

Late Paleozoic gold mineral systems in north-east Queensland

Recent geochronology and metallogenic research

Vladimir Lisitsin
Geological Survey of Queensland

Townsville, 5 June 2019

Outline

- Summary of geochronological and metallogenic research of the past 5-7 years (mostly funded by GSQ)
- Focus – on Carboniferous to Permian gold metallogeny of north-east Queensland

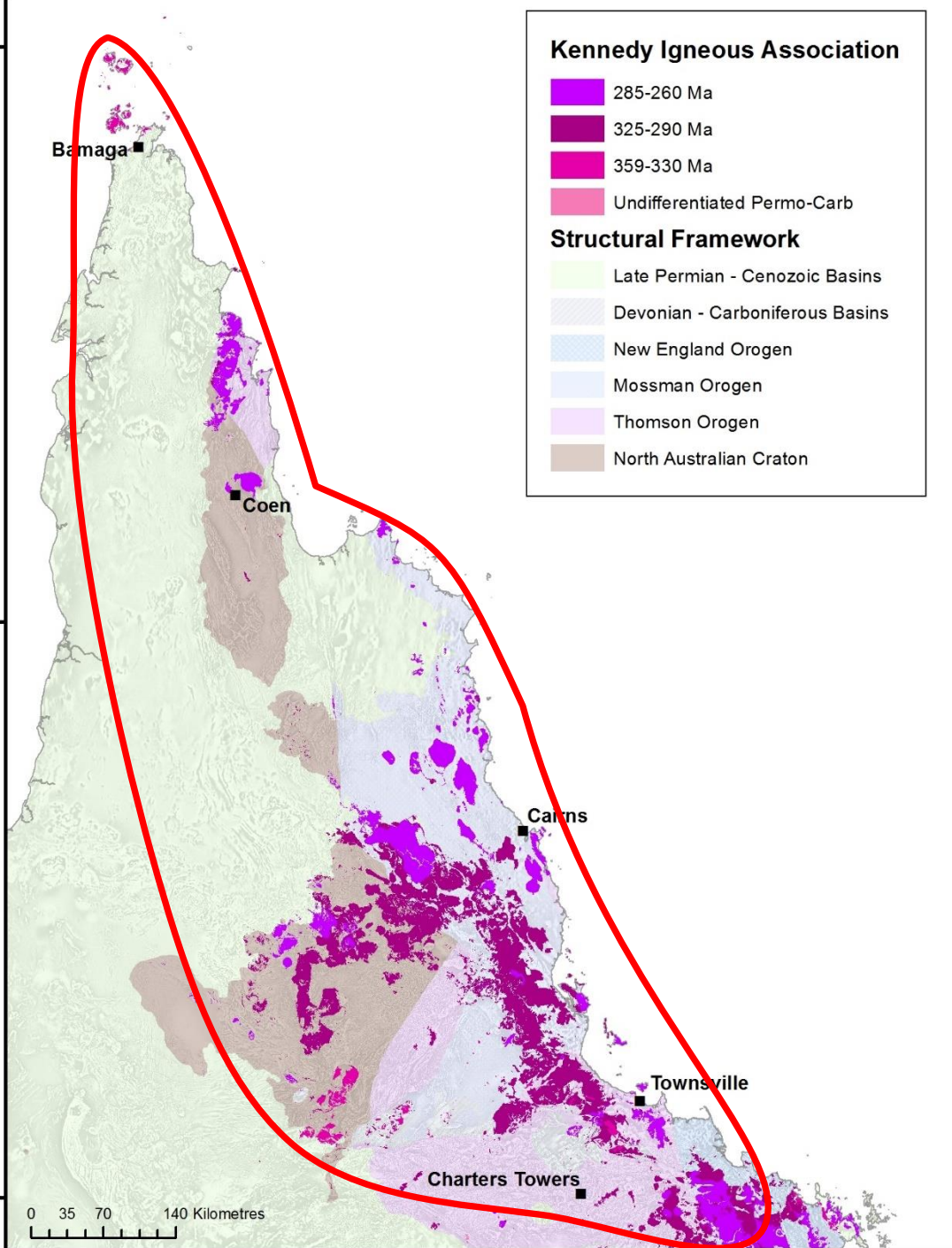
Acknowledgements

Summary of work, performed or funded by GSQ, in collaboration with:

- Klondike Exploration (Gregg Morrison)
- Terra Search (Simon Beams and staff)
- JCU (Zhaoshan Chang, Paul Dirks, staff, post-docs and students)
- Geoscience Australia (U-Pb and Re-Os geochronology)
- ANU (Ar-Ar geochronology – G. Lister, M. Forster)
- University of Alberta, Canada (Re-Os geochronology – Rob Creaser)
- Scottish Universities (O isotopes)
- Multiple companies across the region (access to sites; co-funding research students)

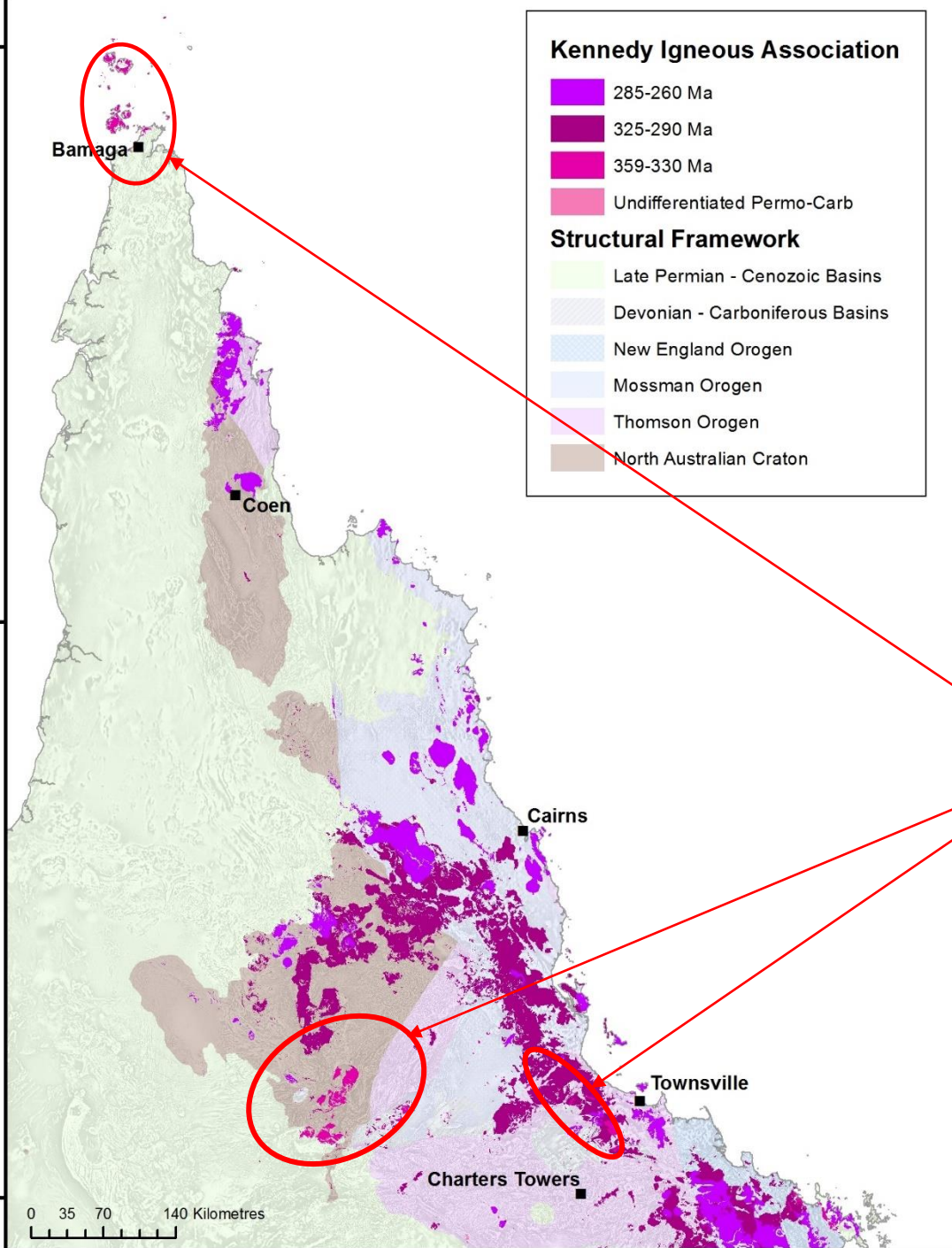


Geological setting of NE QLD



- North-eastern segment of the North Australian Craton
- Along the cratonic margin
 - Neoproterozoic-Ordovician Thomson Orogen
 - Silurian to Devonian Mossman Orogen
 - Devonian to Triassic New England Orogen (NEO)
- In Carboniferous-Permian, all provinces N and W of NEO were affected by felsic magmatism of the Kennedy Igneous Association (KIA)

Kennedy Igneous Association



➤ KIA – extensive felsic magmatism, north and inboard from NEO

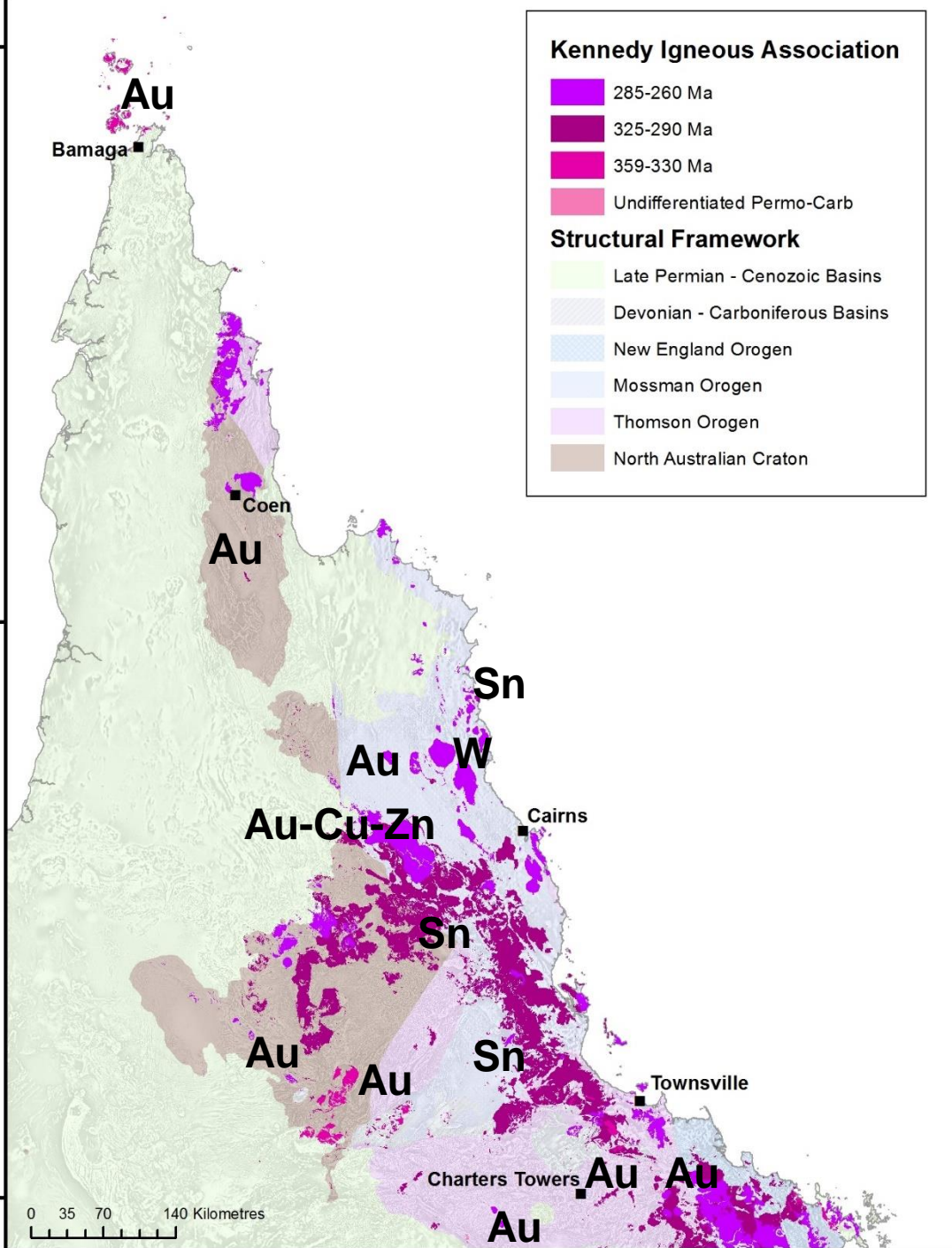
➤ Several epochs – from ~345 Ma to 265 Ma:

(i) early Carboniferous (345-330 Ma) - restricted

(ii) late Carboniferous (325-290 Ma) – most volume

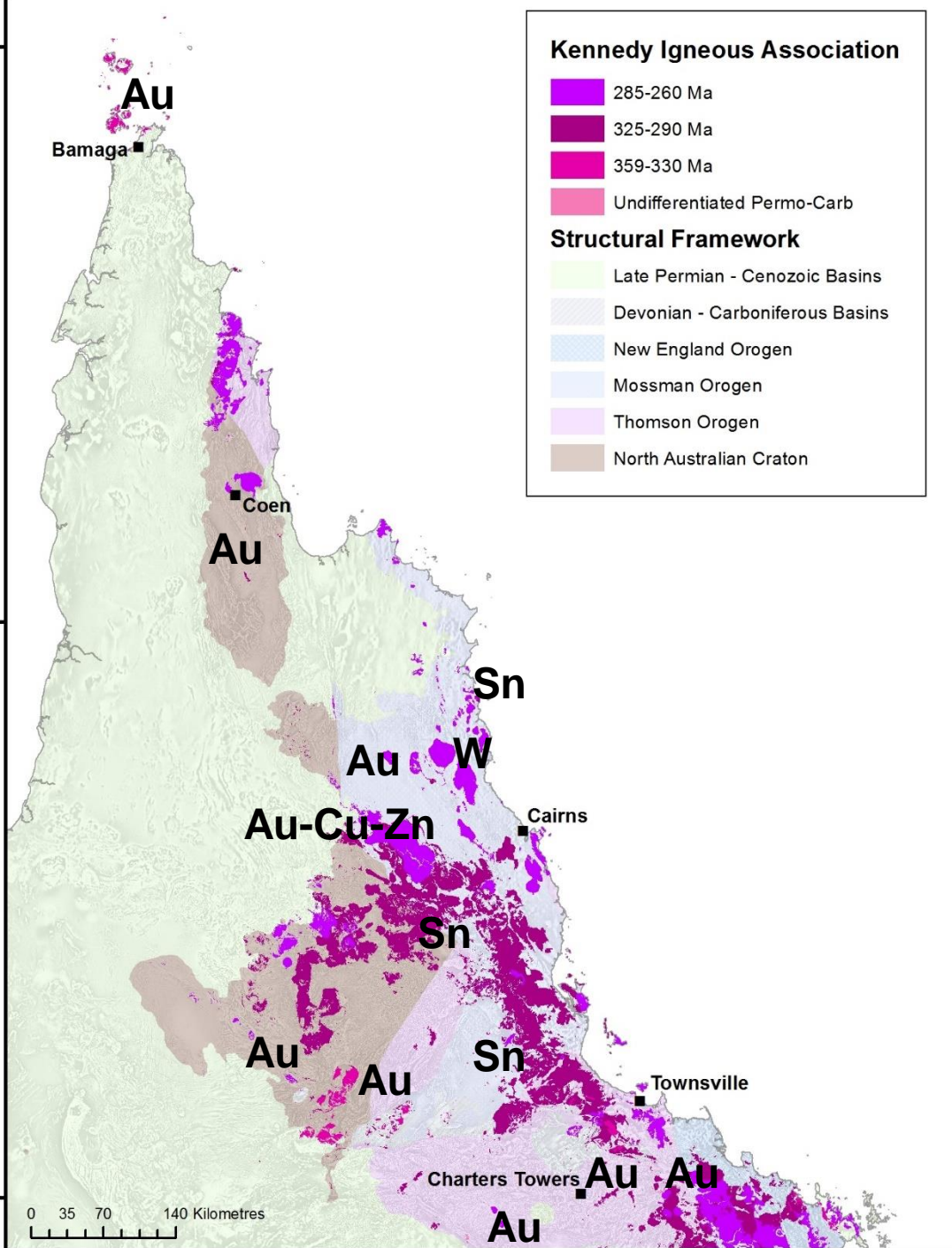
(iii) early to mid-Permian (285-265 Ma) – widest spatial extent; main magmatism in the E and N

