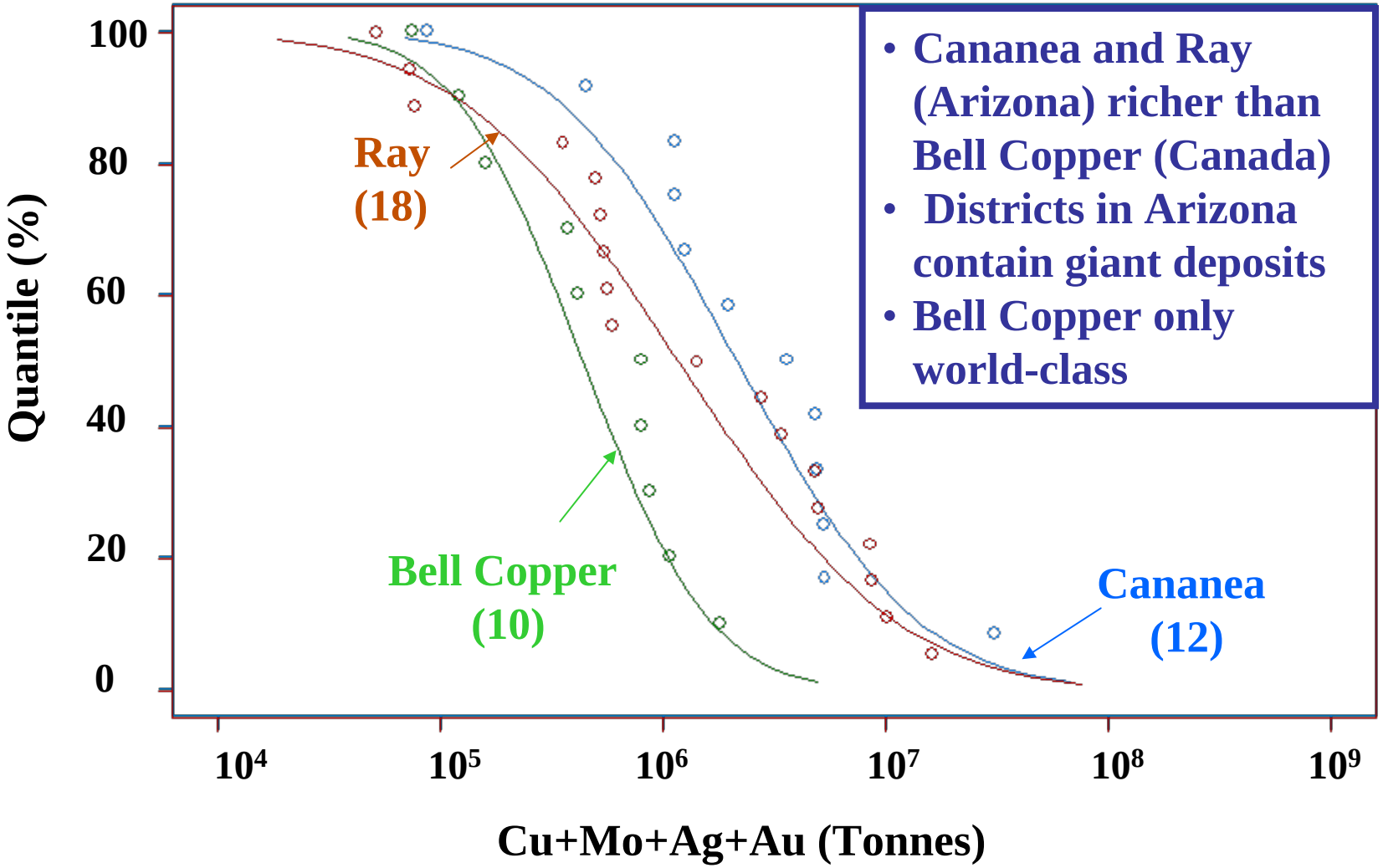
Carlin-Type Gold Deposits (Nevada)





Porphyry Cu-Mo (Cordillera- ~85 to 45 Ma Age)

Porphyry Cu-Mo (Cordillera- ~85 to 45 Ma Age)

