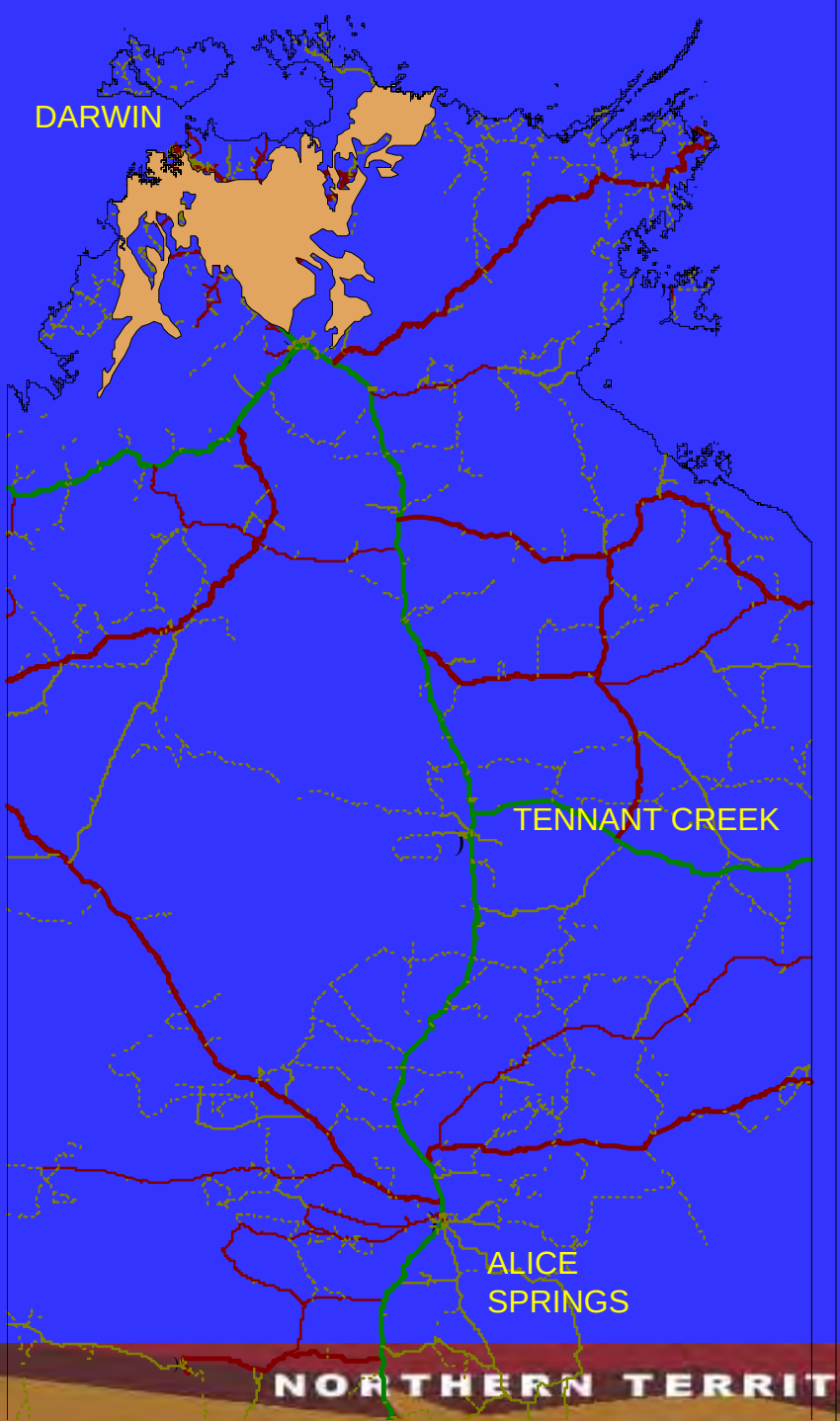


SOME ASPECTS OF METALLOGENESIS IN THE PINE CREEK OROGEN

MASOOD AHMAD

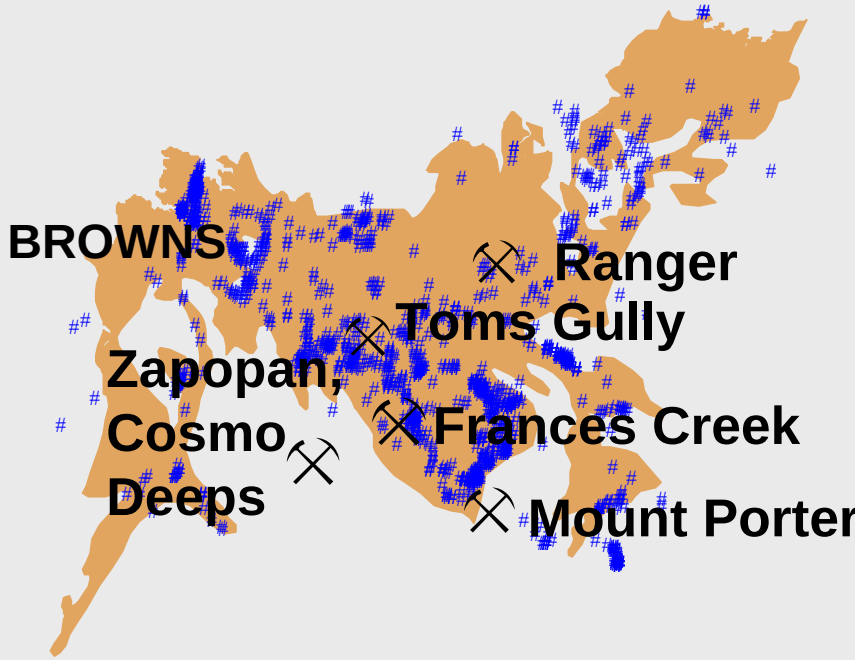
&

ANDREW S WYGRALAK

NORTHERN TERRITORY GEOLOGICAL SURVEY

PINE CREEK OROGEN: PRODUCTION AND RESOURCES

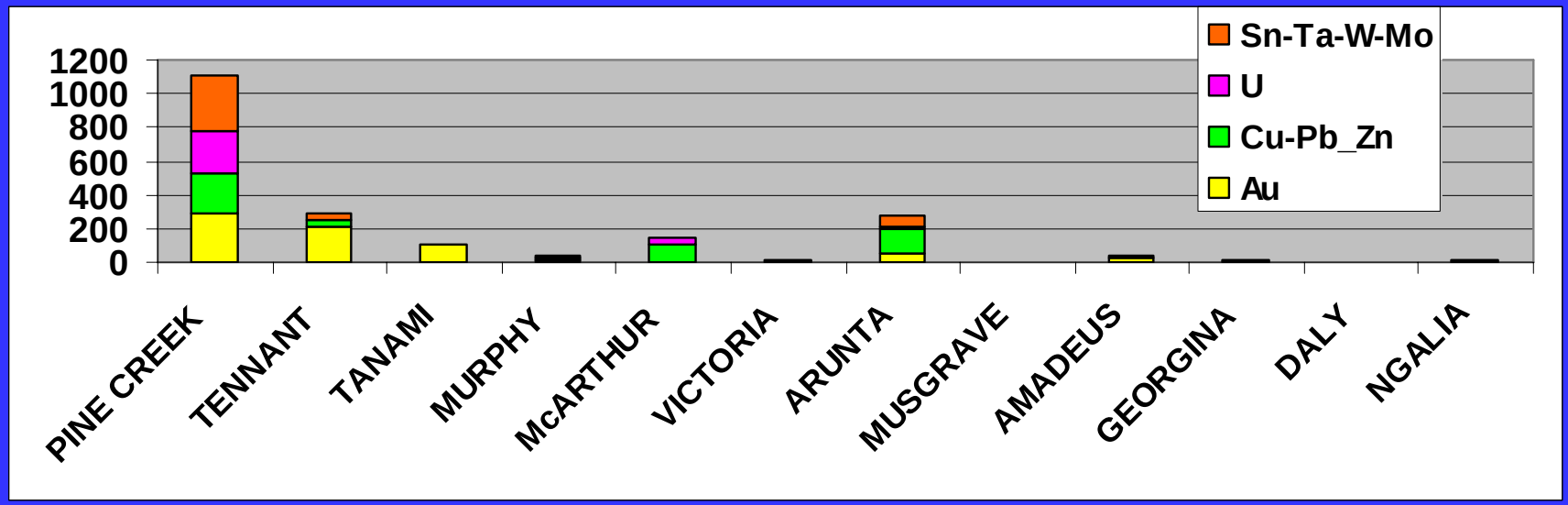
	Past Prod	Resources
Au	4.5 Moz	9 Moz
U	95,000 t	275,000 t
Cu	41,000 t	692,500 t
Pb	0.27 Mt	2.28 Mt
Zn	0.6 Mt	0.3 Mt
Ag	14.5 Moz	38 Moz
Sn	5,000 t	25,000 t
Ta	93 t	850 t
Co	-	104,000 t
Ni	-	93,000 t
Pt	-	54,660 oz
Pl	-	183,270 oz
Fe	6.8 Mt	15 Mt