Kennedy Igneous Association – C-P mineral province



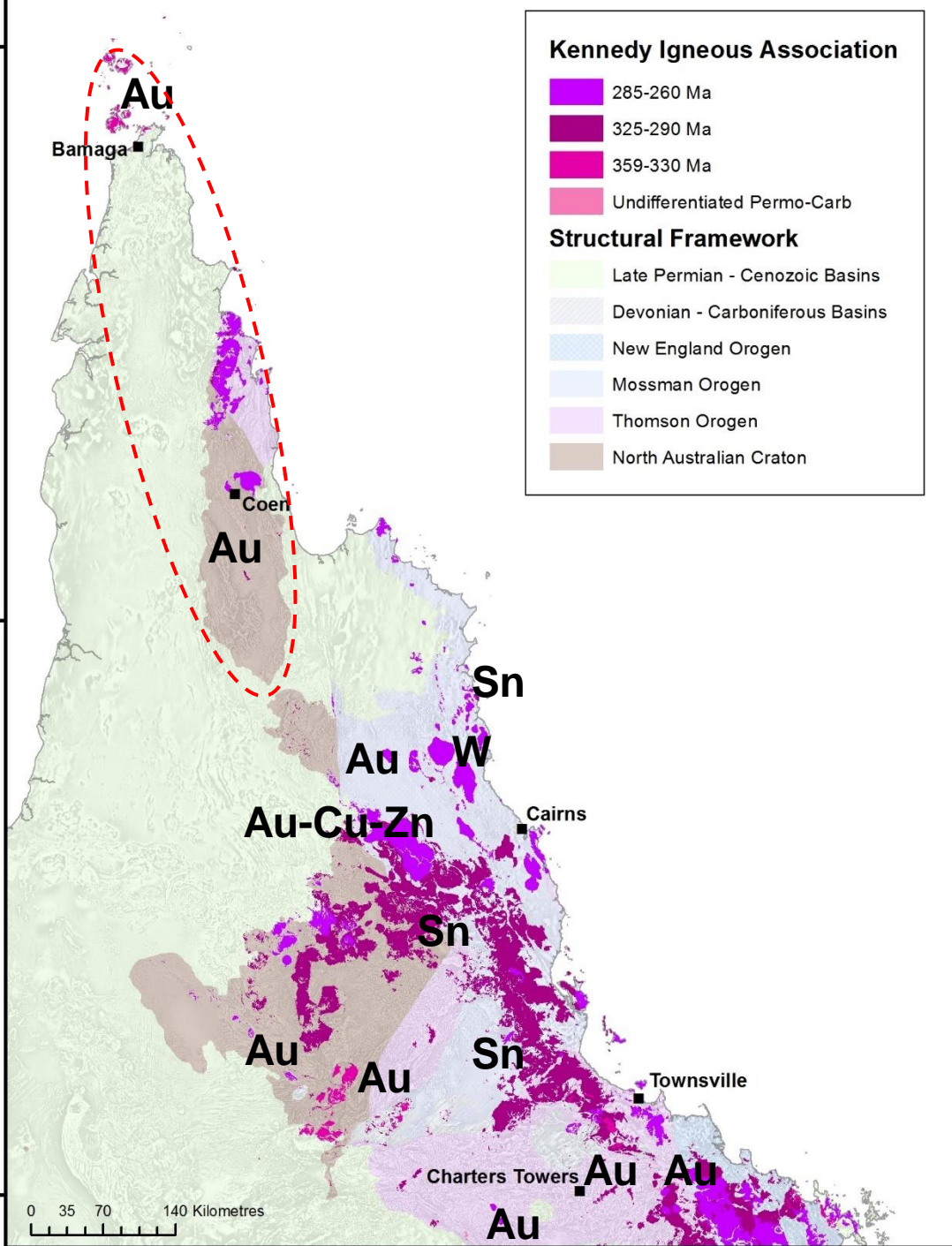
- Diverse C-P mineralisation – mostly coinciding in age with KIA (**345-280-265 Ma**)
- **Au(-Ag), Sn, W, Zn, Cu, Fe, U**
- Veins, breccias, skarns; orogenic, low- and high-S epithermal, IRGD, etc.
- Pre-2014 – paucity of geochronology on mineralisation away from several major deposits

C-P mineral systems – new geochronology (2014-2018)



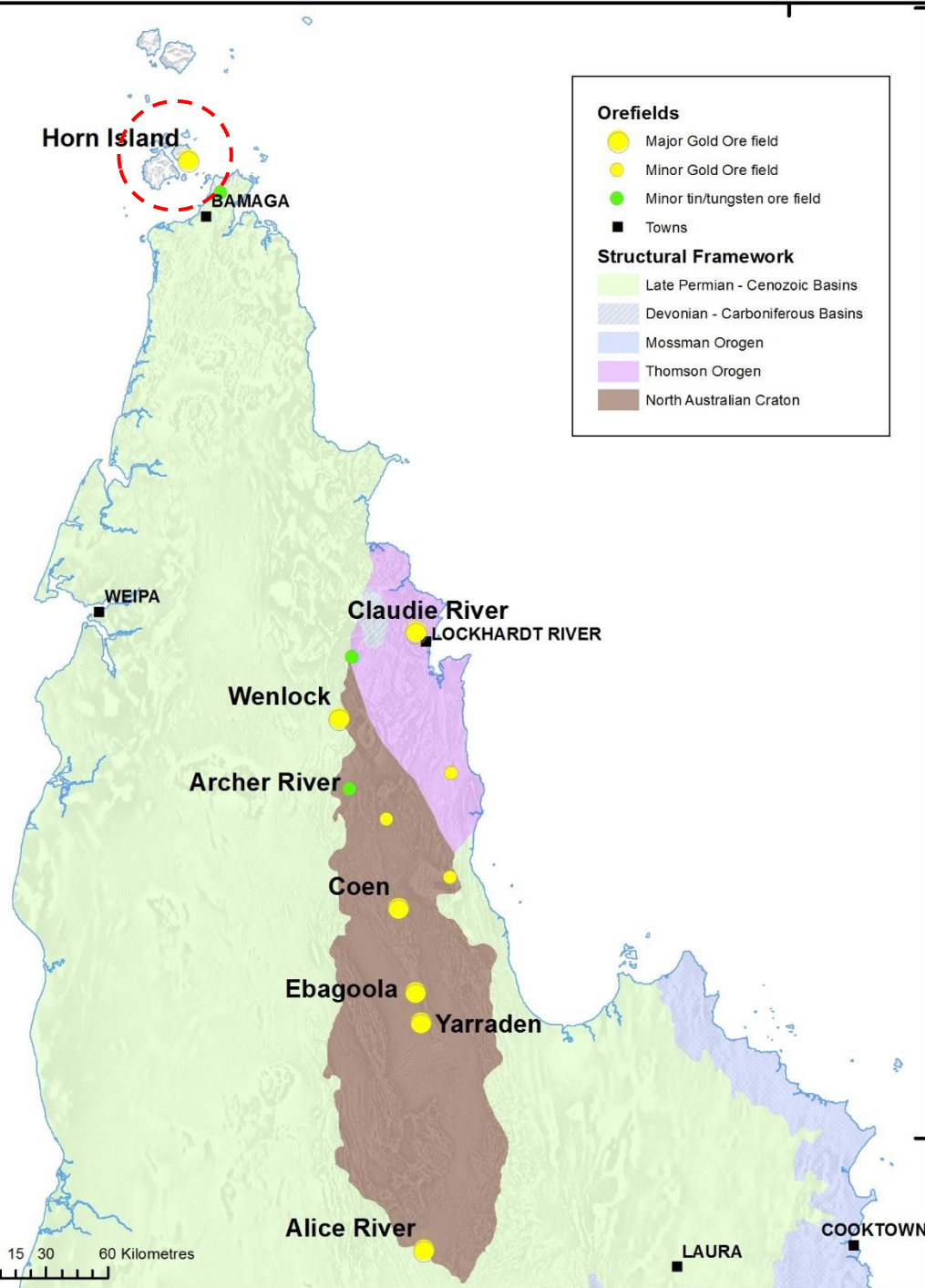
- U-Pb (zircon; SHRIMP – GA) >20
- Re-Os (molydenite) >25
- Ar-Ar >65
- U-Pb (zircon; LA - JCU) >150
- K-Ar (Terra Search) >40

Carboniferous-Permian mineral systems



- Diverse C-P mineralisation – mostly coinciding in age with KIA (**345-280-265 Ma**)
- **Au(-Ag), Sn, W, Zn, Cu, Fe, U**
- Veins, breccias, skarns
- The largest (and best studied) deposits – in the south
- Least understood – at Cape York

C-P Au mineral systems – Cape York



Relatively minor historic goldfields (2 – with current exploration projects):

➤ Horn Island (~0.8 t Au production; 15 t Au resource)

➤ Coen (~1.5 t Au)

➤ Ebagoola (~800 kg Au)

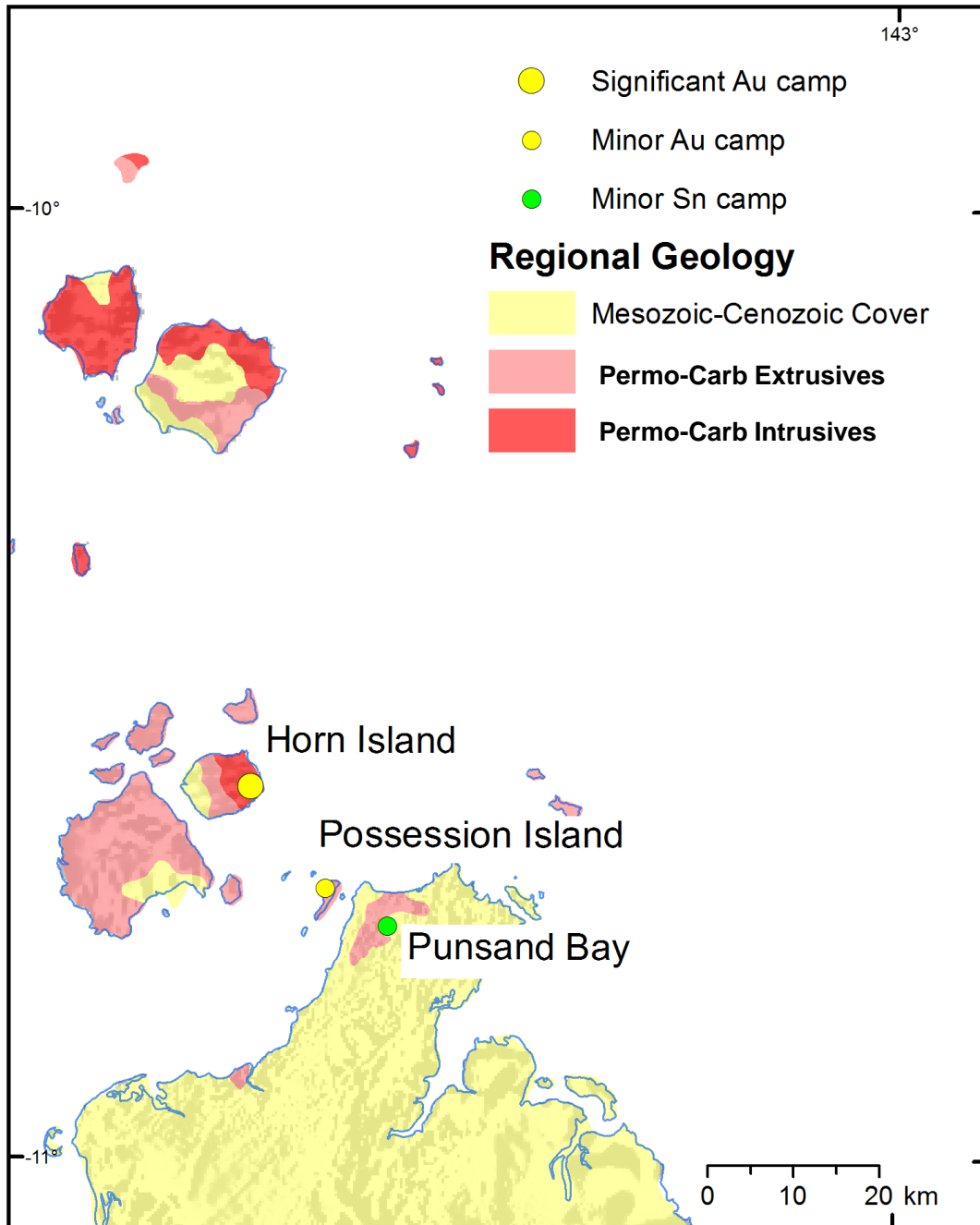
➤ Yarraden (~550 kg Au)

➤ Alice River

Minor Sn-W (mostly alluvial):

➤ Archer River (314 t Sn)

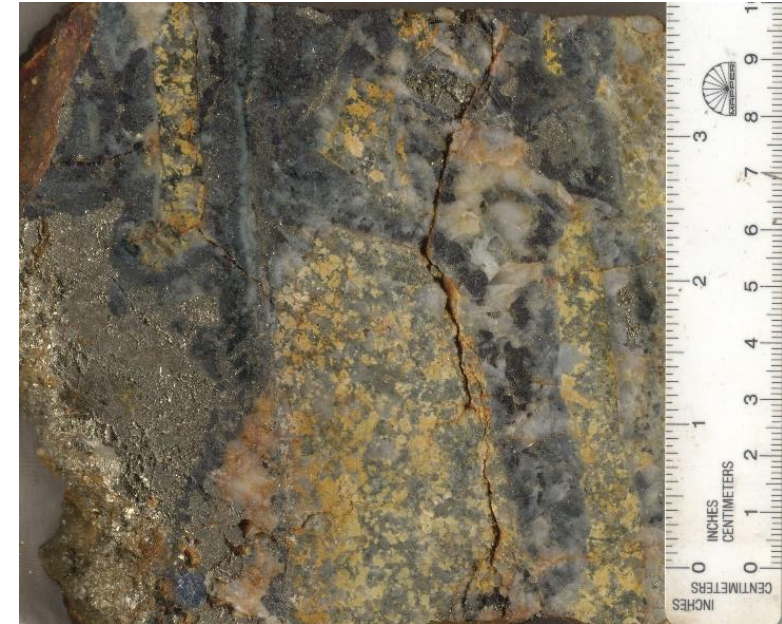
Horn Island region



- Horn Island gold mine (800 kg Au production, 15 t Au resource)
- Until recent geochronological work by GSQ (and GA), both igneous rocks and Au assumed to be early Permian or “Permo-Carboniferous”