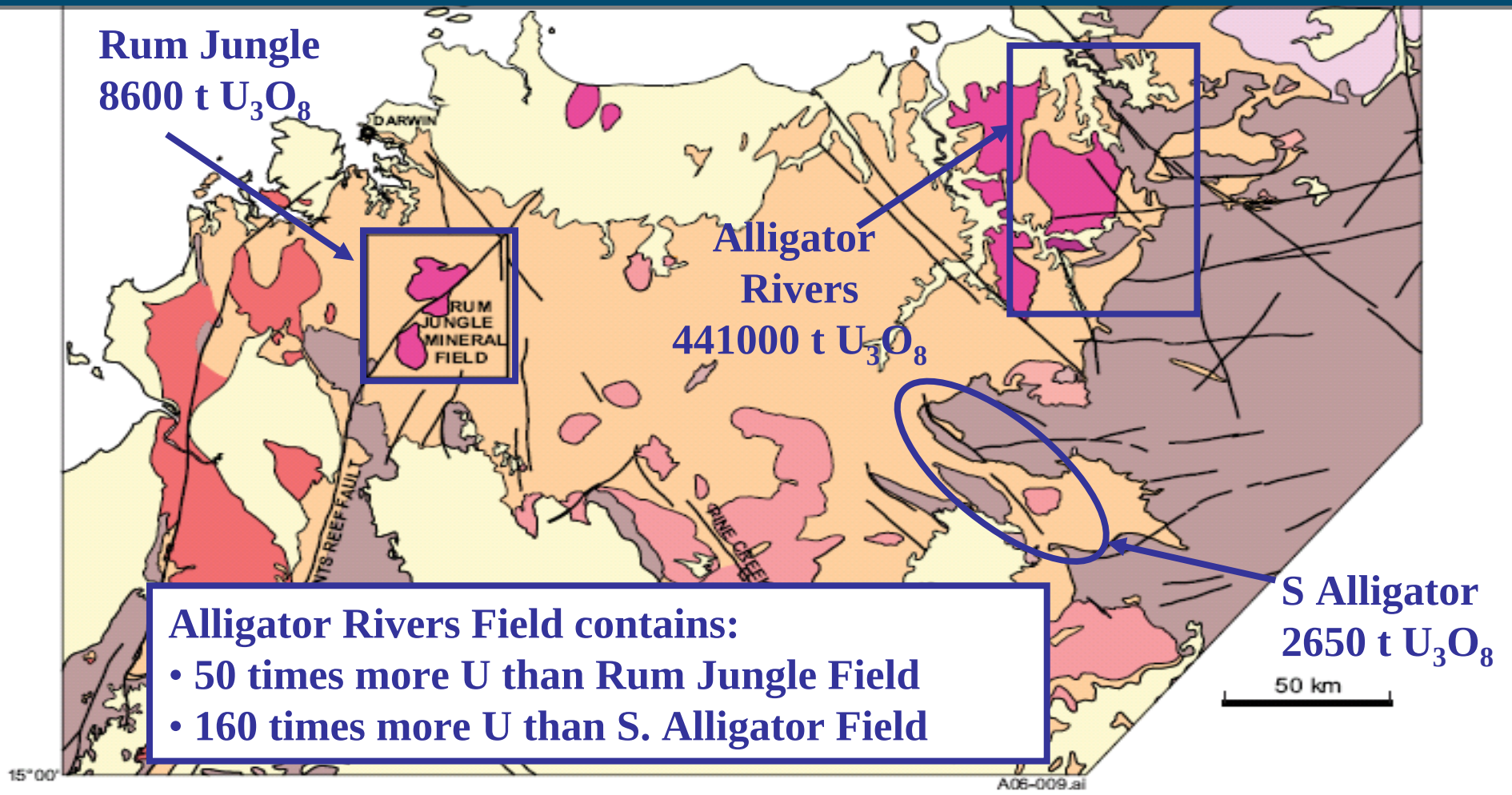


Conclusions Part II

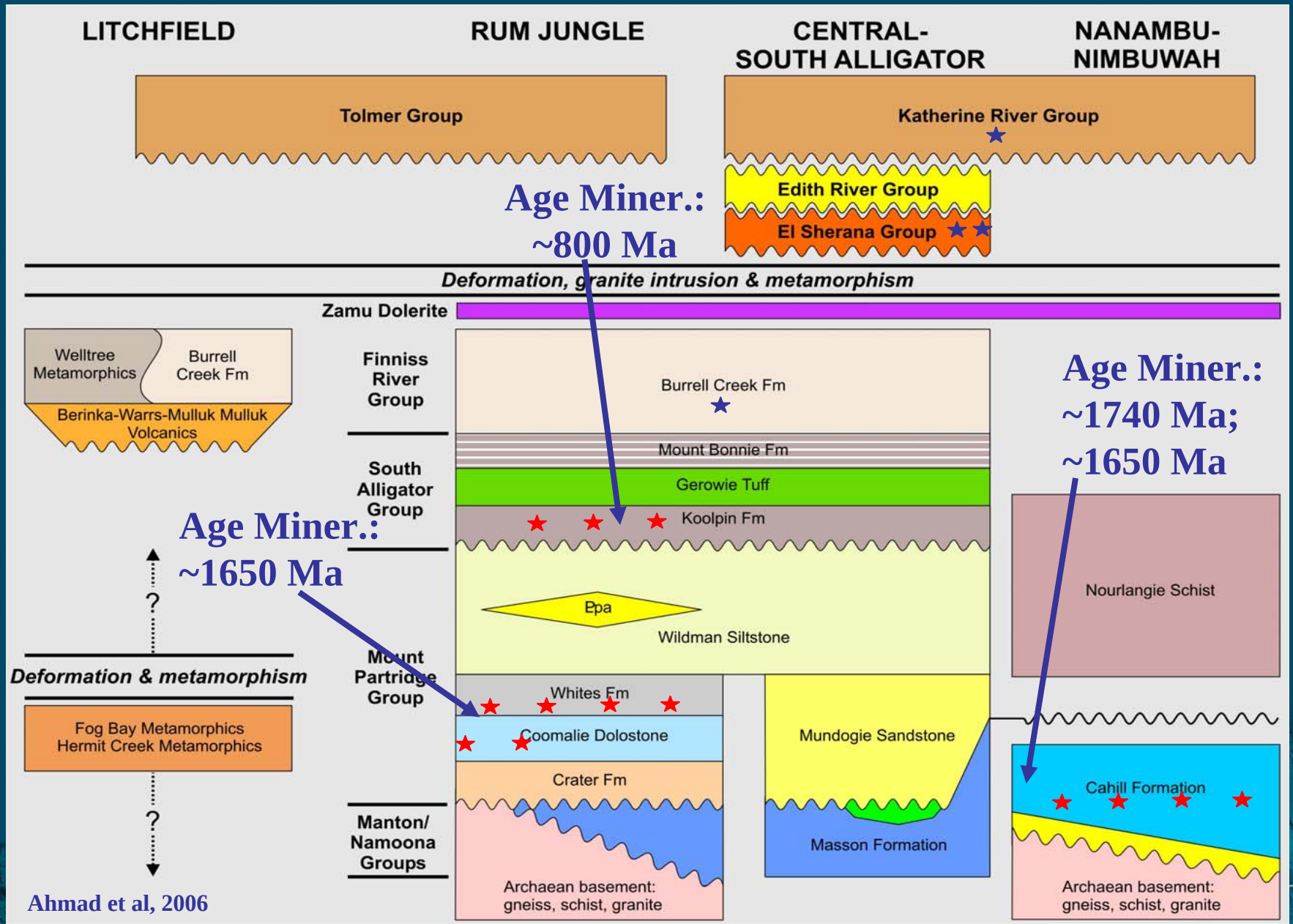
- Terranes, belts and districts within individual cratons/ regions show different metal endowment
- Metal endowment curves for belts and districts containing giant and super-giant deposits are different from those which do not contain them
- Regional-scale features probably control metal endowment

Regional-Scale Factors controlling Endowment: Unconformity-Related Uranium in the Pine Creek Orogen

Unconformity-Related Uranium (Pine Creek Orogen)