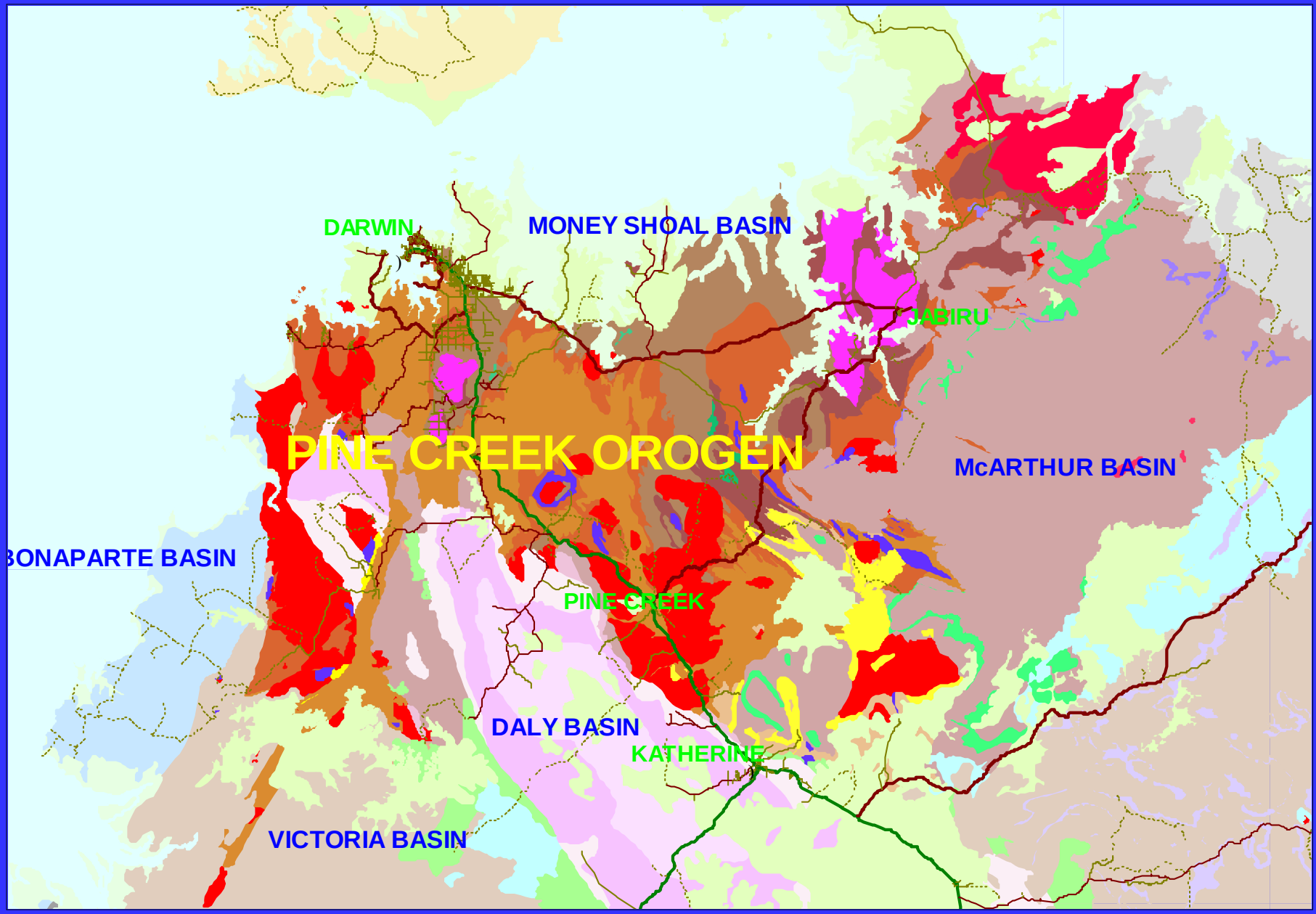
- Over 1000 mineral occurrences

DISTRIBUTION OF MINERAL COMMODITIES

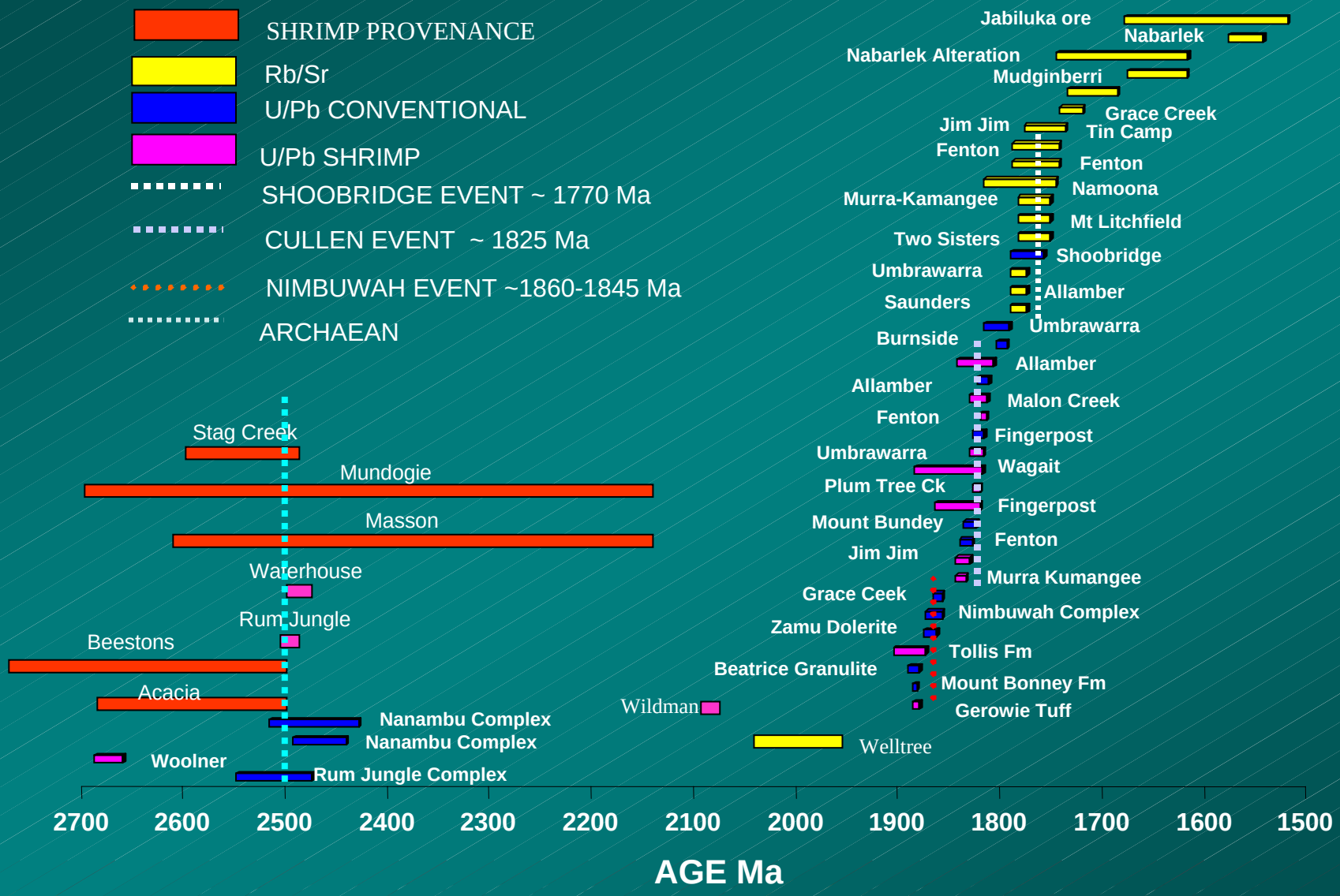
No of Occurrences



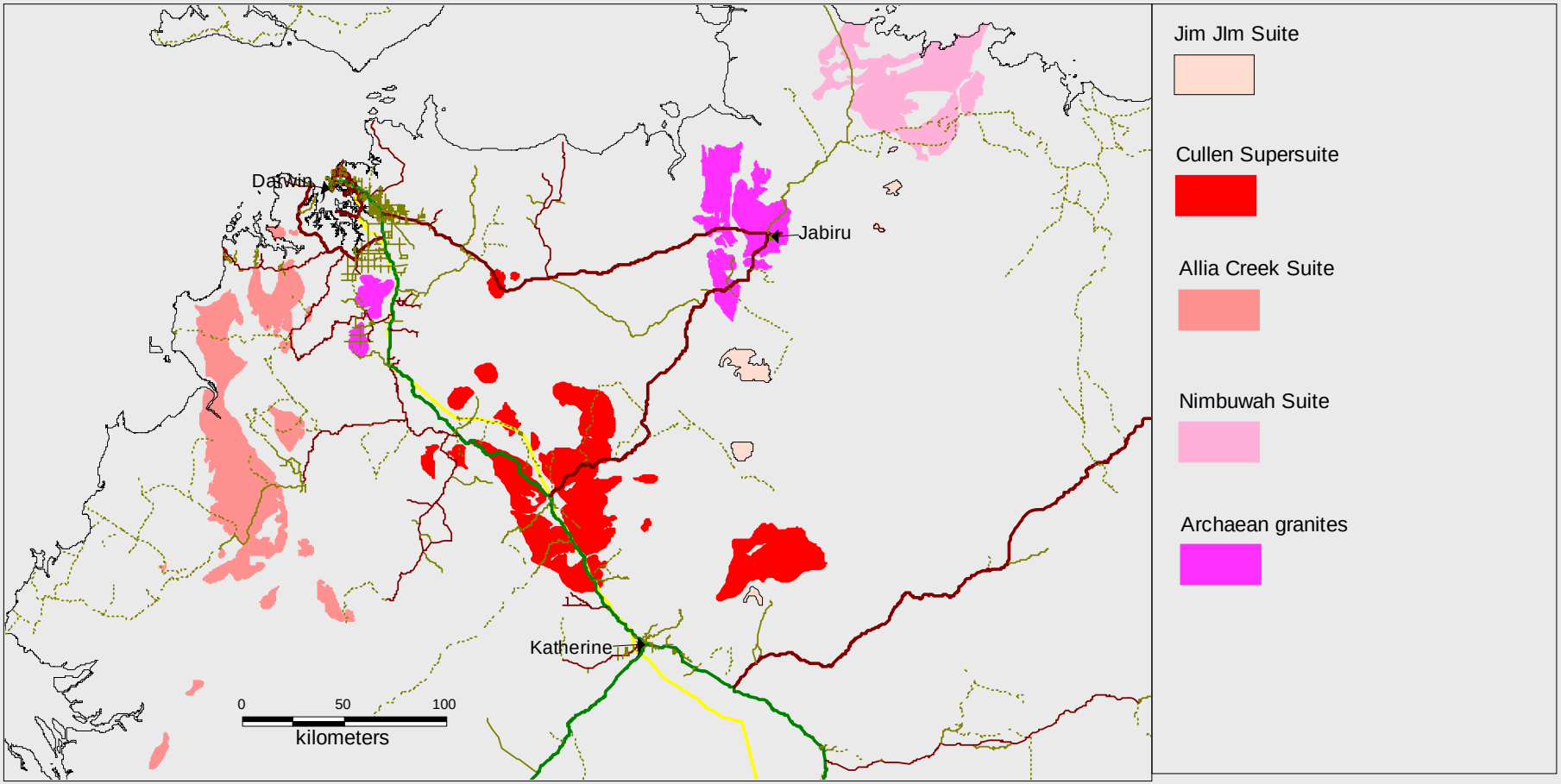
TOLMER GROUP Phosphate	KATHERINE RIVER GROUP U, Au, PGE	Radiometric ages
CULLEN EVENT		1825 Ma
Edith River Group		
El Sherana Group Au, Pt, Pd, U		
NIMBUWAH EVENT/ BARRAMUNDI OROGENY		1840-1860 Ma
DOLERITE INTRUSIONS	ZAMU DOLERITE / DOLERITE INTRUSUIONS	
COSMO SUPERGROUP		
WEST/RUM JUNGLE REGION	CENTRE/SOUTH ALLIGATOR REGION / EAST ALLIGATOR RIVER REGION	
Fog Bay Metamorphics Welltree Metamorphics	FINNISS RIVER GROUP Burrell Creek Formation Au, Sn	1862 Ma