Horn Island gold deposit

- Horn Island gold mine (800 kg Au production, 15 t Au resource)
- Until recent geochronological work by GSQ, both igneous rocks and Au assumed to be early Permian or “Permo-Carboniferous”
- Dominant mineralisation – Qtz-Py-Ga-Sp-Au veins in granite (with sericite alteration), rare Qtz-Mo veins; late-stage carbonate-fluorite and epithermal quartz veins



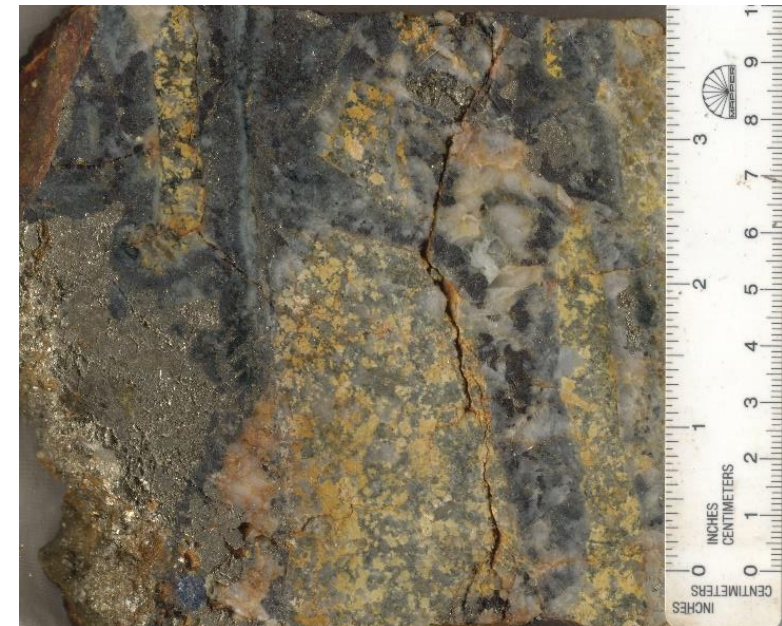
Horn Island gold deposit

- U-Pb (SHRIMP) on host granites – 343-344 Ma
- Re-Os on Qtz-Mo veins – 342-344 Ma
- **Ar-Ar on sericite alteration and veins (with Qtz-Ga-Sp-Au) – ~315-320 Ma**
- $\delta^{18}\text{O}_{\text{VSMOW}}(\text{Qtz}) = 11\text{‰}$ (magmatic source?)
- U-Pb (SHRIMP) on (mostly) barren rhyolite dyke – 310 Ma
- **Main Au – late Carboniferous, unrelated to host granites (and associated minor Mo-W-Bi-Te mineralisation)**

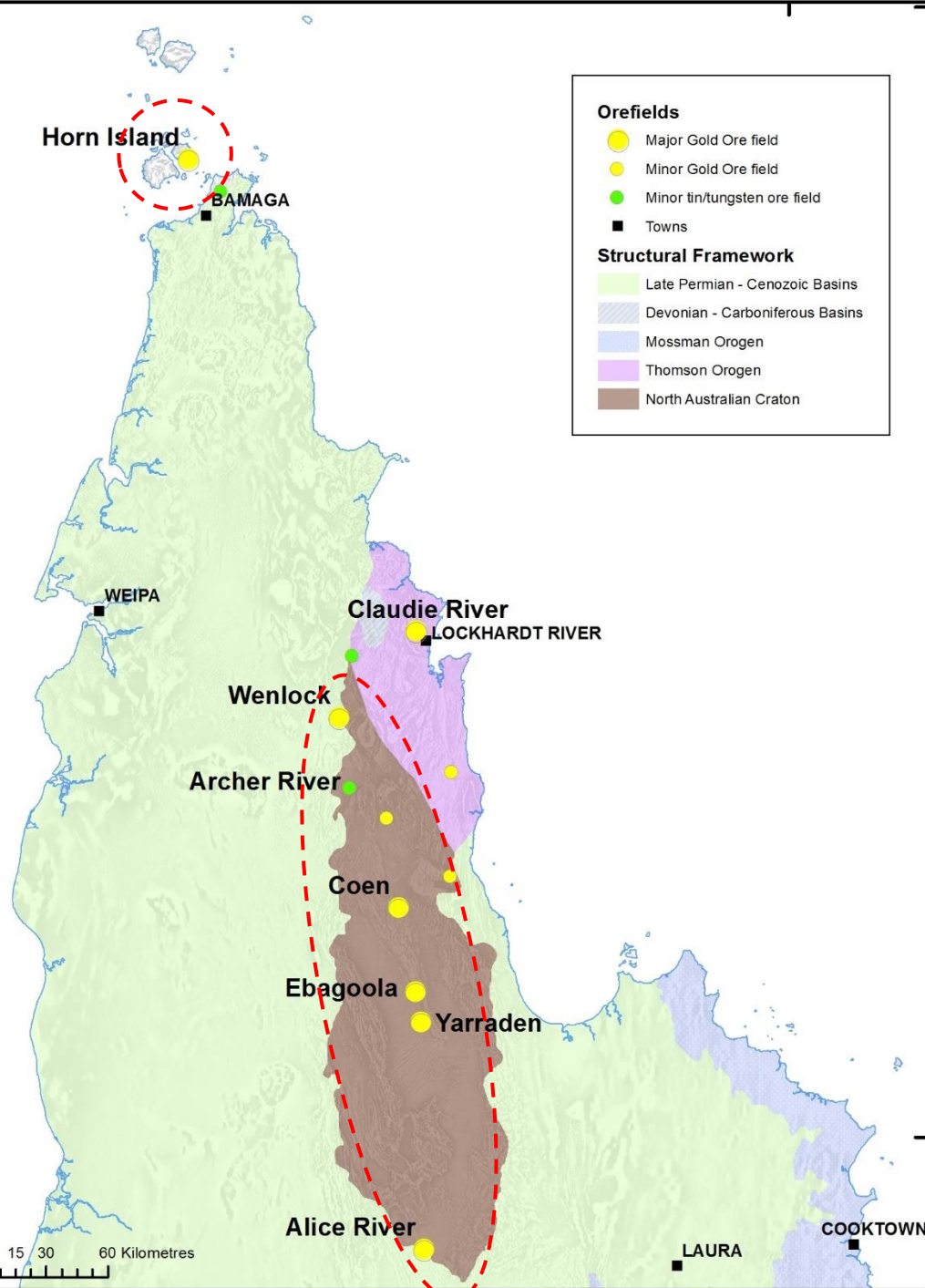
New geological interpretation (incorporating above results) – in ASX announcement of Alice Queen Ltd (31 May 2019)



Qtz-Mo



C-P gold mineral systems – Cape York



Relatively minor historic goldfields (2 – with current exploration projects):

➤ Horn Island (~0.8 t Au production; 15 t Au resource)

➤ Coen (~1.5 t Au)

➤ Ebagoola (~800 kg Au)

➤ Yarraden (~550 kg Au)

➤ Wenlock (~150 kg Au)

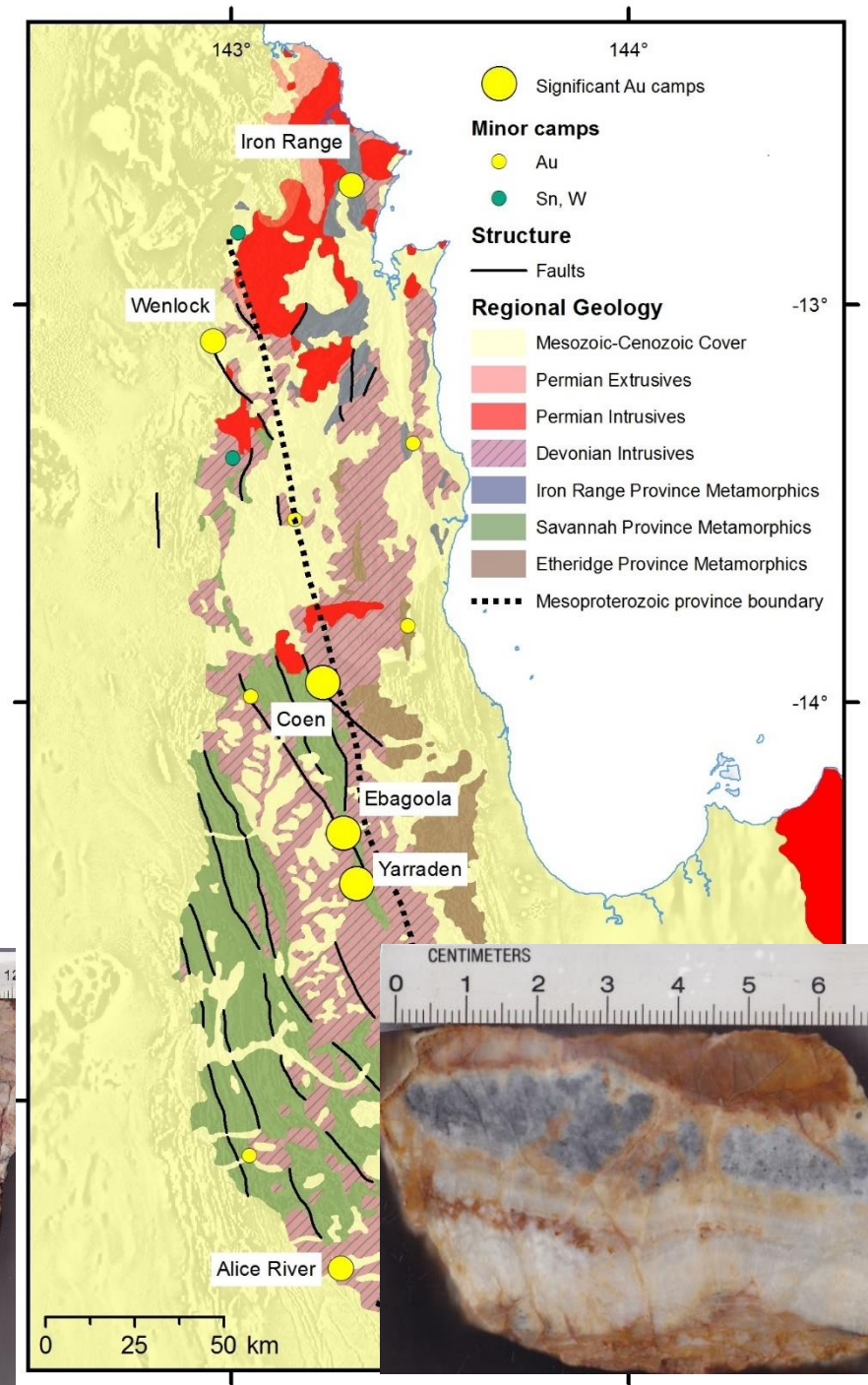
➤ Alice River

Minor Sn-W (mostly alluvial)

➤ Archer River (314 t Sn)

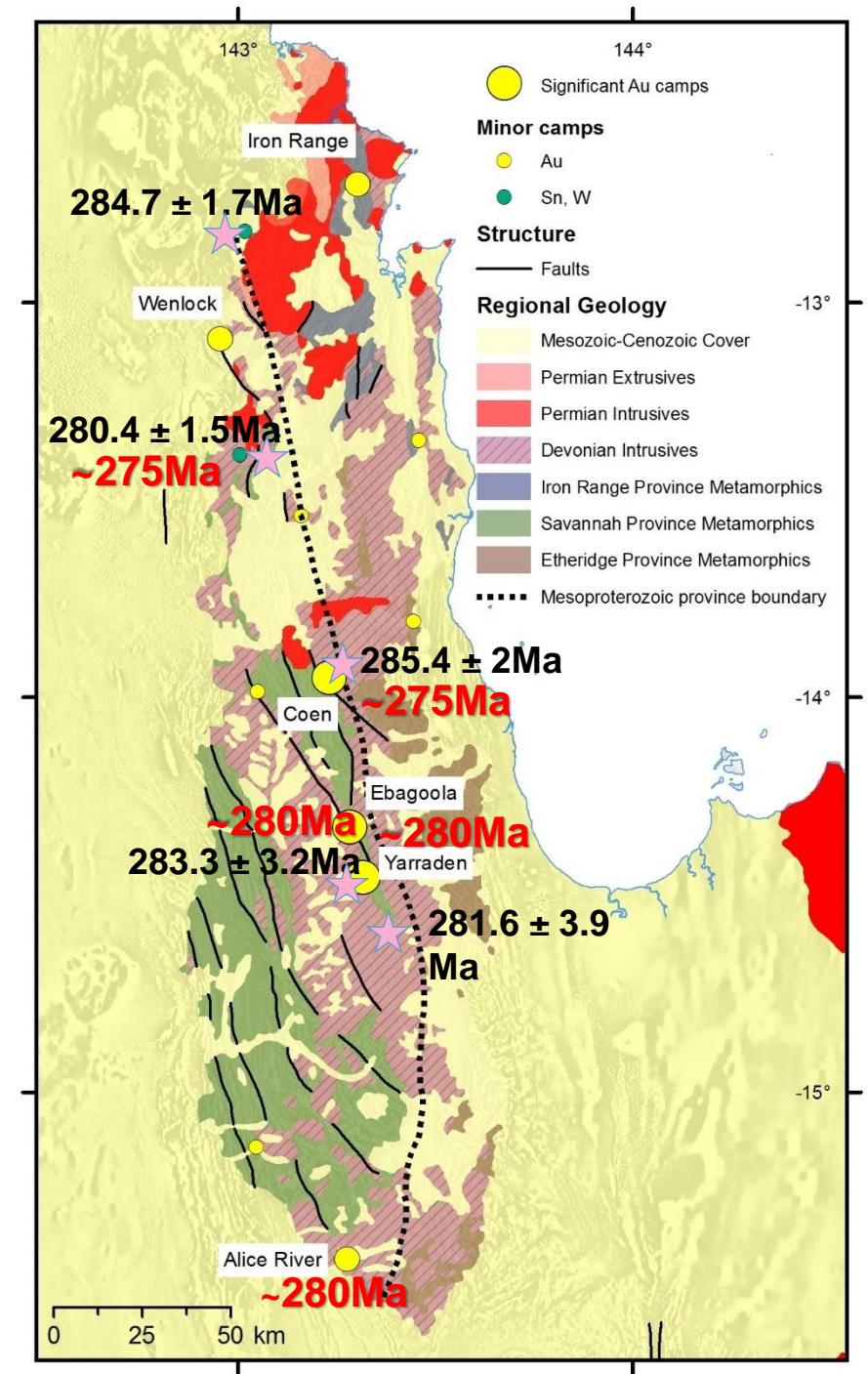
Gold mineral systems – Coen region

- Qtz-Py-Asp-Au(\pm Ga) veins in PR metamorphics, D granites and rhyolite dykes; sericite alteration; Au-Ag-As \pm Sb(Pb-Zn) geochemistry
- “Shear-hosted”? D and P-C?
- Until recent geochronological work by GSQ, no reliable age constraints on gold mineralisation