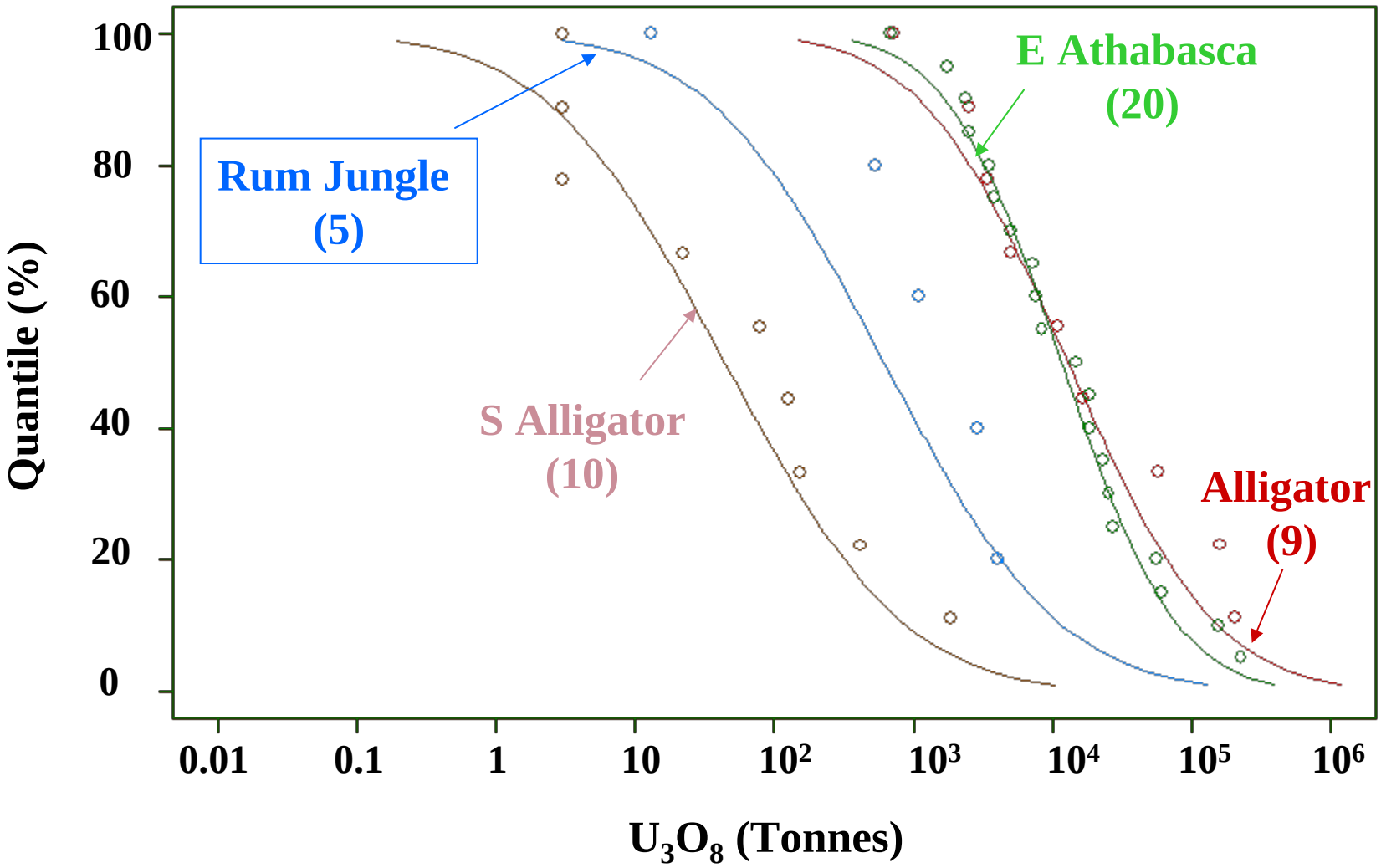


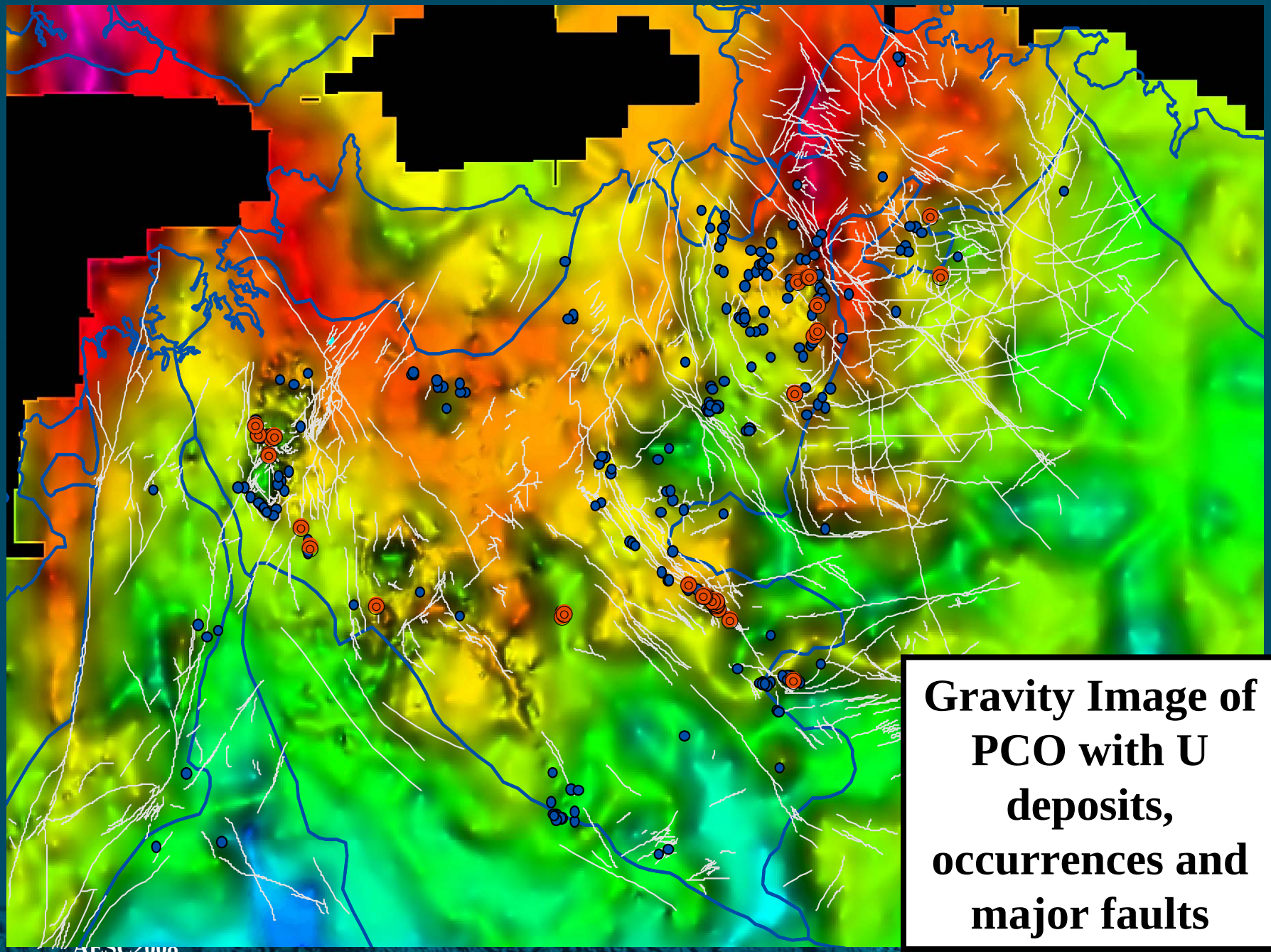
Stratigraphical/Lithological Control



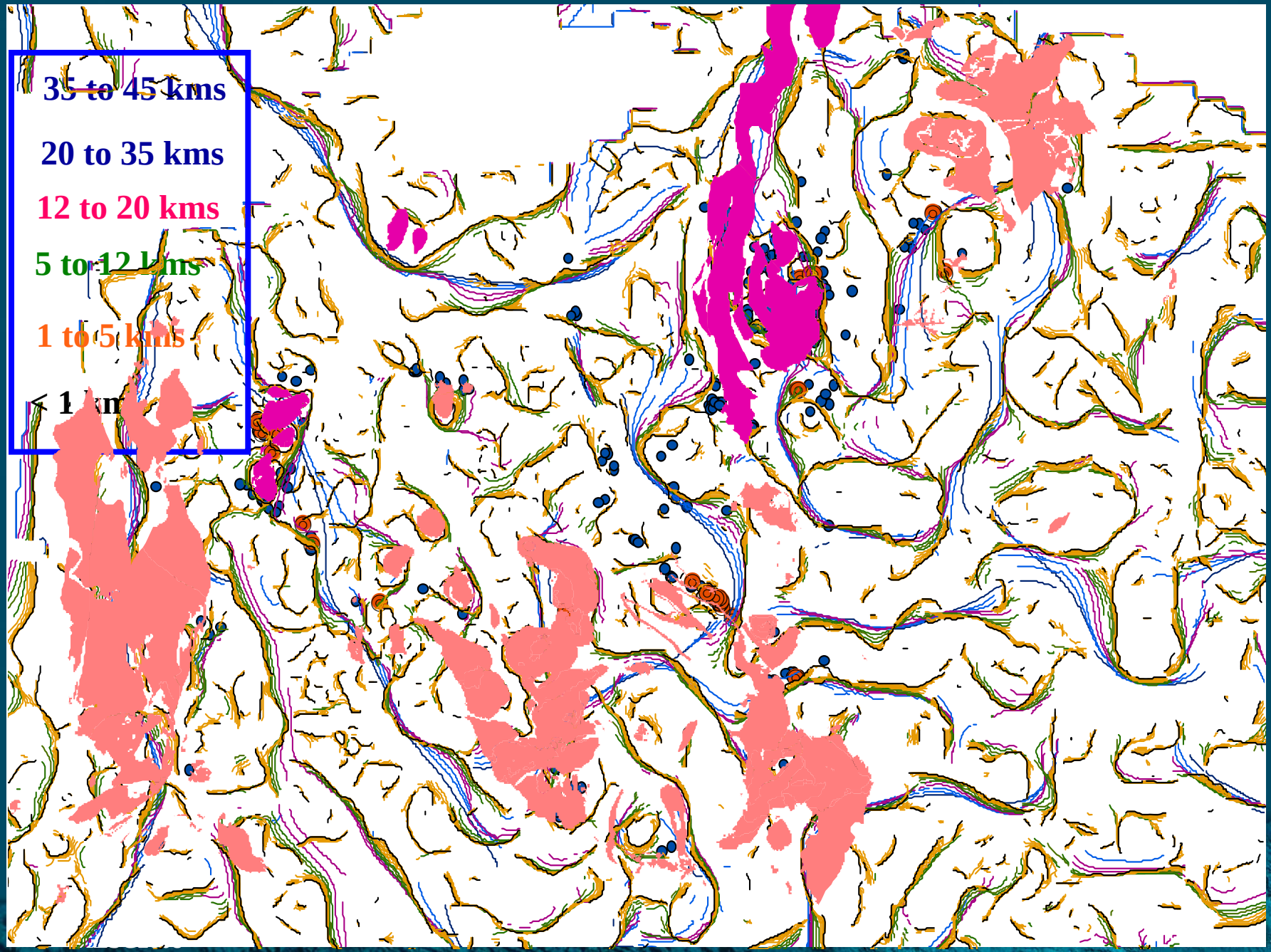
Ahmad et al, 2006

Unconformity-Related Uranium





Gravity Image of PCO with U deposits, occurrences and major faults

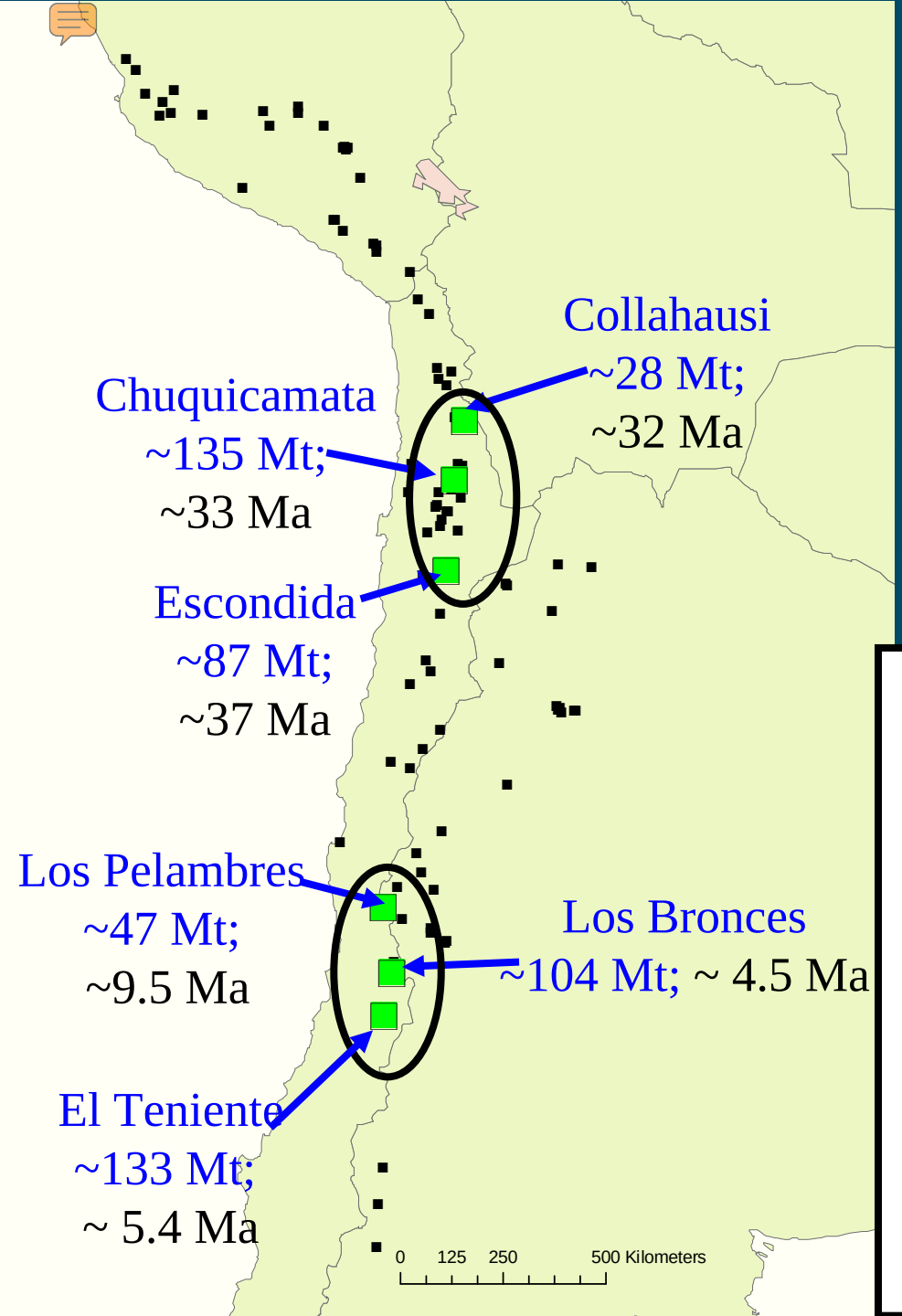

35 to 45 kms
20 to 35 kms
12 to 20 kms
5 to 12 kms
1 to 5 kms
< 1 km

Regional Gravity Highs and Uranium Endowment

- **Proximity to the edges of gravity highs: richest deposits associated with the 'worms' (UCH of 12 to 20 Kms) which may represent positions of maximum gradients of deeper-crustal features**