Hermit Creek Metamorphics	SOUTH ALLIGATOR GROUP Mount Bonnie Formation Au, Zn Gerowie Tuff Au Koolpin Formation Au Nouralangie Schist Myra Falls Metamorphics U	1864 Ma
WOODCUTTERS SUPERGROUP		
MOUNT PARTRIDGE GROUP Whites Formation U, Cu, Ni, Zn,Pb Coomalie Dolostone Magnesite Crater Formation Th MANTON GROUP Celia Dolostone Magnesite Beestons Formation	MOUNT PARTRIDGE GROUP Wildman Siltstone Au Mundogie Sandstone NAMOONA GROUP Masson Formation Zn, Pb, U Nouralangie Schist Upper Cahill Formation Lower Cahill Formation U KAKADU GROUP Mount Besdow Gneiss Mount Howship Gneiss	2029 Ma
RUM JUNGLE COMPLEX STANLEY METAMORPHICS	WOOLNER GRANITE DIRTYWATER METAMORPHICS NANAMBU COMPLEX	2500 Ma 2700 Ma


DARWIN
MONEY SHOAL BASIN
JABIRU
PINE CREEK OROGEN
McARTHUR BASIN
BONAPARTE BASIN
PINE CREEK
DALY BASIN
KATHERINE
VICTORIA BASIN