Geochronology – Coen region

- U-Pb SHRIMP on felsic dykes hosting Au – 283-285 Ma
- Broadly synchronous with the Wolverton Granite (280.4 ± 1.5 Ma) and a rhyolitic plug at Spion Kop (281.6 ± 3.9 Ma)
- Ar-Ar on pervasive sericite in rhyolite dykes with Au mineralisation – ~280Ma
- Ar-Ar on muscovite in Au and W veins – ~275 Ma
- $\delta^{18}\text{O}_{\text{VSMOW}}(\text{Qtz}) = 0\text{‰}-5\text{‰}$ (meteoric) to $13\text{‰}-15\text{‰}$ (distal magmatic?)
- **Early Permian metallogenic event – correlating with epithermal Au at Georgetown and Mt Carlton**



C-P gold mineral systems – Cape York

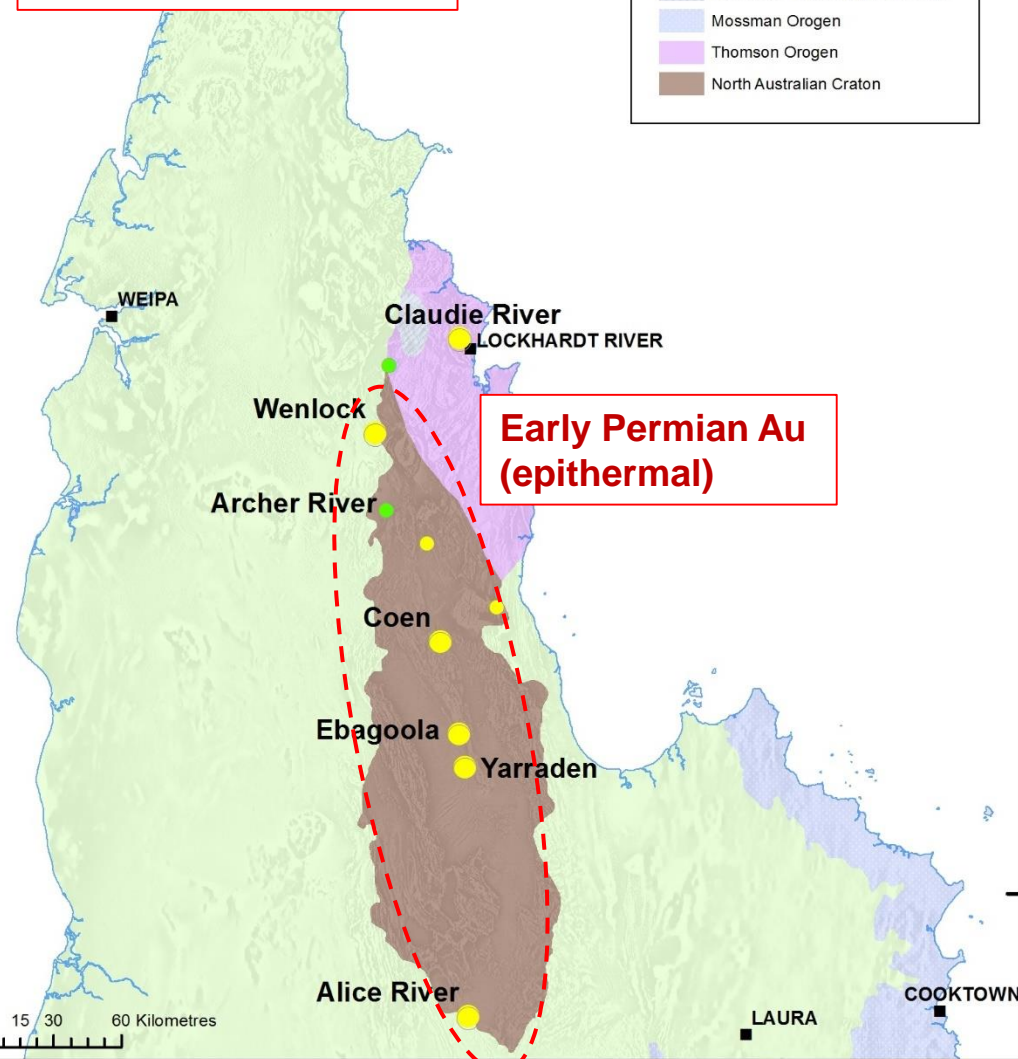
Late Carboniferous Au (IRGD)

Orefields

- Major Gold Ore field
- Minor Gold Ore field
- Minor tin/tungsten ore field
- Towns

Structural Framework

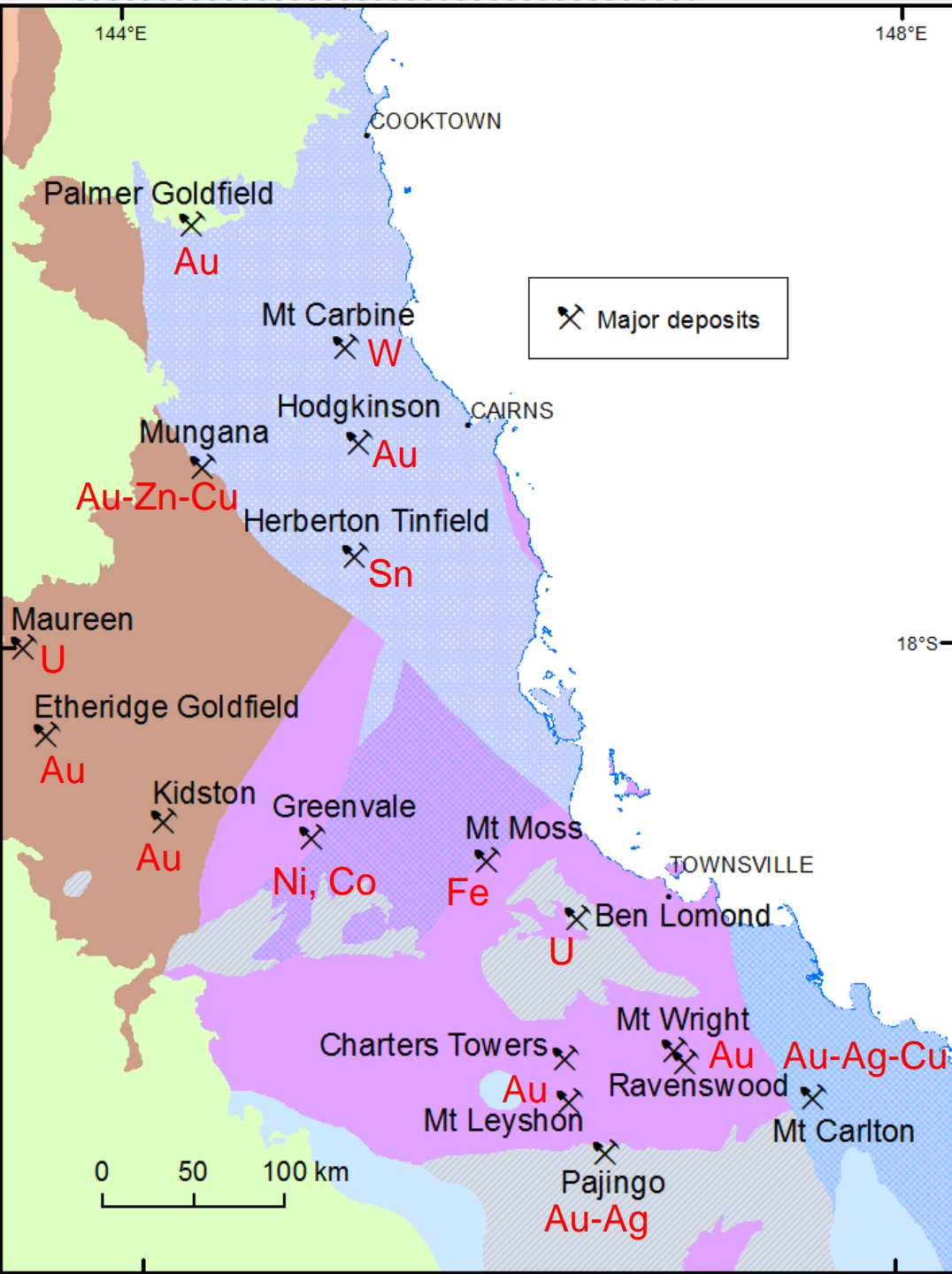
- Late Permian - Cenozoic Basins
- Devonian - Carboniferous Basins
- Mossman Orogen
- Thomson Orogen
- North Australian Craton



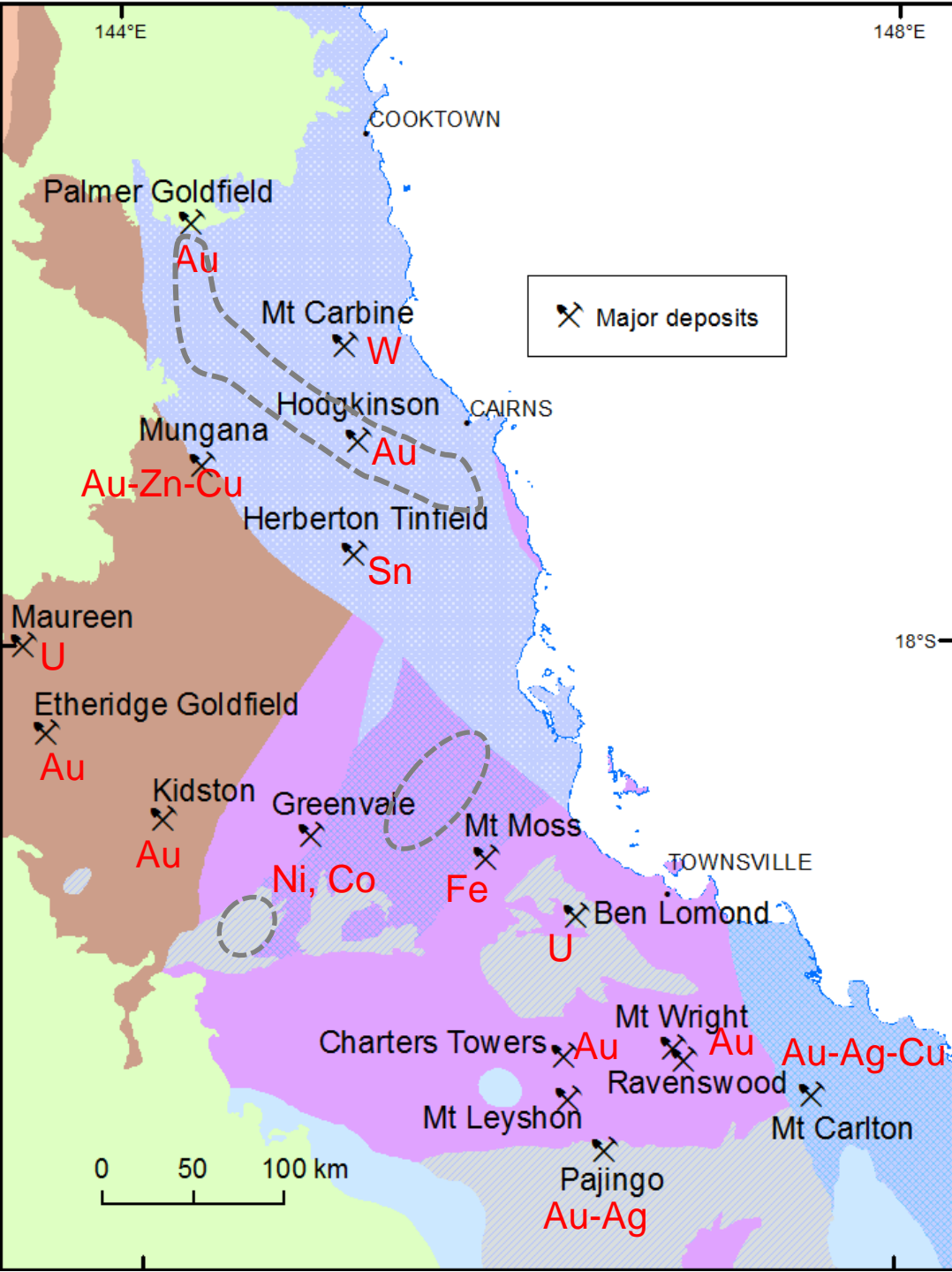
Two distinct mineral systems:

- Late Carboniferous (~315 Ma) IRGS at Horn Island
- Early Permian (~275 Ma) epithermal Au in the Coen region

C-P mineral systems – Mossman Orogen to NEO



- Diverse C-P mineralisation – mostly coinciding in age with KIA (345-280-265 Ma)
- **Au(-Ag), Sn, W, Zn, Cu, Fe, U**
- The largest C-P gold deposits NE QLD



Orogenic gold – Mossman Orogen

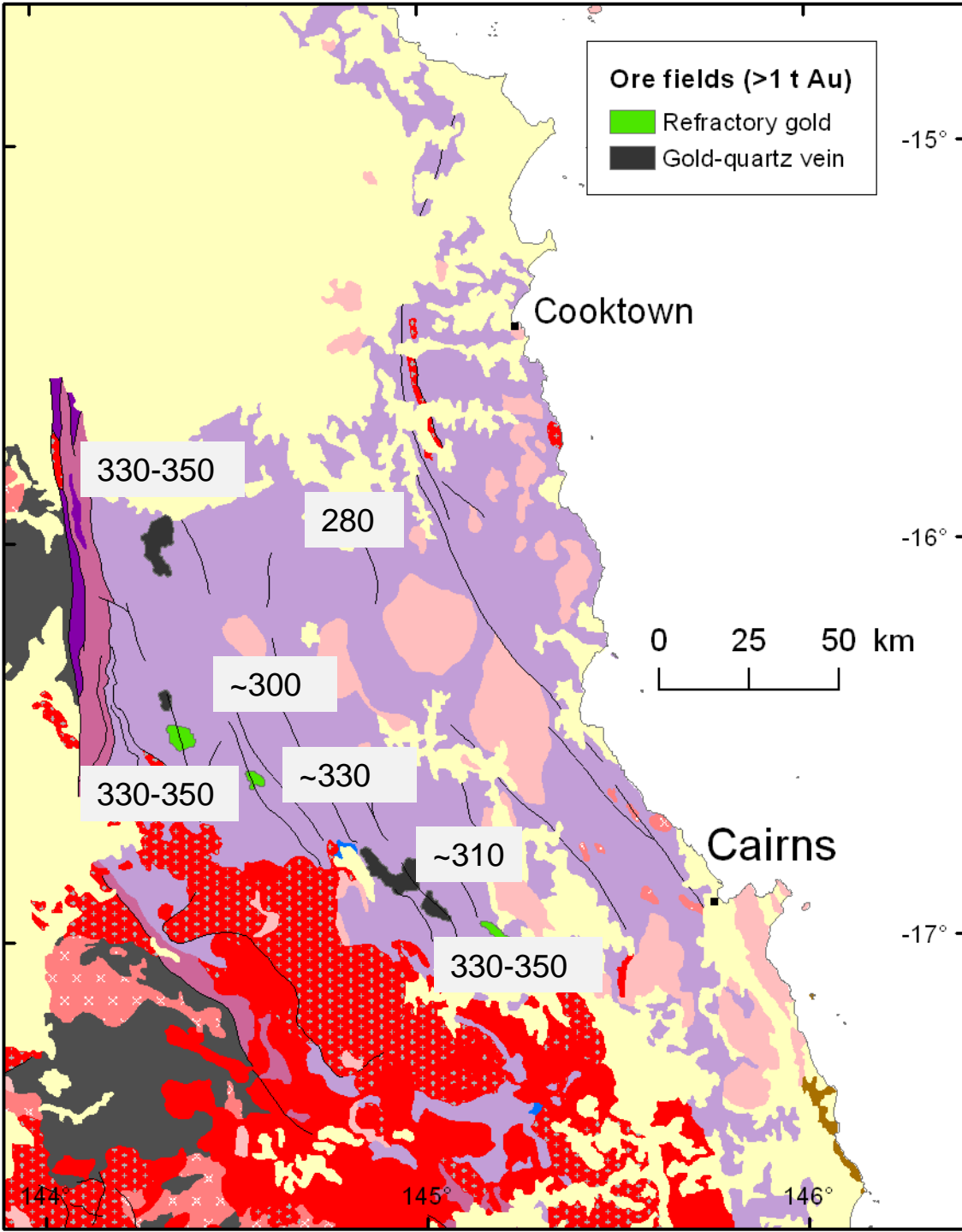
- Multiple orogenic Au deposits – in the Hodgkinson and Broken River provinces
- Qtz-Py-Asp-(Sb)-Au veins and stockworks (Au-As-Sb-W geochemistry)