- **In the Athabasca Basin, the gravity-high ridge is associated with a regional structure. In the PCO more work is required to understand the 'worm' (the position of the gravity gradient)**

Super-giant Deposits (Cu-Mo-Au, Andes)



- **2 Clusters with super-giants:**
  - **size: 200 to 300 Kms**
  - **~ 1000 Kms apart**
  - **Distribution of large fertile magma chambers?**
- **Three episodes of mineralisation:**
  - **2 younger episodes more endowed**
  - **each of the younger episodes forms one Super-giant cluster**

What makes a Giant or Super-giant system?

- Are they more efficient mineral systems? If yes, what makes them more efficient?
  - Size of the container (sub-basin, magma chamber, volcanic centre. etc)
  - Metal content of the source (particularly for metals for which enrichment factor is 1000 and more)
- Nature of the crust (primitive or evolved)
  - As shown in the Yilgarn Craton (VHMS with primitive or juvenile crust; KANS with more evolved crust)

What makes a Giant or Super-giant system?

- **Superimposition of multiple mineral systems (poly-chronic and poly-genetic)**
  - **Super Pit: at least 3 episodes of mineralisation**
  - **Olympic Dam: low grade Cu-Au mineralisation during magnetite alteration upgraded during haematitic alteration**
  - **porphyry deposits (Andes): porphyry, epithermal, supergene**
  - **Mt Isa Cu: copper system superimposed on a Zn-Pb-Ag system**

Conclusions and Implications

- Exploration models need to be based on well-endowed areas (Yilgarn/Eastern Goldfields vs Pilbara for Archaean Greenstone Gold)
- What is the foot print of a giant and super-giant deposit ?
  - Halo of smaller deposits and occurrences?
  - Districts with smoke, but no major deposits may be prospective for “single-(super)giant-only” districts
- The greatest potential for exploration around super-giant deposits may be as extensions of these deposits: the presence of a (super)giant sterilises the regions for other giant accumulation of metals

Questions?