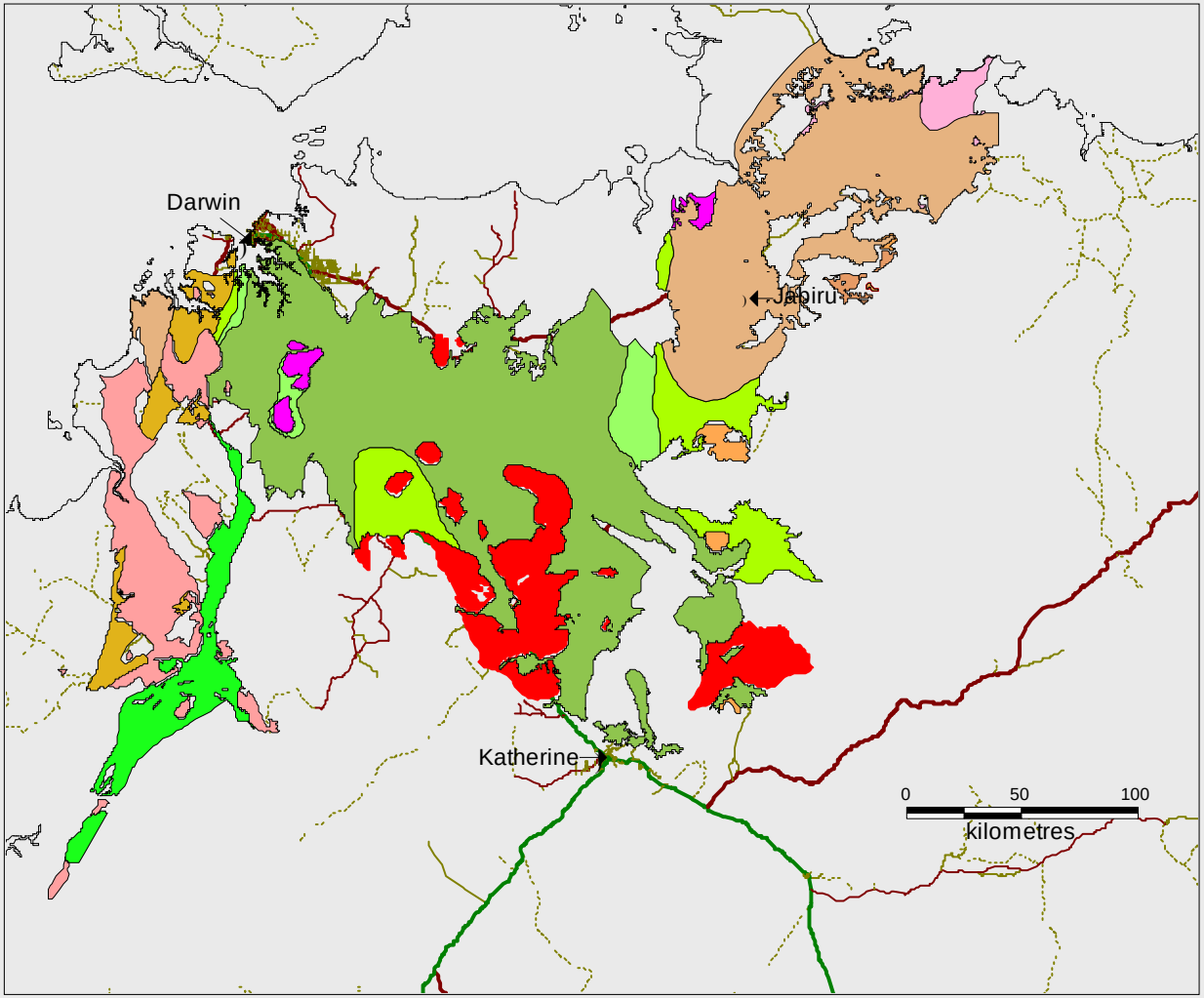
PINE CREEK GEOCHRONOLOGY

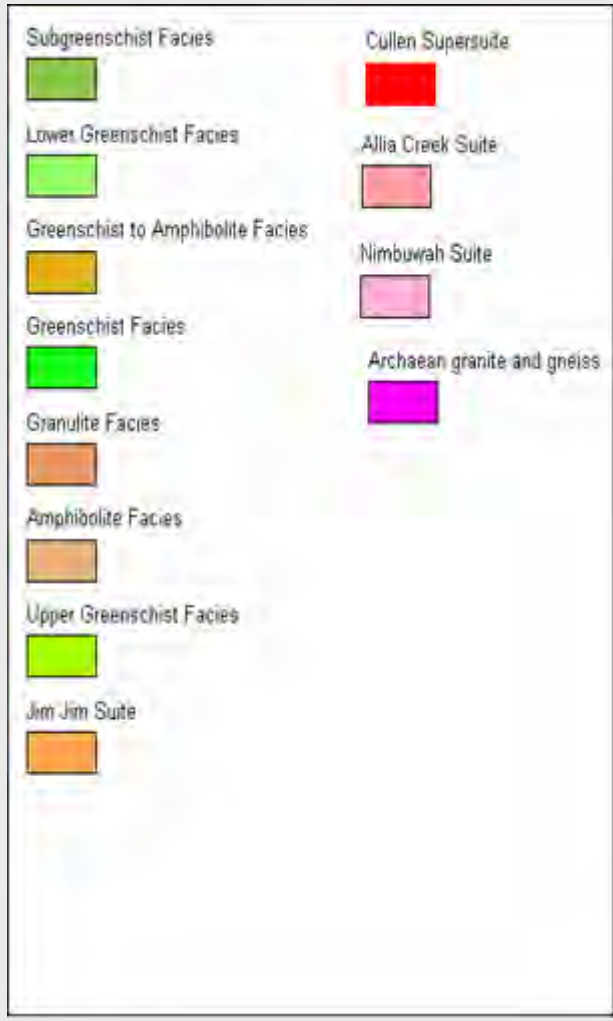


Granite Suites

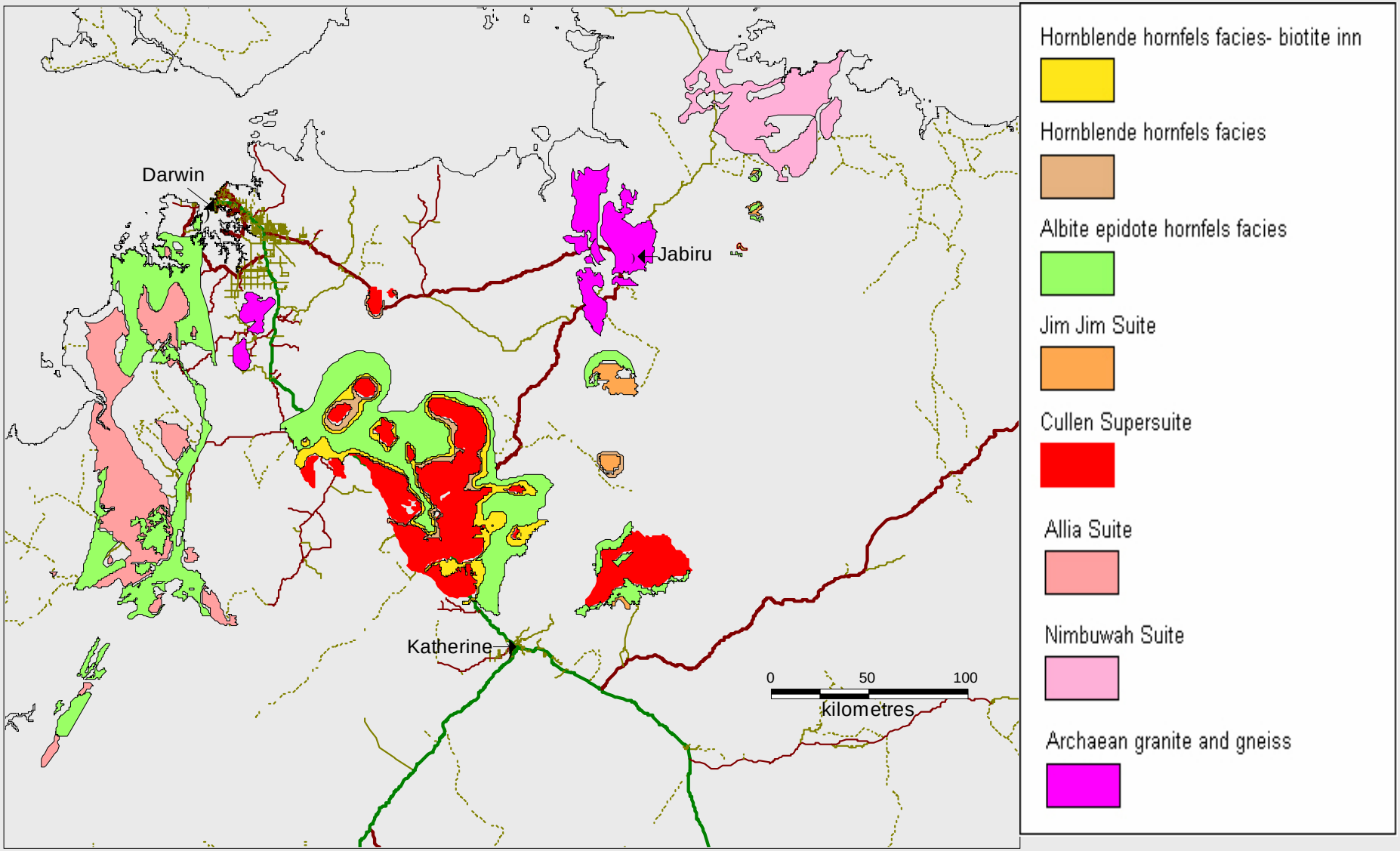


Regional Metamorphism