Orogenic gold – Ar-Ar geochronology

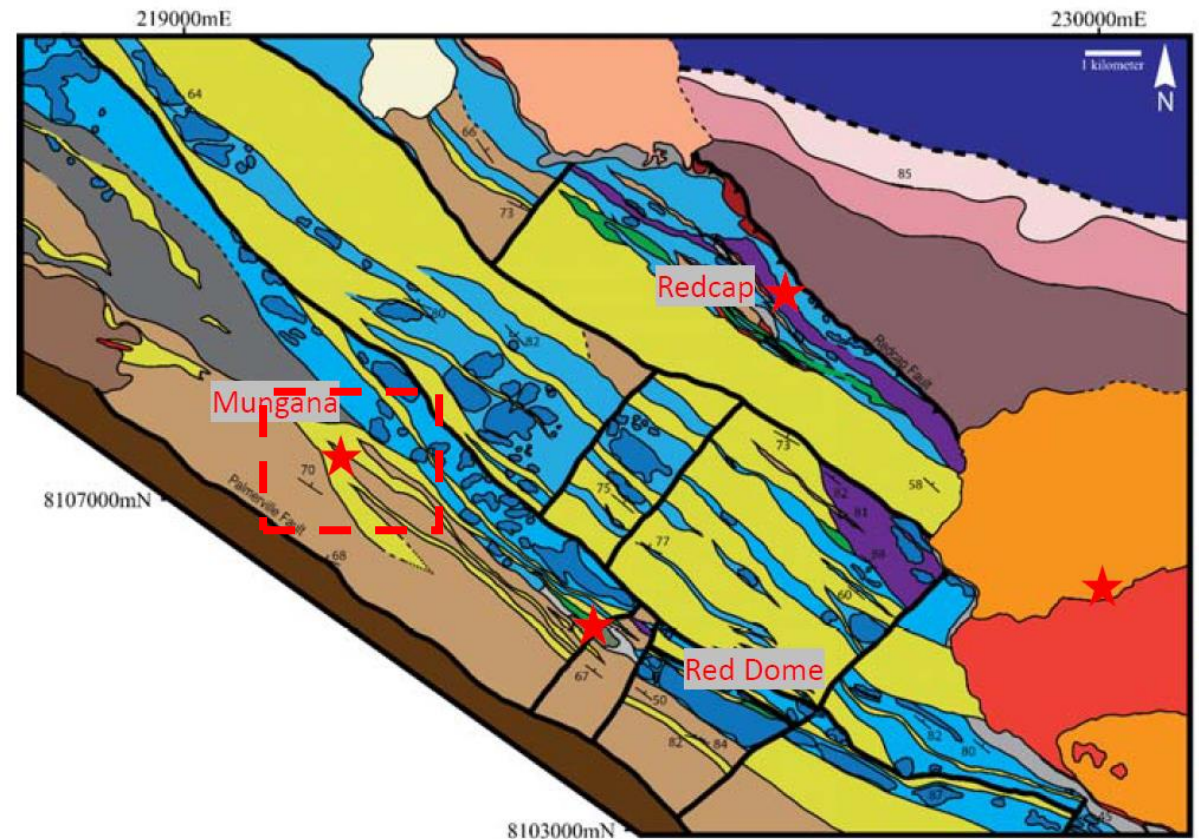
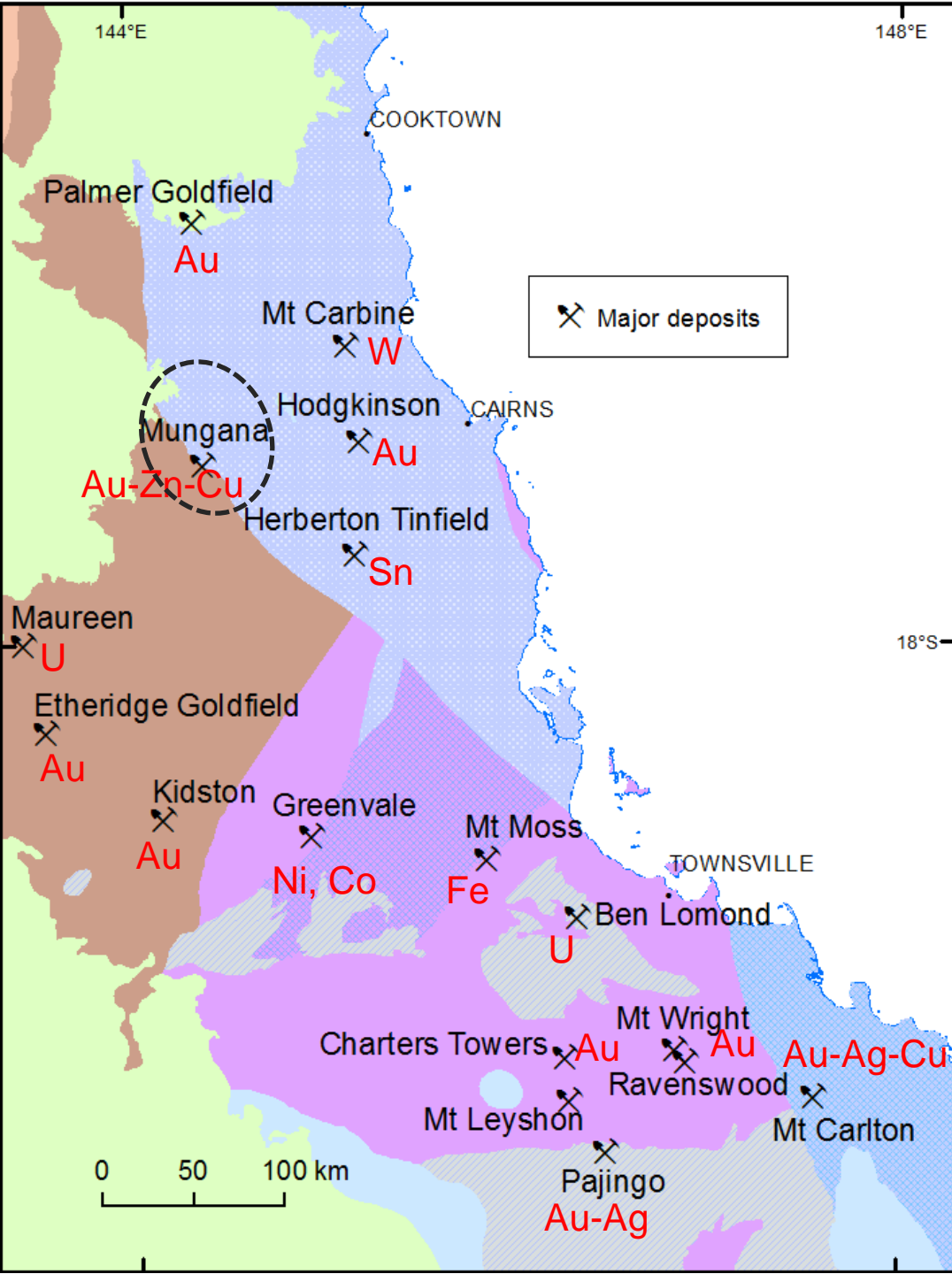
15 Ar-Ar dates on sericite alteration indicate Carboniferous age:

- ~330-350 Ma (refractory Au-Sb)
- 300-310 Ma (**Au-Qtz vein**)
- 280 Ma (minor Au-Qtz vein) – one deposit ‘off-trend’
- Age span and episodes – the same as the KIA



Au-Cu and Zn-Cu-Pb-Zn mineral systems – Chillagoe district

Carboniferous Zn-Cu skarns, Au-Cu porphyry – genesis, relationships?



Peter Illig (PhD), 2016-

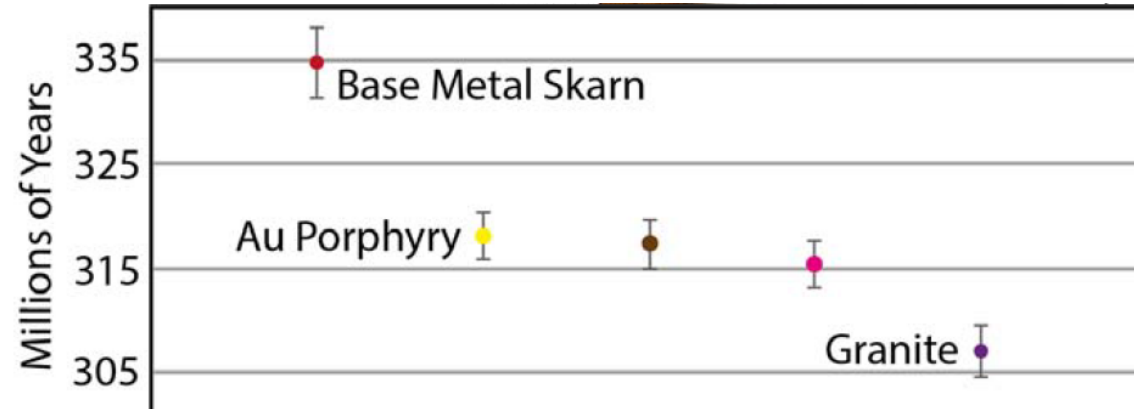
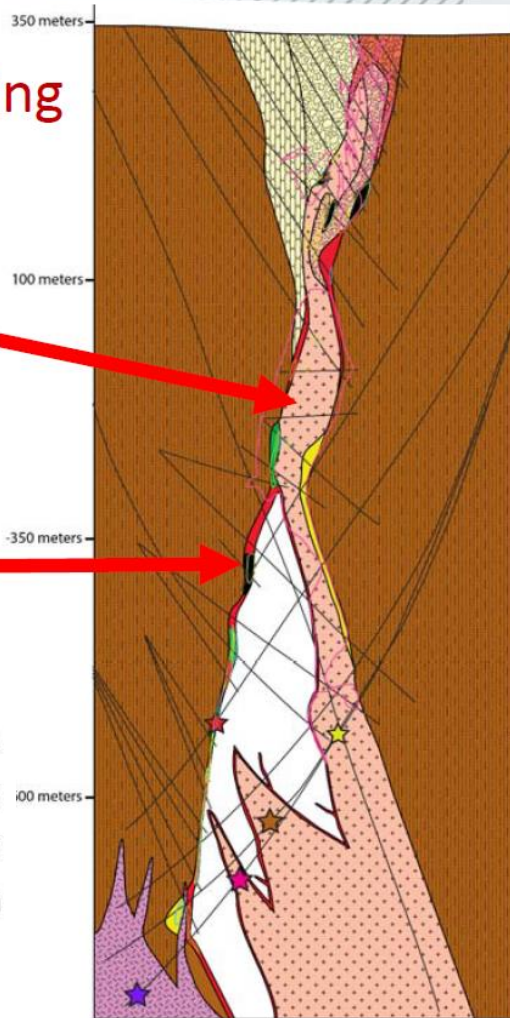
Mungana Au and Zn-Cu-Pb-Zn mineral systems

Two Overprinting Deposits

Au Porphyry

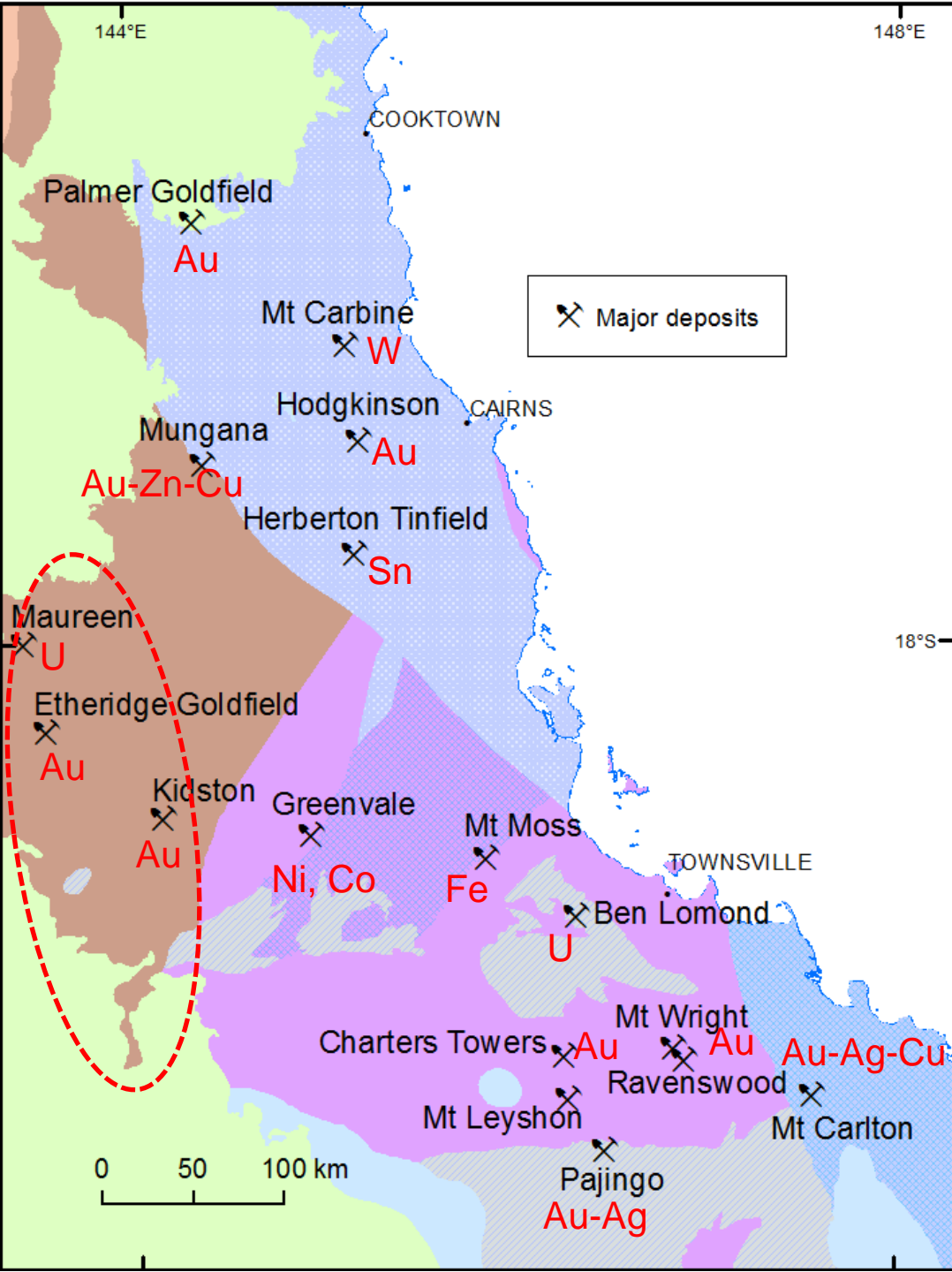
Zn-Pb-Cu-Ag Skarn

- ★ U-Pb 318.1 +/- 2.3 Ma
- ★ U-Pb 317.3 +/- 2.3 Ma
- ★ U-Pb 315.4 +/- 2.2 Ma
- ★ U-Pb 307.1 +/- 2.5 Ma
- ★ Re-Os 335 +/- 2 Ma