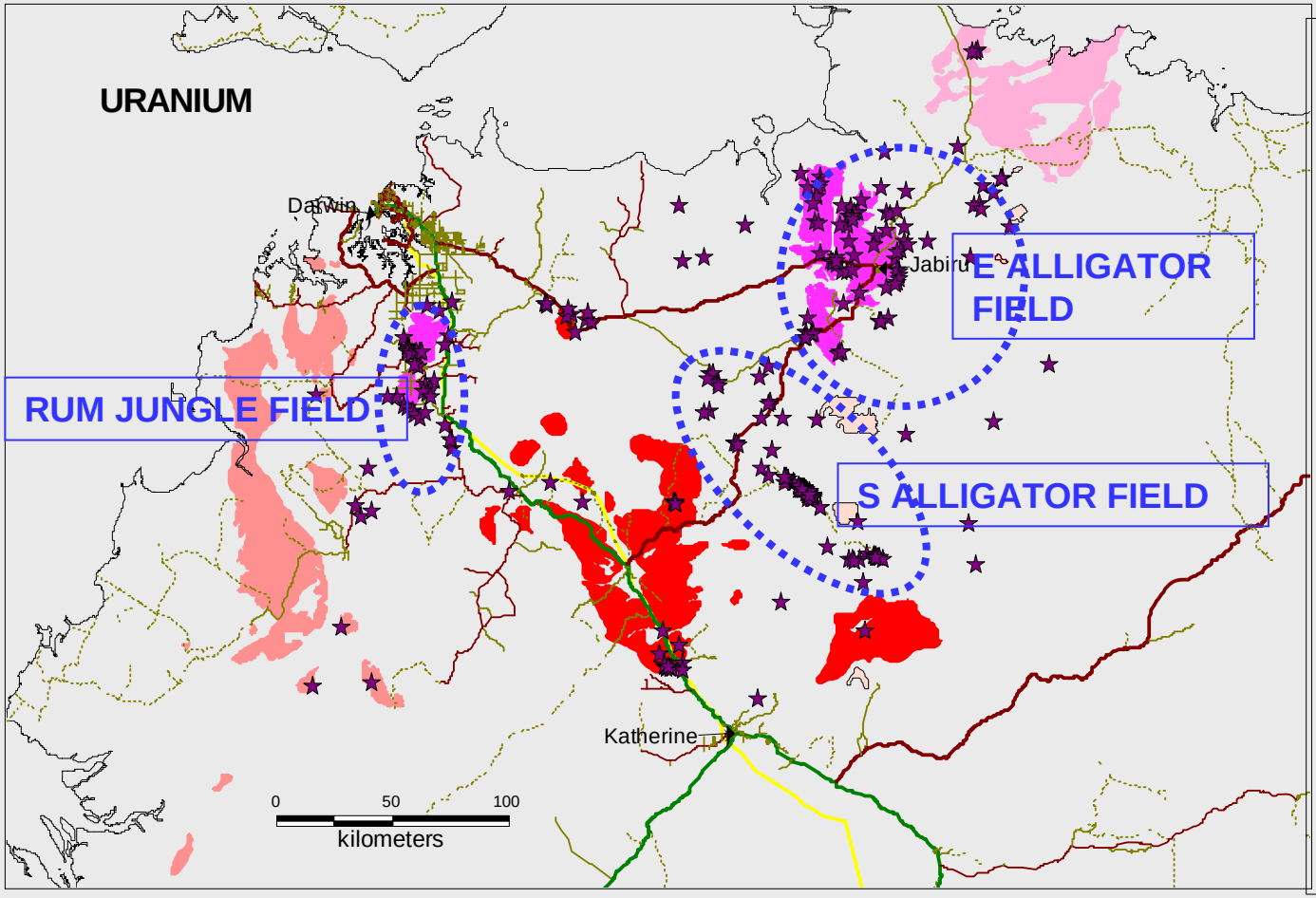




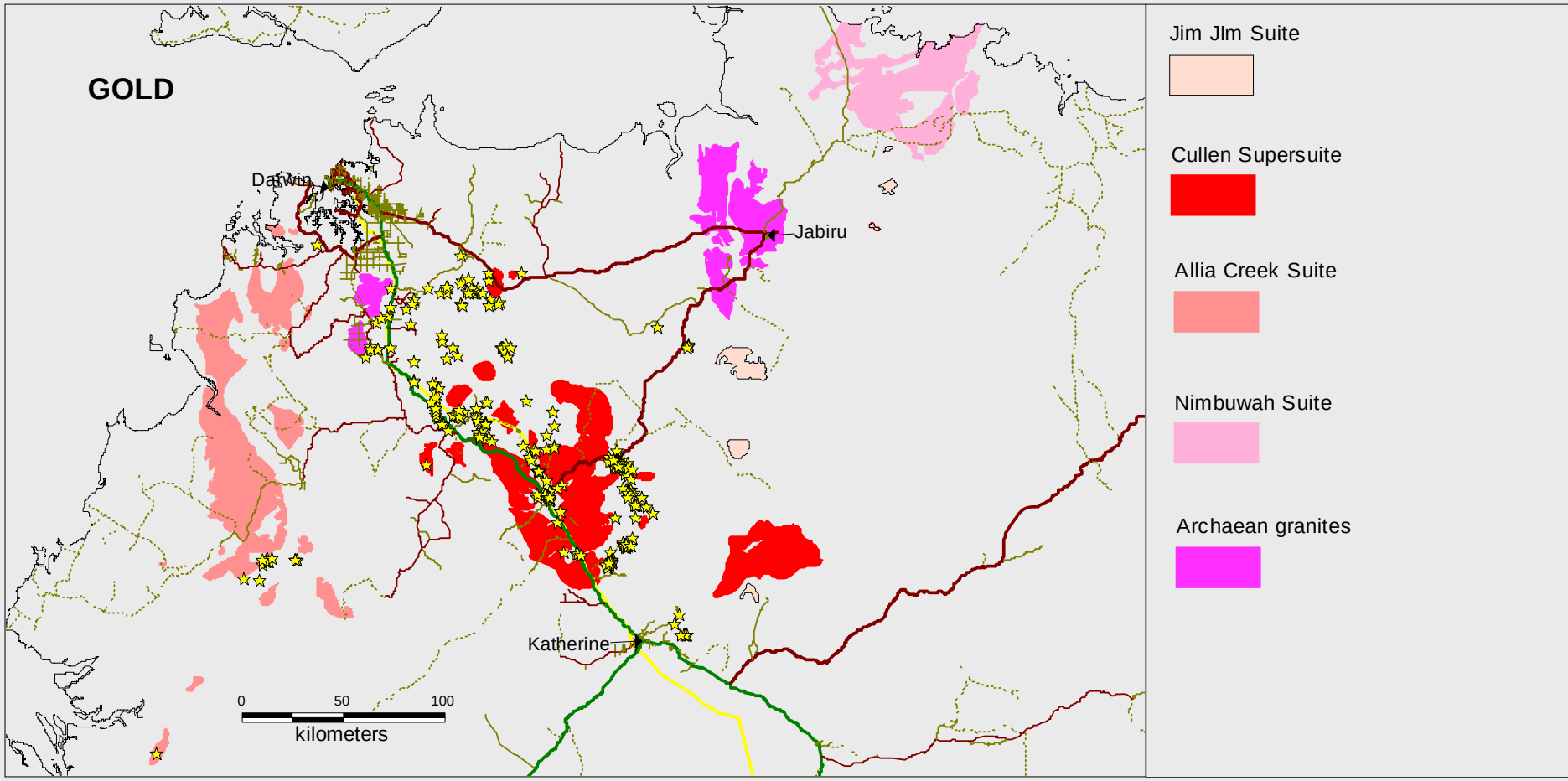
Contact Metamorphism



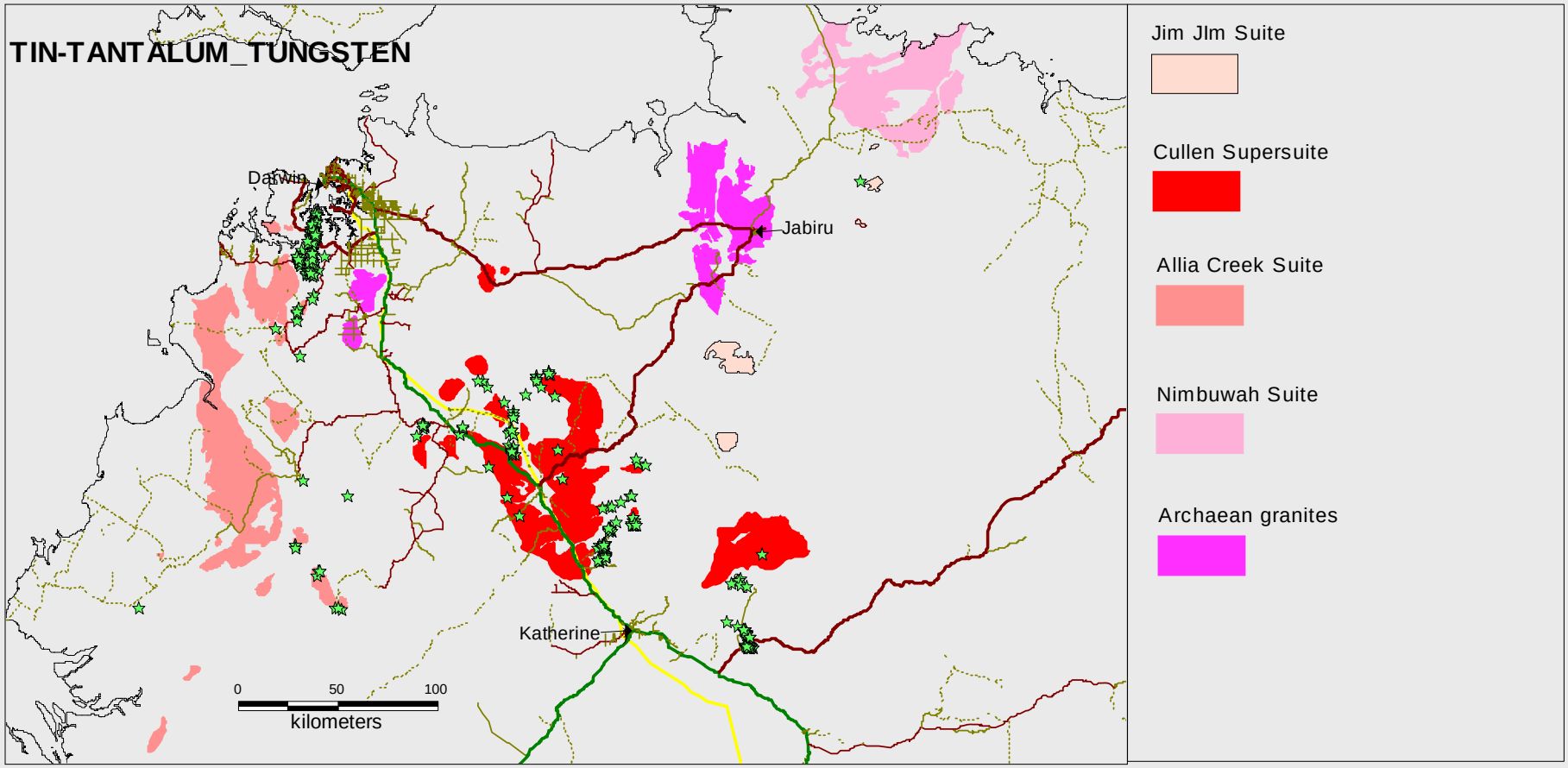
Distribution of uranium occurrences