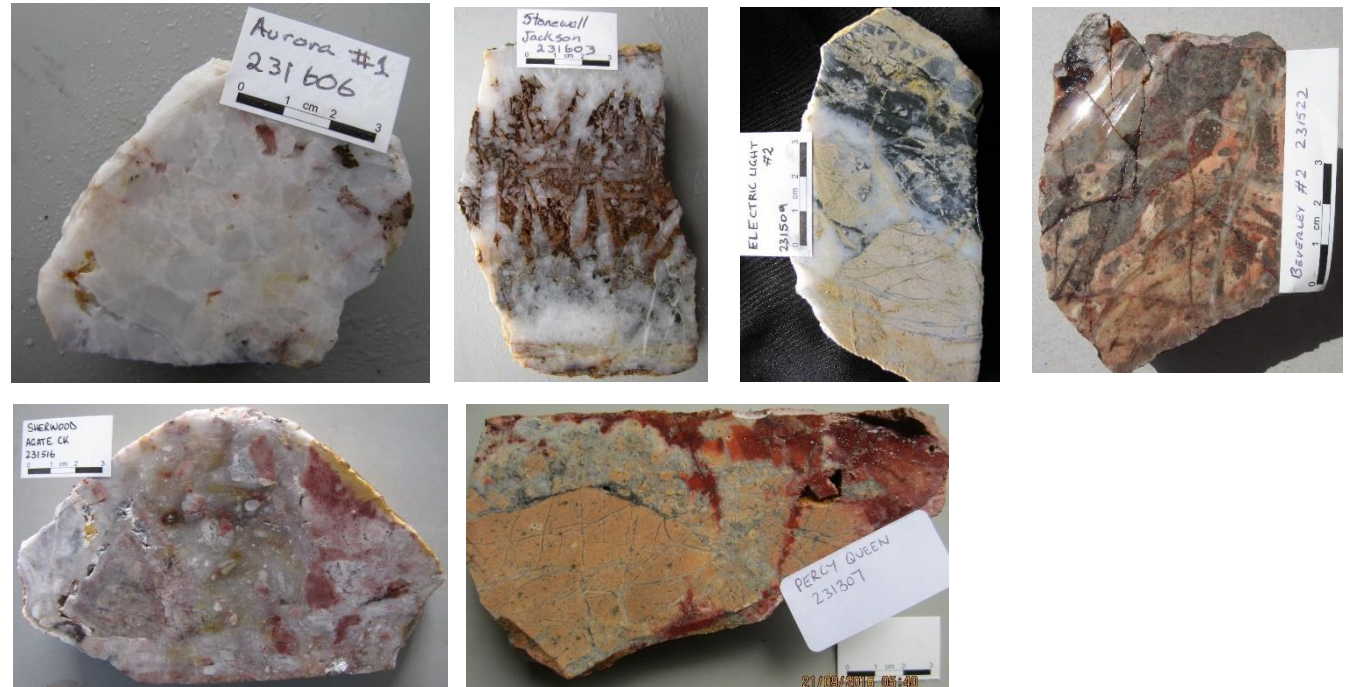


- Zn-Cu skarn – 335 Ma
- Au porphyry (IRGD) – 317 Ma

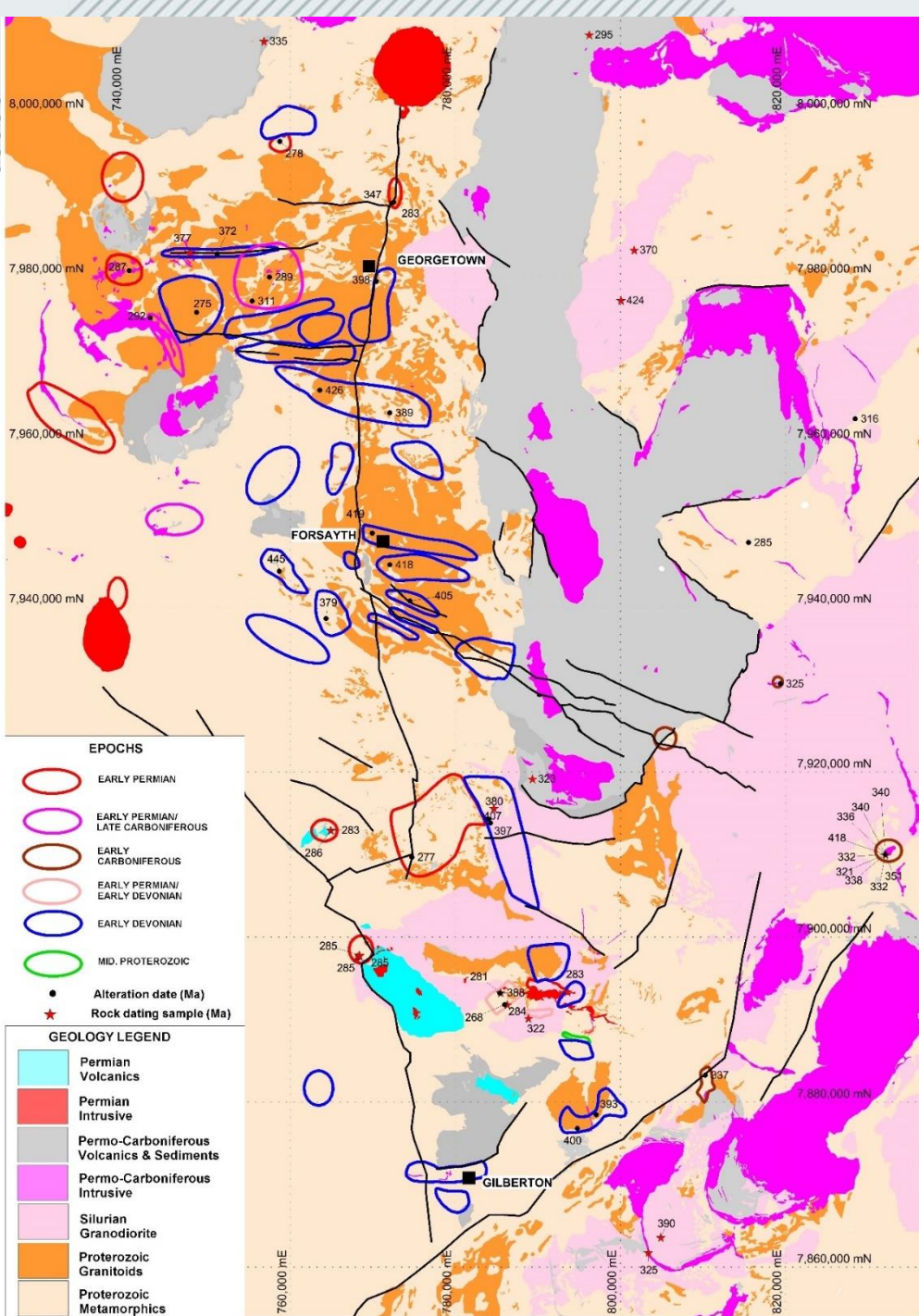
Gold mineral systems – Georgetown



- A variety of styles (and previously often assumed ages)
- Devonian orogenic Au; Carboniferous IRGS; Carboniferous(?) porphyry Cu; Permian(?) epithermal Au

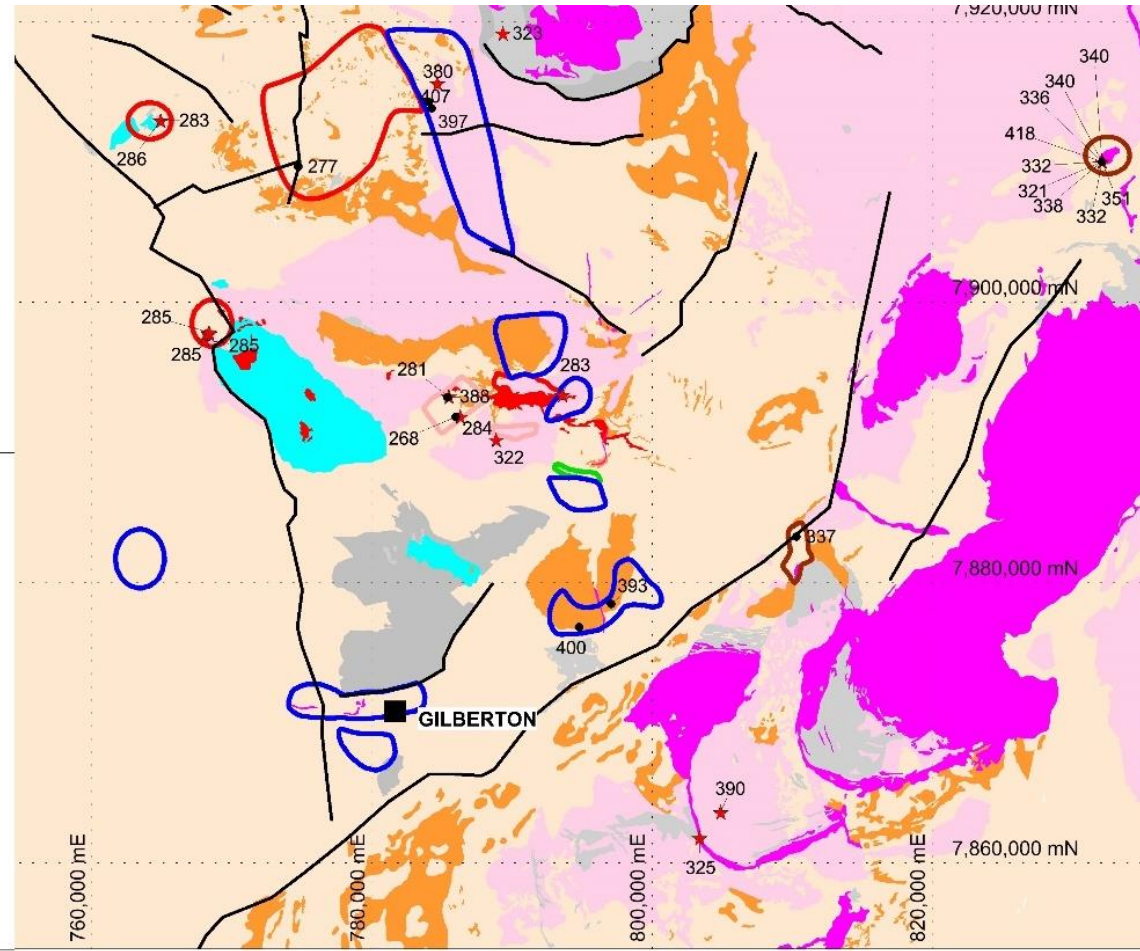


Gold mineral systems – Georgetown



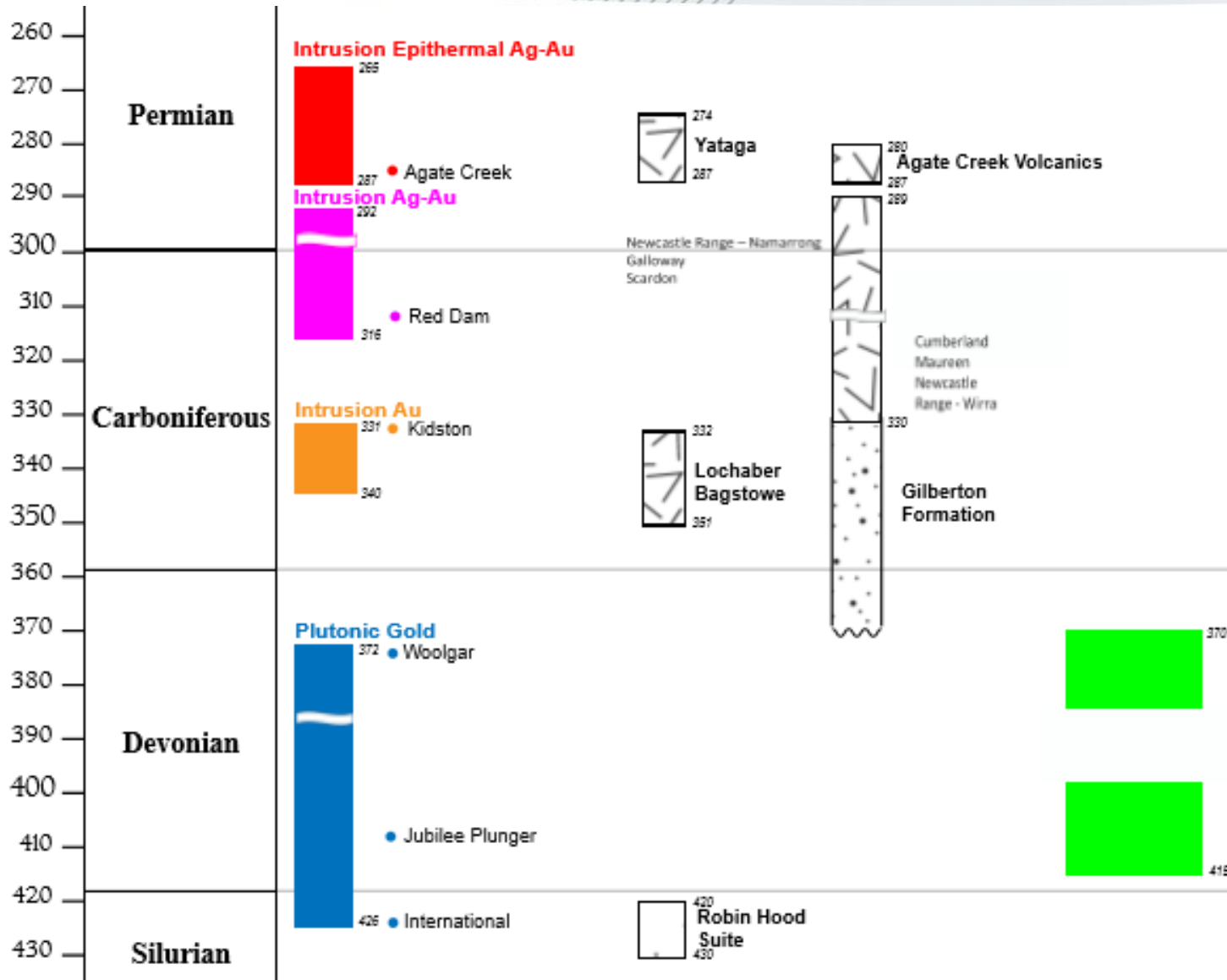
- EARLY PERMIAN
- EARLY PERMIAN/ LATE CARBONIFEROUS
- EARLY CARBONIFEROUS
- EARLY PERMIAN/ EARLY DEVONIAN
- EARLY DEVONIAN
- MID. PROTEROZOIC
- Alteration date (Ma)
- ★ Rock dating sample (Ma)