Distribution of gold occurrences

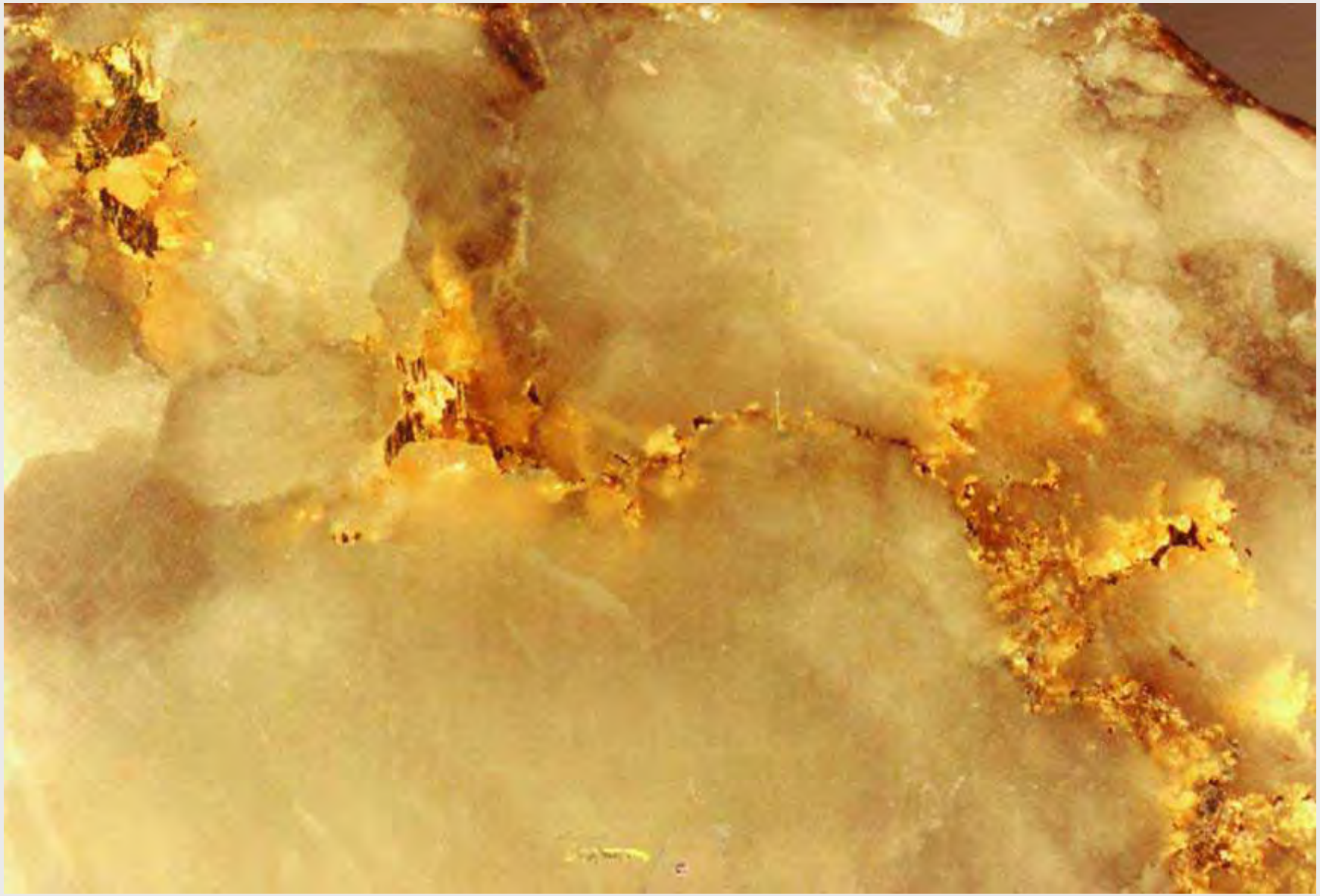


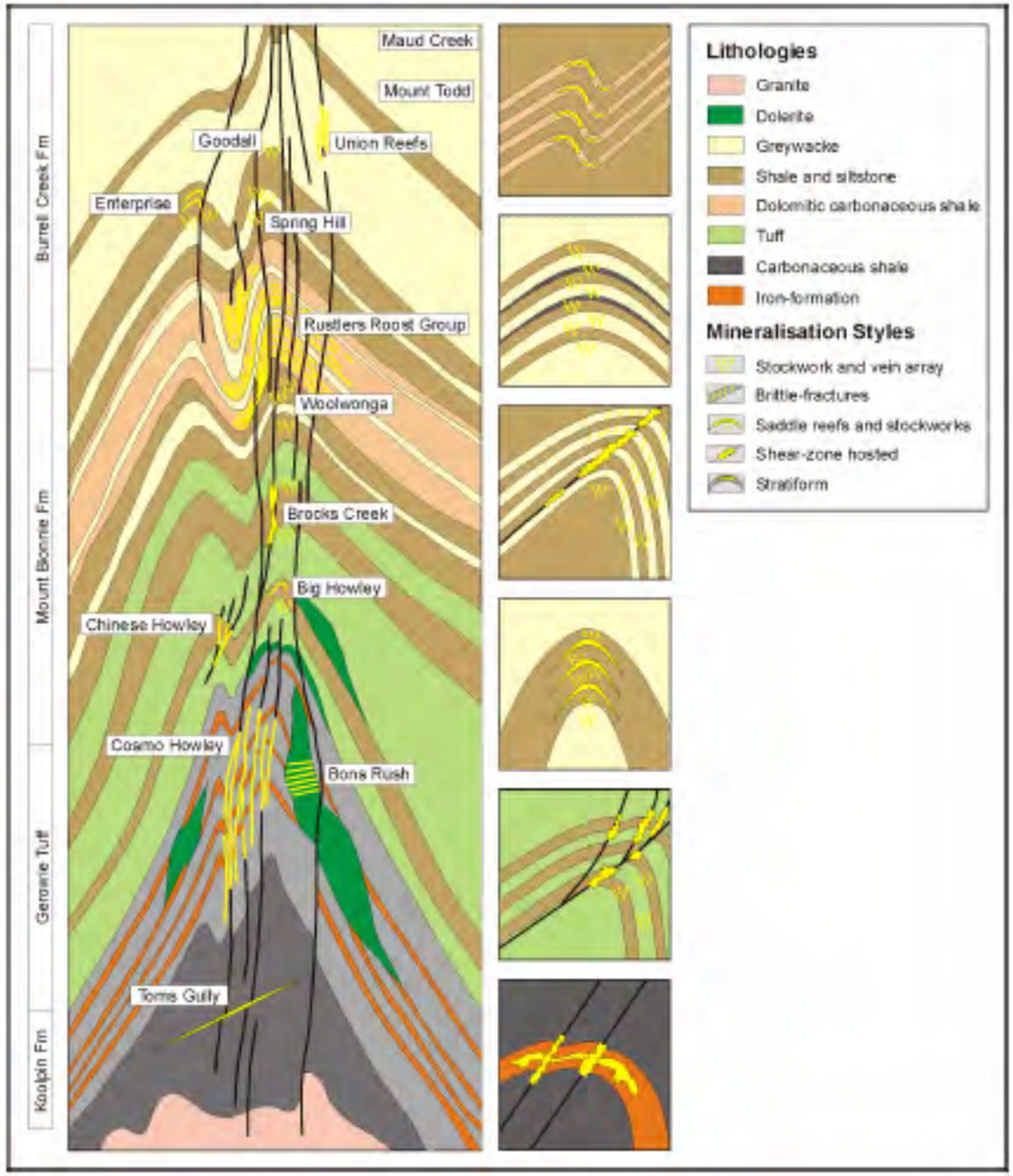
Distribution of tin, tantalum and tungsten occurrences