- GEOLOGY LEGEND**
- Permian Volcanics
 - Permian Intrusive
 - Permo-Carboniferous Volcanics & Sediments
 - Permo-Carboniferous Intrusive
 - Silurian Granodiorite
 - Proterozoic Granitoids
 - Proterozoic Metamorphics



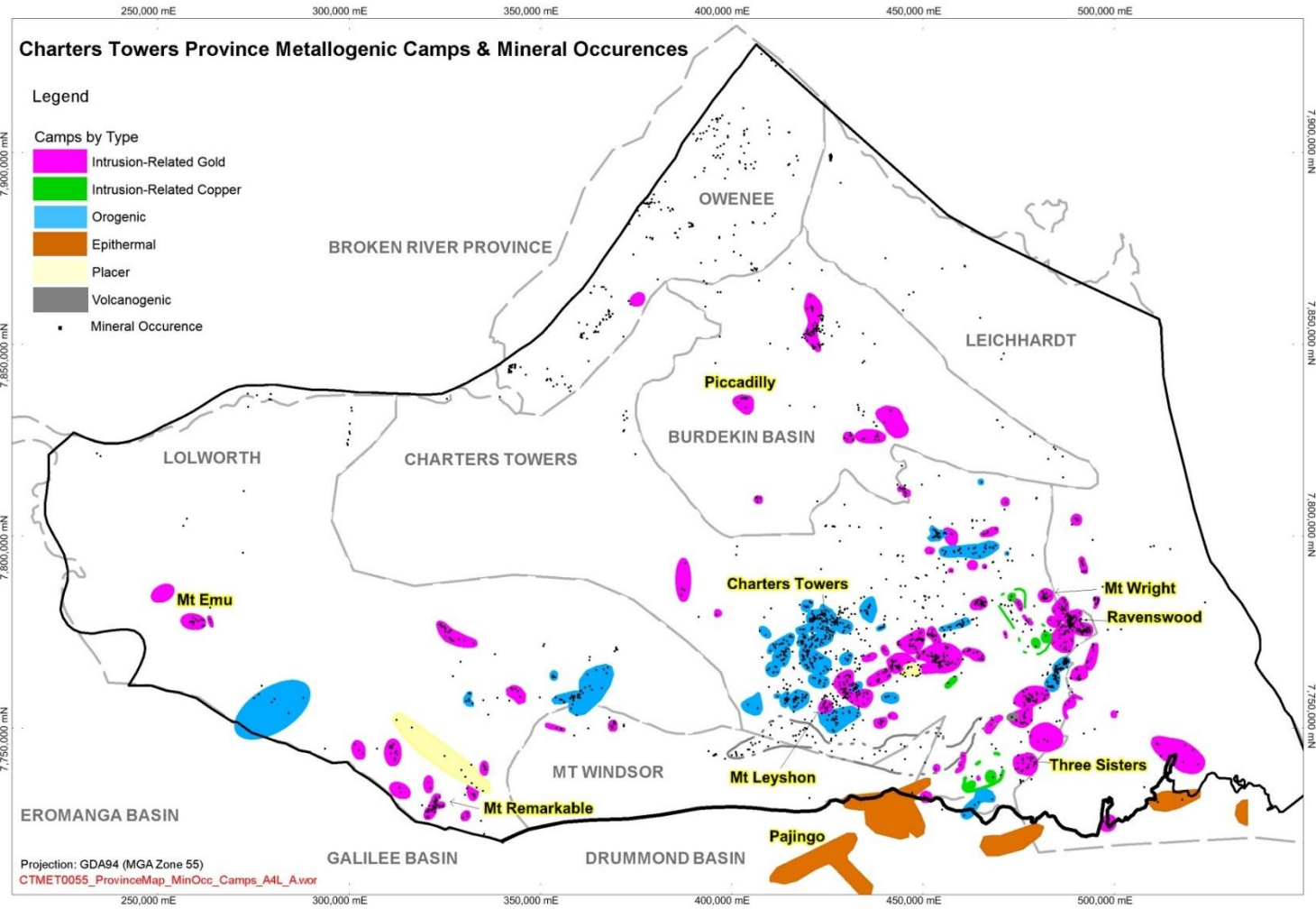
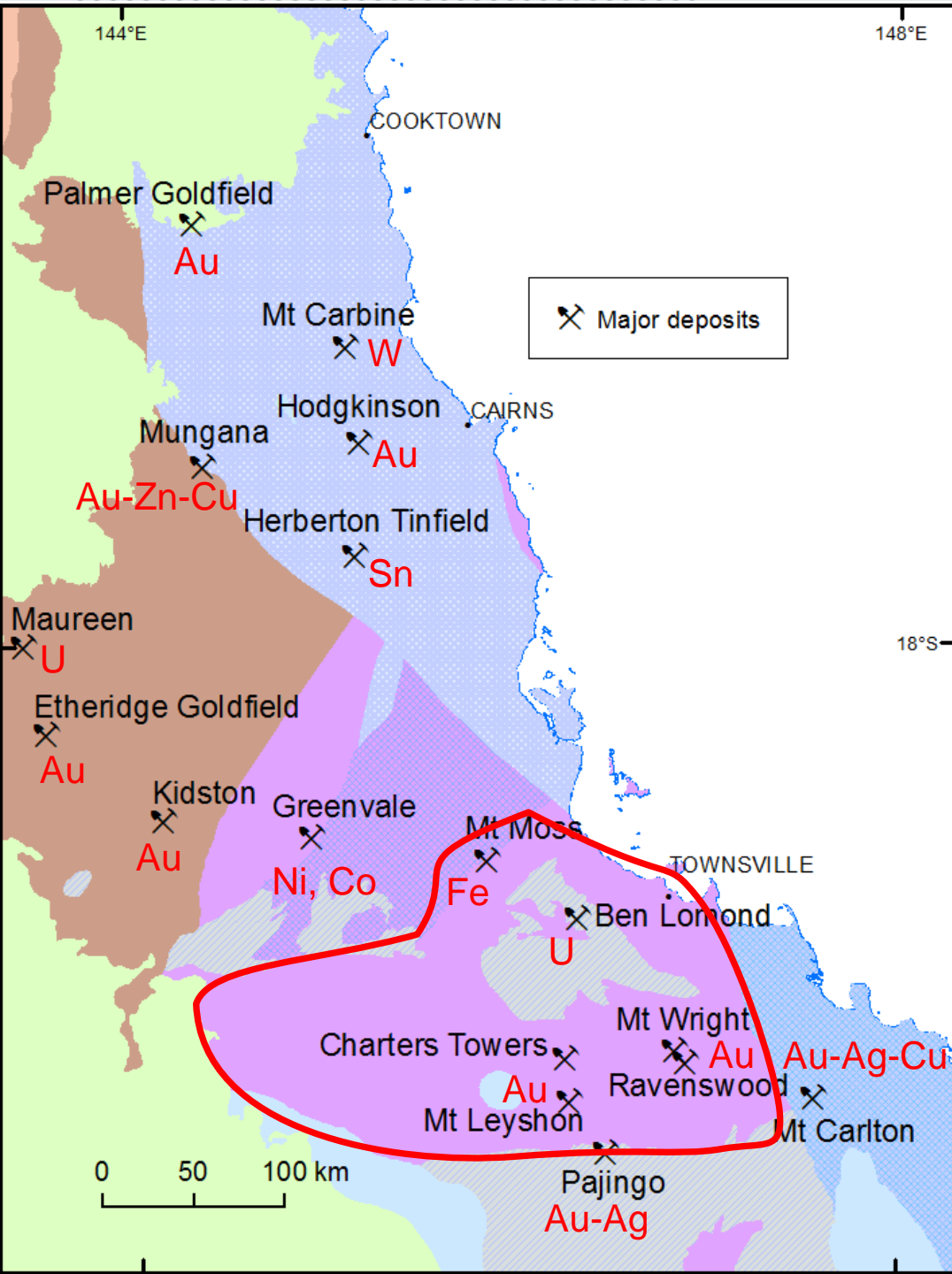
Morrison, Mustard, Cody, 2017

Gold mineral systems – Georgetown



- Most deposits – Devonian ‘plutonic’ (≡ orogenic); Au-Bi-Te-Pb-Zn-As – suggesting magmatic inputs
- Intrusion-related: early Carboniferous (**Kidston**) and early Permian
- Epithermal – early Permian (Agate Creek)

Gold mineral systems – Charters Towers Province

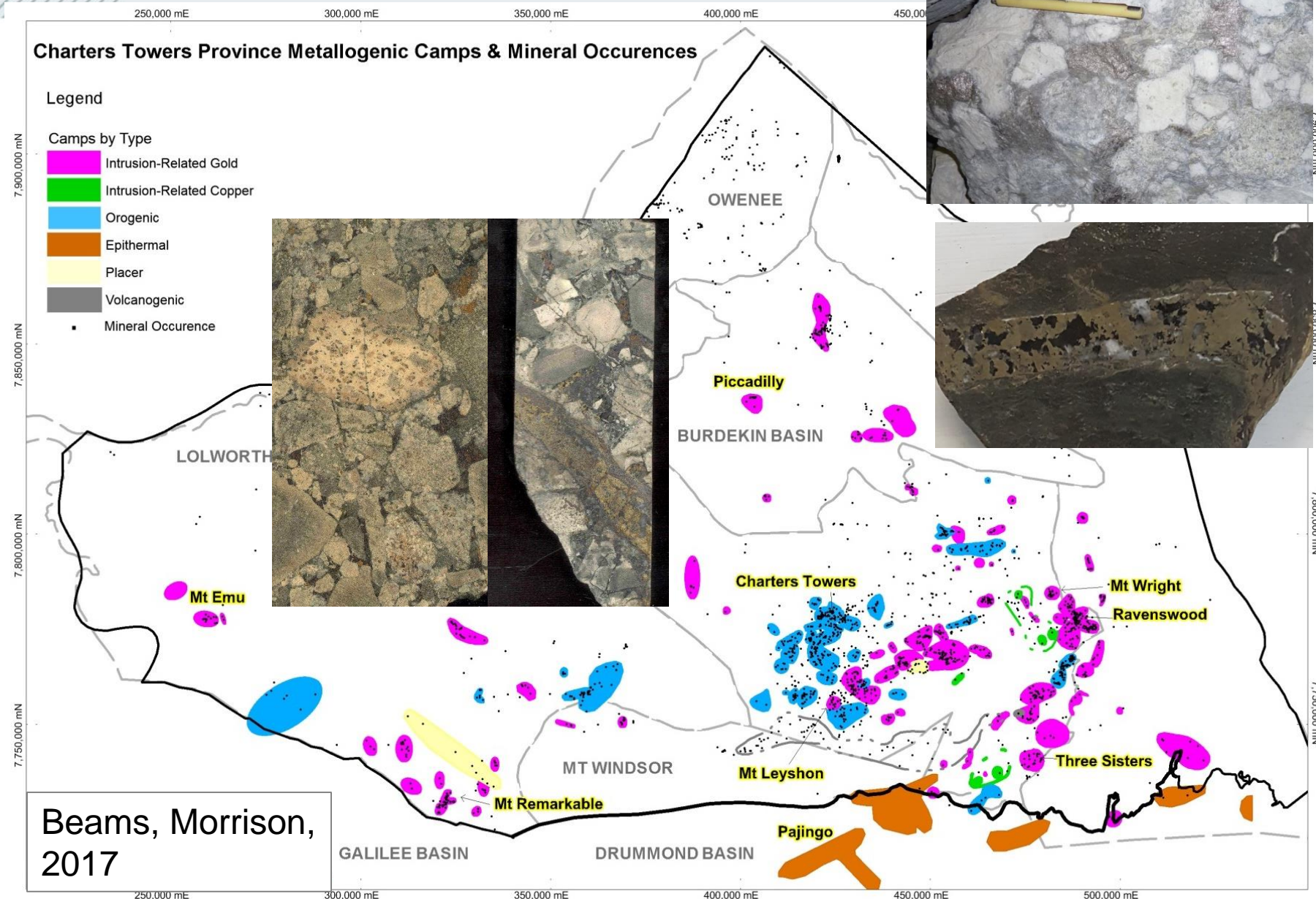


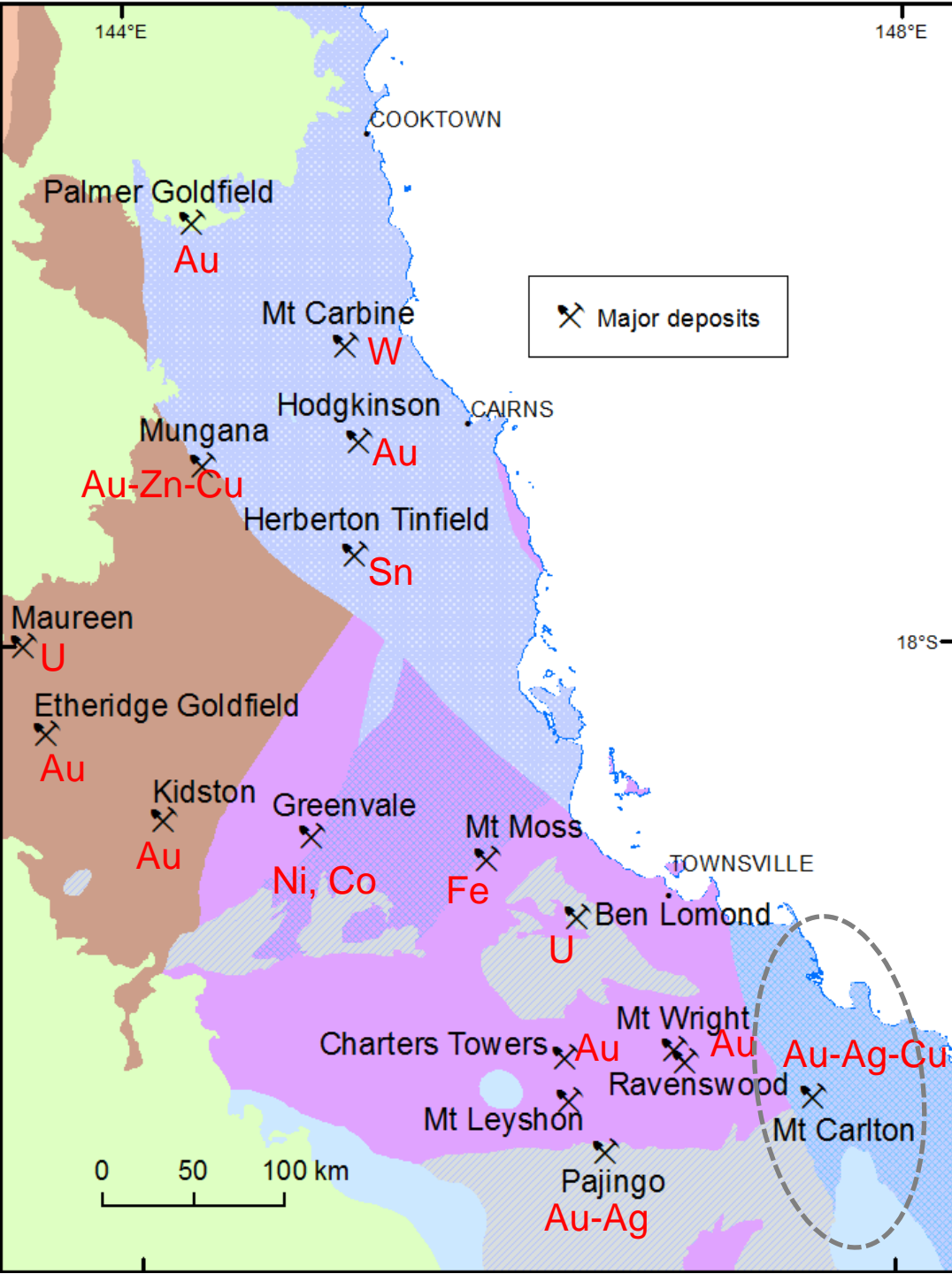
Beams, Morrison,
2017

Gold mineral systems – Charters Towers Province

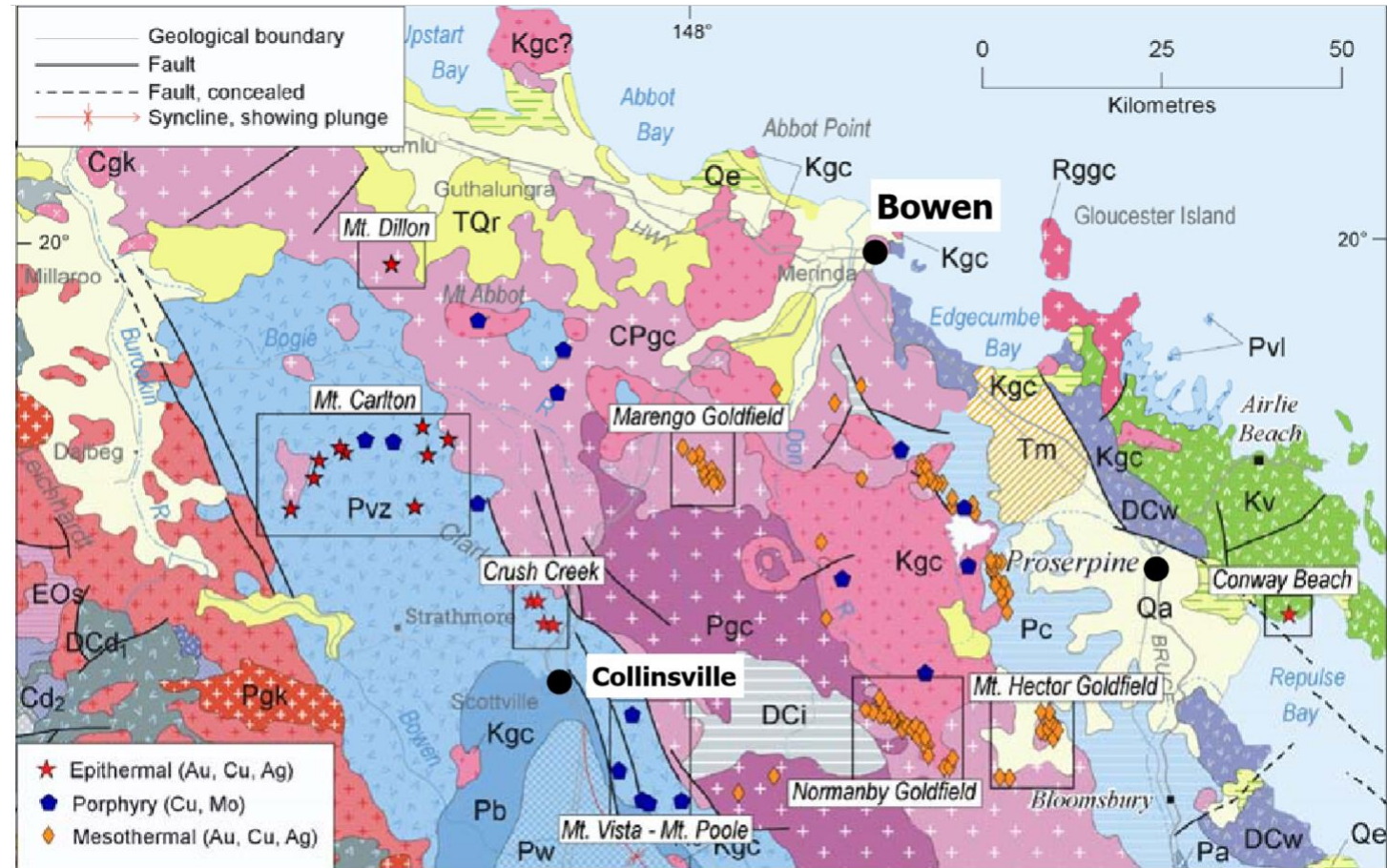
Two distinct Au mineral systems, distinguishable by geochemistry:

- Devonian orogenic (Au-Ag-Pb-Zn-Cu)
- Carboniferous intrusion-related (Au-As-Te-Bi-Cu-Pb-Zn-Ag-Sb(Mo-W), km-scale zonation)

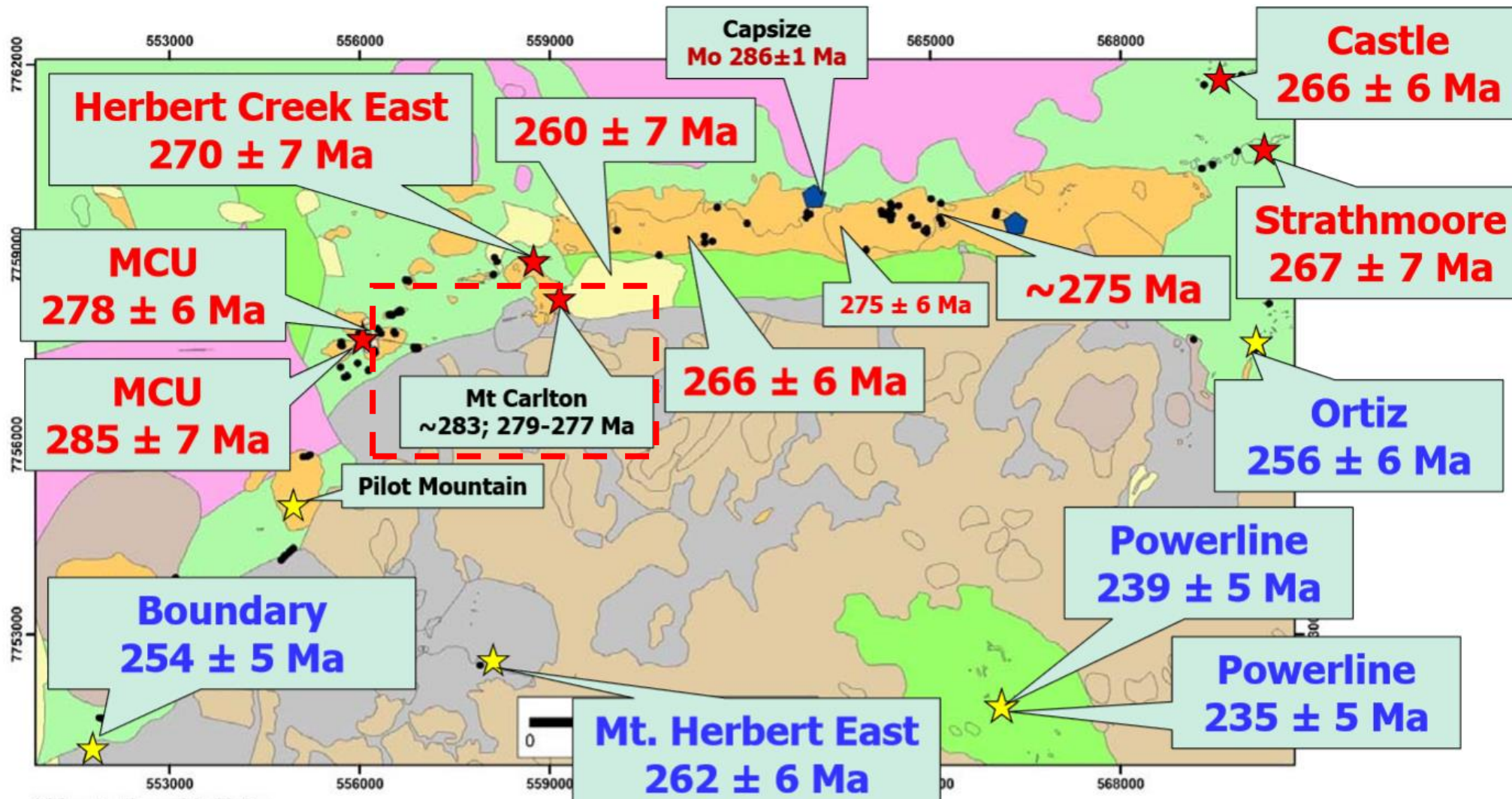




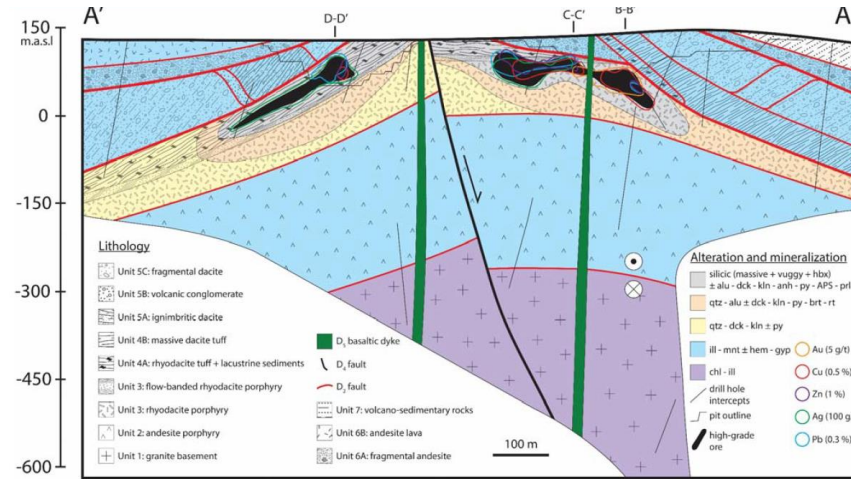
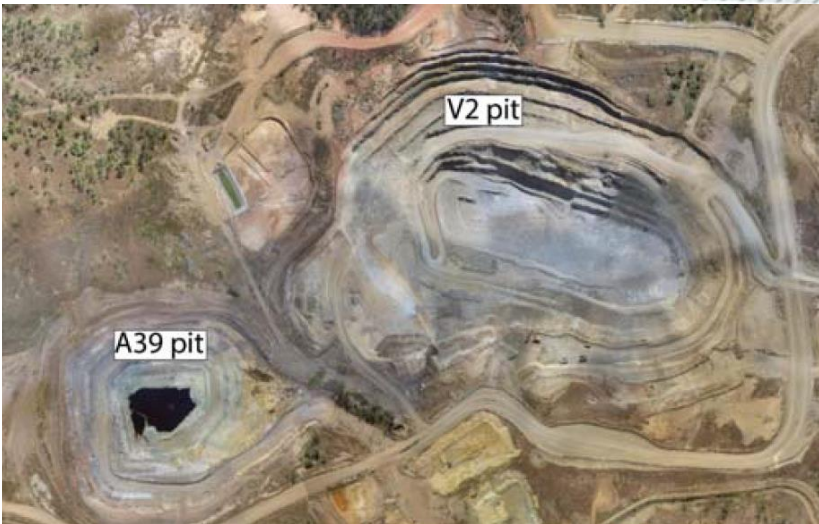
Gold mineral systems – northern Bowen Basin and Urannah



High- and Low-sulphidation deposits – Mt Carlton district





Mt Carlton high-sulphidation gold deposit



Mineral	Stage 1 hydrothermal alteration		Stage 2 hydrothermal mineralization			Stage 3 hydroth. veins and void filling	Stage 4 D ₂ deformation
	1A: alteration halo core → distal	1B: veins and void filling	2A Cu-Au-Ag	2B Zn-Pb-Au-Ag	2C Cu-Au-Ag		
quartz	disseminated, platy	plumose	in vein halo				
alunite							
dickite							
kaolinite							
pyrophyllite							
APS minerals							
illite/montmorillonite		in Unit 1					
chlorite							
barite							
anhydrite/gypsum	in fractures						
rutile							in veins around fault zones
pyrite							

Fredrik Sahlström et al., 2018

 *Economic Geology*, v. 113, no. 8, pp. 1733–1767



The Paleozoic Mount Carlton Deposit, Bowen Basin, Northeast Australia: Shallow High-Sulfidation Epithermal Au-Ag-Cu Mineralization Formed During Rifting

Fredrik Sahlström,^{1,†} Paul Dirks,¹ Zhaoshan Chang,¹ Antonio Arribas,^{1,2,*} Isaac Corral,¹ Matthew Obiri-Yeboah,³ and Chris Hall²

¹*Economic Geology Research Centre (EGRU), College of Science and Engineering, James Cook University, Townsville, Queensland 4811, Australia*

²*Department of Earth and Environmental Sciences, University of Michigan, Ann Arbor, Michigan 48109-1005, USA*

³*Evolution Mining, Mt. Carlton Operations, Garbutt, Queensland 4814, Australia*

Abstract

Mount Carlton is a Paleozoic high-sulfidation epithermal deposit located in the northern segment of the Bowen Basin, northeast Queensland, Australia. The deposit is hosted in Early Permian volcanic and sedimentary rocks, and an open-pit mining operation includes the Au-rich V2 pit in the northeast and the Ag-rich A39 pit in the southwest. Mineralization at Mt. Carlton occurred during active rifting, partly contemporaneously with the deposition of volcanic sediments in localized half-graben and graben basins. Steep normal faults and fracture

Summary – timing and nature of C-P metallogenic events in NE QLD

- Orogenic, intrusion-related and epithermal Au (and Sn-W) mineral systems across NE Queensland – diverse manifestations of the same regional thermal and magmatic events driving the Kennedy Igneous Association
- **350-335 Ma** - **IRGS** (Kidston); **epithermal Au** (Pajingo); orogenic Au (Hodgkinson Province), Sn (Kangaroo Hills)
- **325-290 Ma** – orogenic Au (HP); **IRGS** (Ravenswood, Mungana – Au, Mt Leyshon, Horn Island); **Sn** (Herberton); Bi-Mo-W
- **285-275 Ma** – widespread Au (**epithermal** – Mt Carlton, Agate Creek, Cape York Peninsula) and local Sn-W deposits (Mt Carbine)
- **265-235 Ma** – low-sulphidation epithermal Au in the northern Bowen Basin