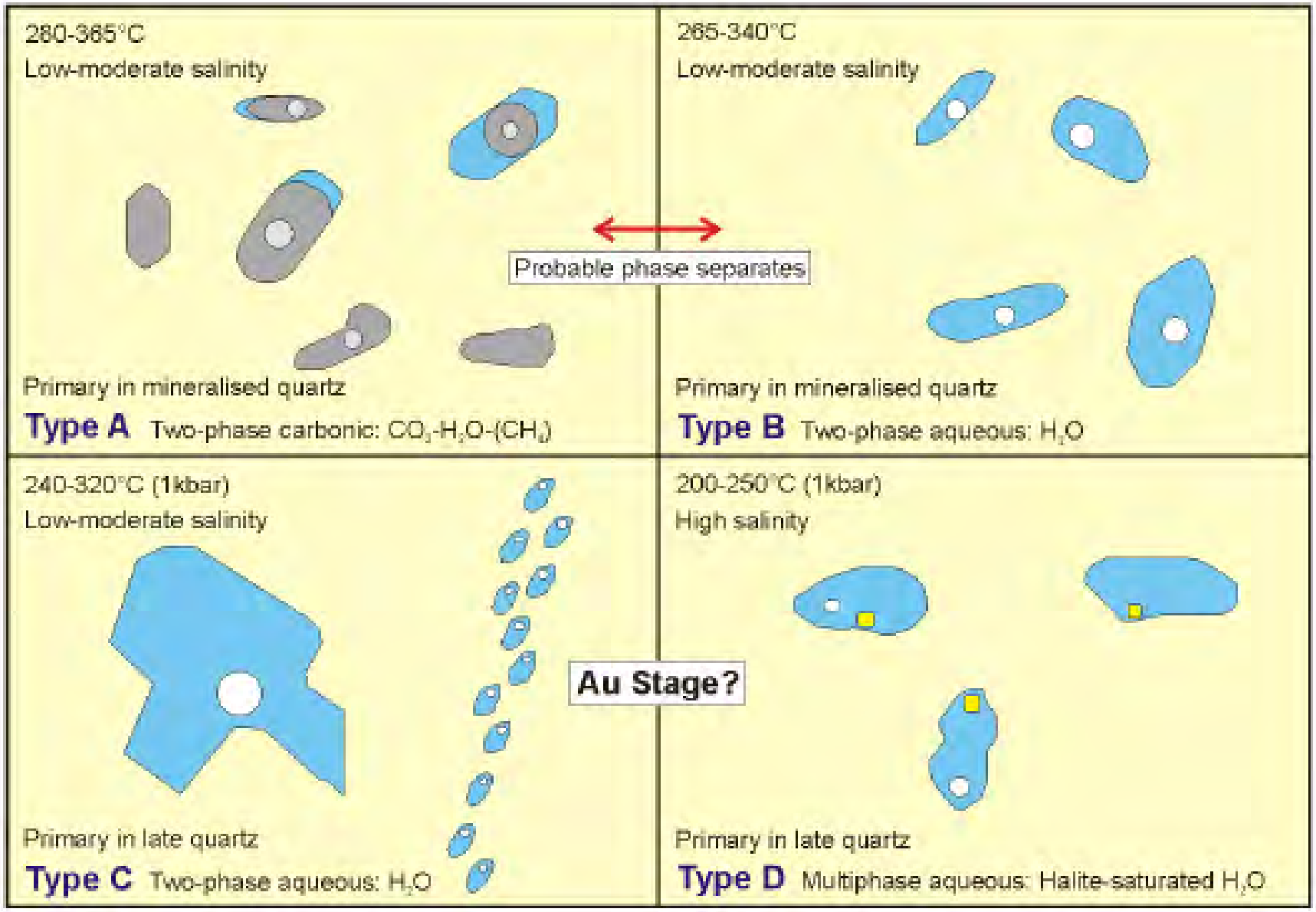


COMPARISON

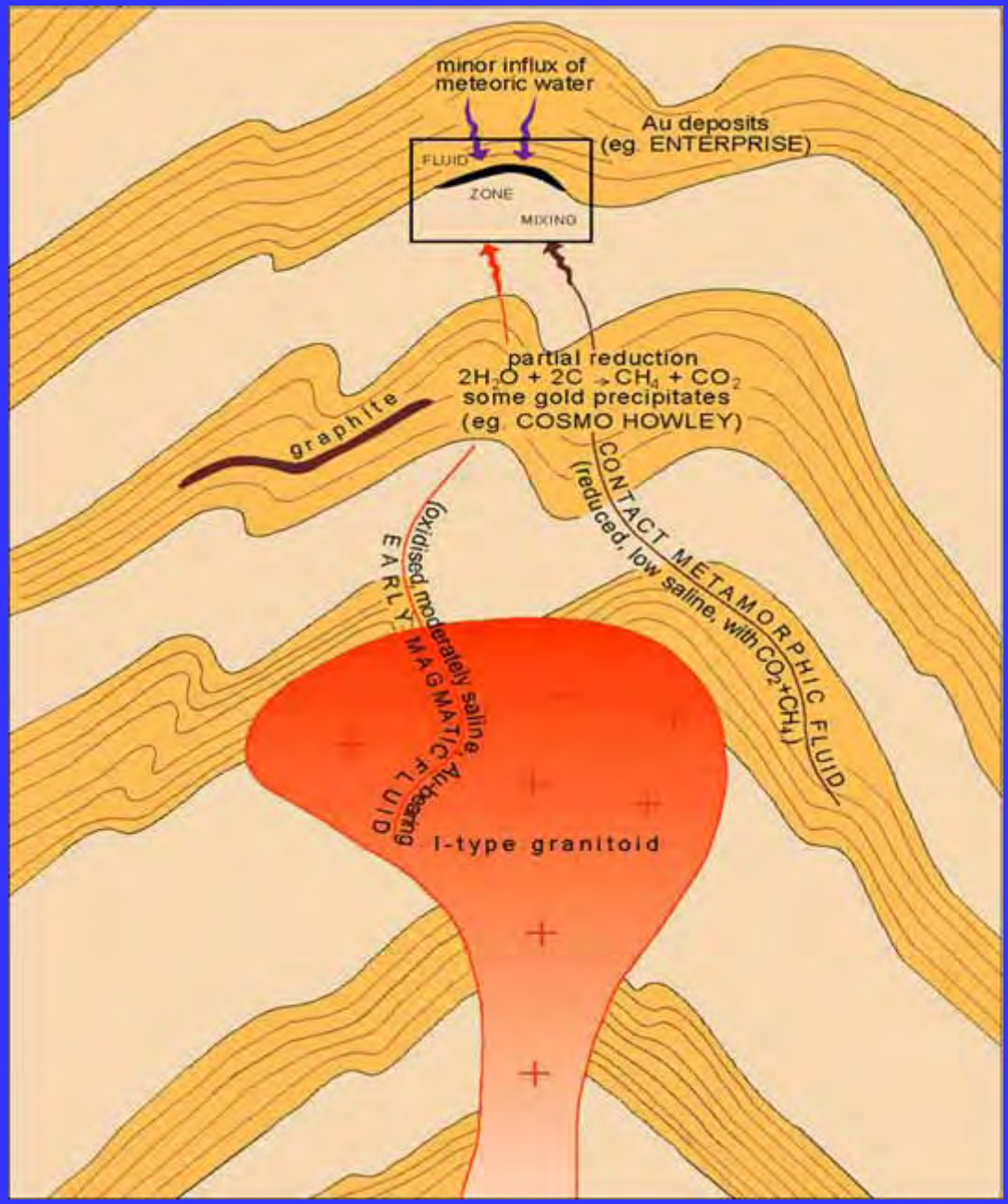
WESTERN PCO	CENTRAL PCO	S ALLIGATOR	E ALLIGATOR
•Metamorphic grade increases westward from lower greenschist to amphibolite; superimposed thermal metamorphism •Predominantly S-type granites dated at ~ 1850 Ma •Over 150 known Sn-Ta bearing pegmatites	•Sub greenschist ; superimposed thermal metamorphism •2500 Ma Archaean Inliers •Predominantly I-Type ~1825 Ma old granites •Most gold deposits •Rum Jungle uranium deposits •Browns Pb-Cu-Ni-Co-Zn •Batchelor magnesite	Sub greenschist facies; grade increasing eastward; superimposed thermal metamorphism •Predominantly I-Type ~1825 Ma subvolcanic high level plutons •Small uranium-gold occurrences •Coronation Hill Au-Pt-Pd	•Amphibolite-granulite facies regional metamorphism •Archaean basement •Unconformity type uranium deposits some with Au-Pt-Pd •Region is mainly explored for uranium •Prospective for other commodities

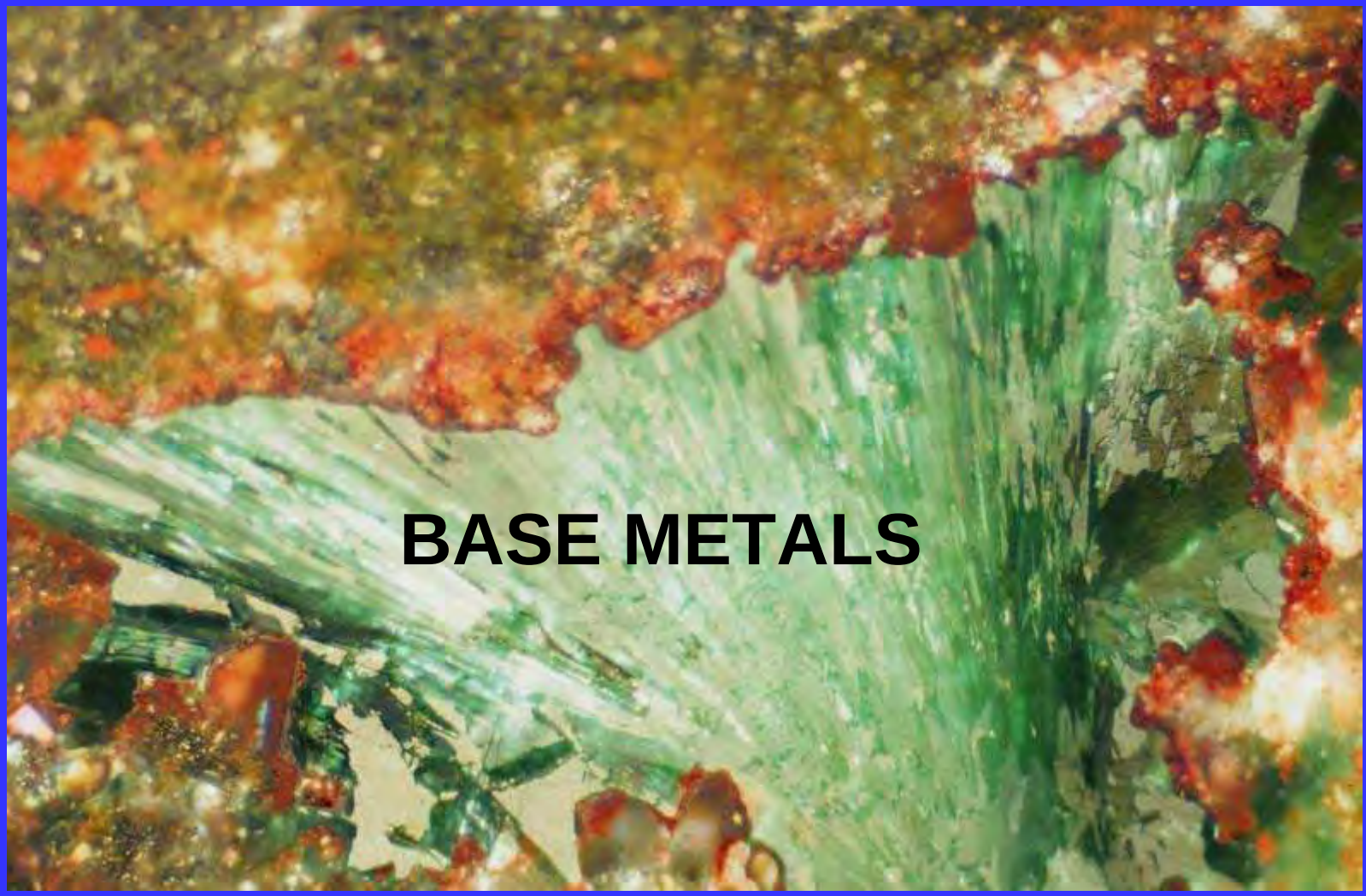



Burrell Creek Fm
Mount Bonnie Fm
Geromie Tuff
Koolpin Fm
Maud Creek
Mount Todd
Goodall
Union Reefs
Enterprise
Spring Hill
Rustlers Roost Group
Woolwonga
Brocks Creek
Big Howley
Chinese Howley
Cosmo Howley
Bons Rush
Toms Gully
Lithologies
Granite
Dolerite
Greywacke
Shale and siltstone
Dolomitic carbonaceous shale
Tuff
Carbonaceous shale
Iron-formation
Mineralisation Styles
Stockwork and vein array
Brittle-fractures
Saddle reefs and stockworks
Shear-zone hosted
Stratiform

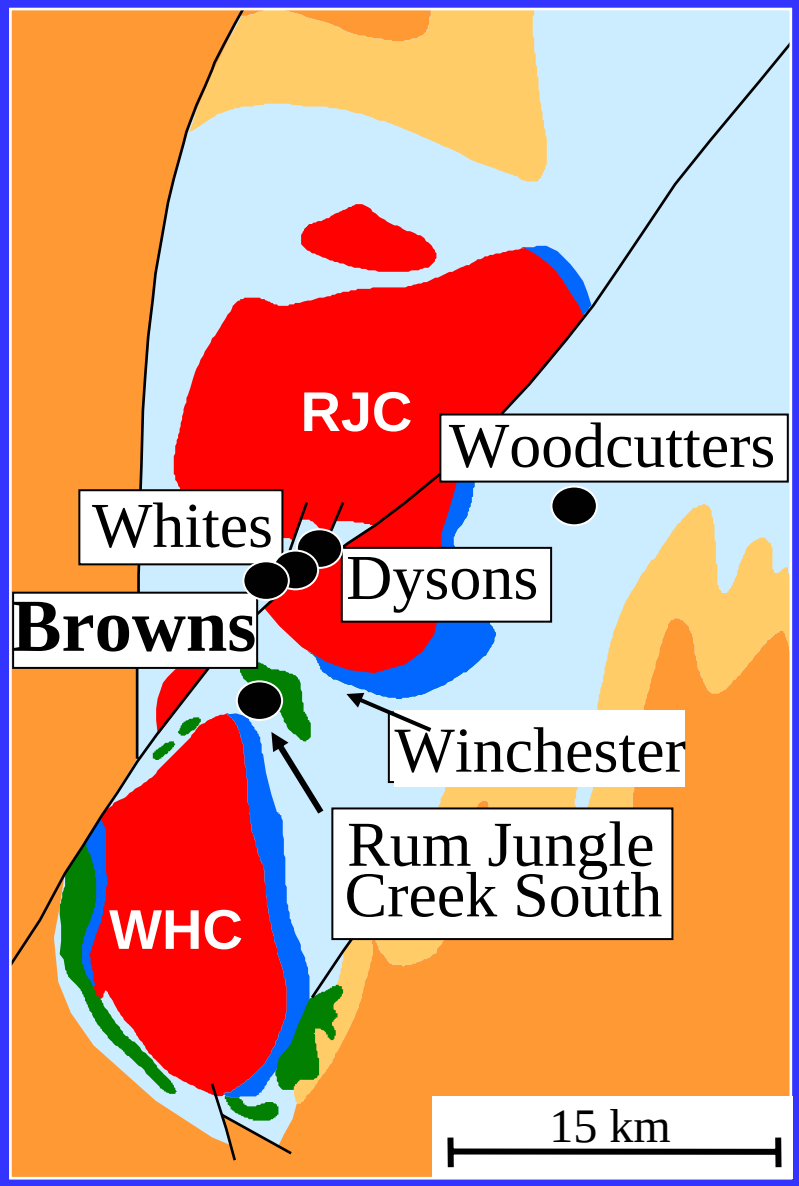

280-365°C
Low-moderate salinity
Primary in mineralised quartz
Type A Two-phase carbonic: CO_2-H_2O-(CH_4)
265-340°C
Low-moderate salinity
Probable phase separates
Primary in mineralised quartz
Type B Two-phase aqueous: H_2O
240-320°C (1kbar)
Low-moderate salinity
Au Stage?
Primary in late quartz
Type C Two-phase aqueous: H_2O
200-250°C (1kbar)
High salinity
Primary in late quartz
Type D Multiphase aqueous: Halite-saturated H_2O
H_2O_L
H_2O_V
CO_{2L}
CO_{2V}
NaCl
Quartz
10μm

GENETIC PARAMETERS	RESULTS	REMARKS
Spatial association	Proximal to ~1825 Ma Cullen Supersuite Granites & most are within the thermal aureole	A genetic link with granites is possible
Fluid Inclusions	High concentration of CO_2 andCH_4 Halite saturation High Ca, Mg	Possibly metamorphic Possible igneous link Possible metamorphic source
Hydrogen and oxygen isotopes	$\delta^{18}O$ H_2O: 3 to 12‰ δD Fluid inclusions: -50 to -85‰	Possible magmatic Possible mixed magmatic or metamorphic
Sulphur isotopes	$\delta^{34}S$ sulphides 0.5 to 15‰, generally 5±5‰	Possible magmatic source
Carbon isotopes	$\delta^{13}C$ Fluid inclusion +1 to -32‰	Interaction with carbonaceous rocks
U-Pb dating	Cosmo Howley 1820±110Ma lead isotope, Cosmo Howley 1810±10Ma monazite Mount Todd 1854±16Ma monazite Mount Todd 1819±8Ma xenotime Goodall 1727±11Ma monazite Union Reefs 1698±18Ma xenotime	Can be linked to granitic Can be linked to granite Can be linked to granite Can be linked to granite Can be linked to granite Possible age of alteration Possible age of alteration


minor influx of
meteoric water
Au deposits
(eg. ENTERPRISE)
FLUID
ZONE
MIXING
partial reduction
$2H_2O + 2C \rightarrow CH_4 + CO_2$
some gold precipitates
(eg. COSMO HOWLEY)
graphite
CONTACT METAMORPHIC FLUID
(reduced, low saline, with CO_2+CH_4)
EARLY MAGMATIC FLUID
(oxidised moderately saline
Al-bearing
I-type granitoid


BASE METALS

Mineralisation in Rum Jungle



Base metals:

Woodcutters

fault-controlled stratabound mineralisation

4.65Mt @ 12.28% Zn, 5.65% Pb & 87g/t Ag

Browns

Sheet like orebody parallel to bedding

Browns 40Mt @ 4.53% Pb, 0.49% Cu, 0.1% Co, 0.09% Ni & 13g/t Ag

Browns East 3.5 Mt @ 1.295 Cu, 1.28% Pb, 0.13% Co, o.13% Ni, 11 g/t Ag

Also: Whites, Intermediates, Area 55

Uranium:

Vein/unconformity-type uranium

0.66 Mt at 0.425% U_3O_8

Also: Rum Jungle Creek, Dysons

Magnesite:

Stratabound/stratiform magnesite

16.6 Mt 43% MgO

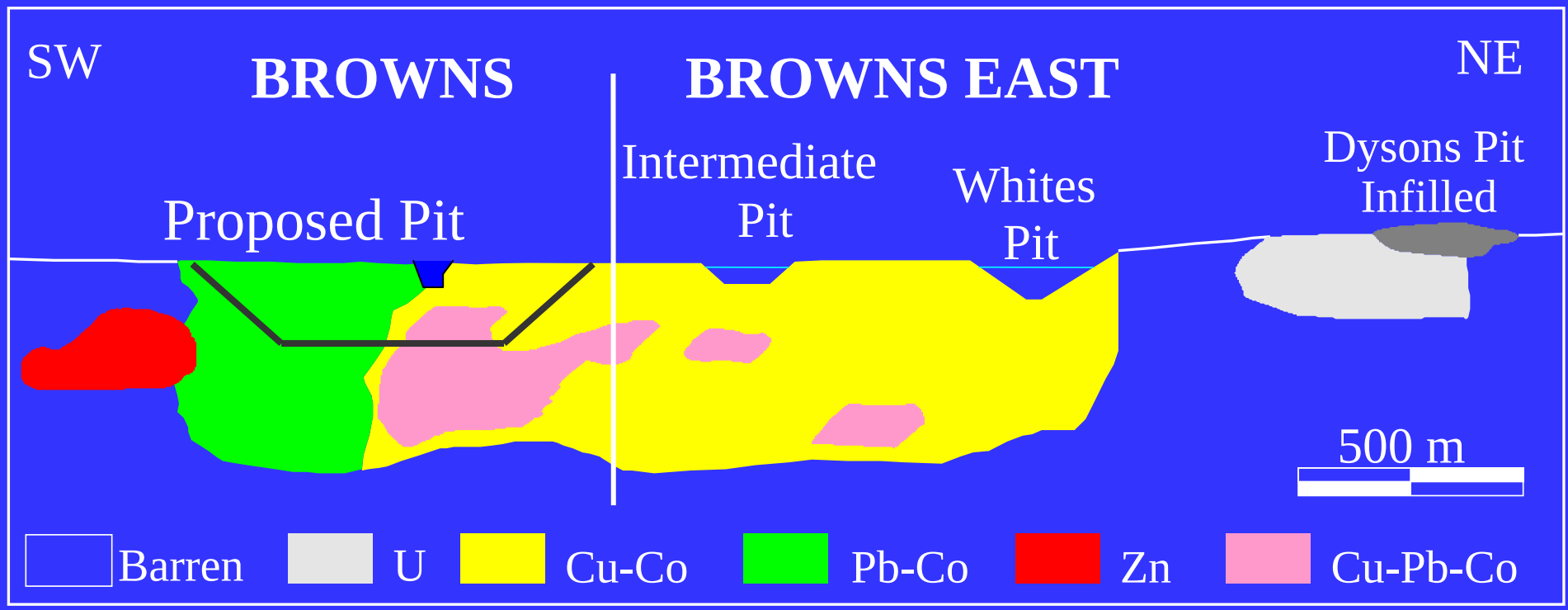
Also: various other deposits

Browns to Dyson L section

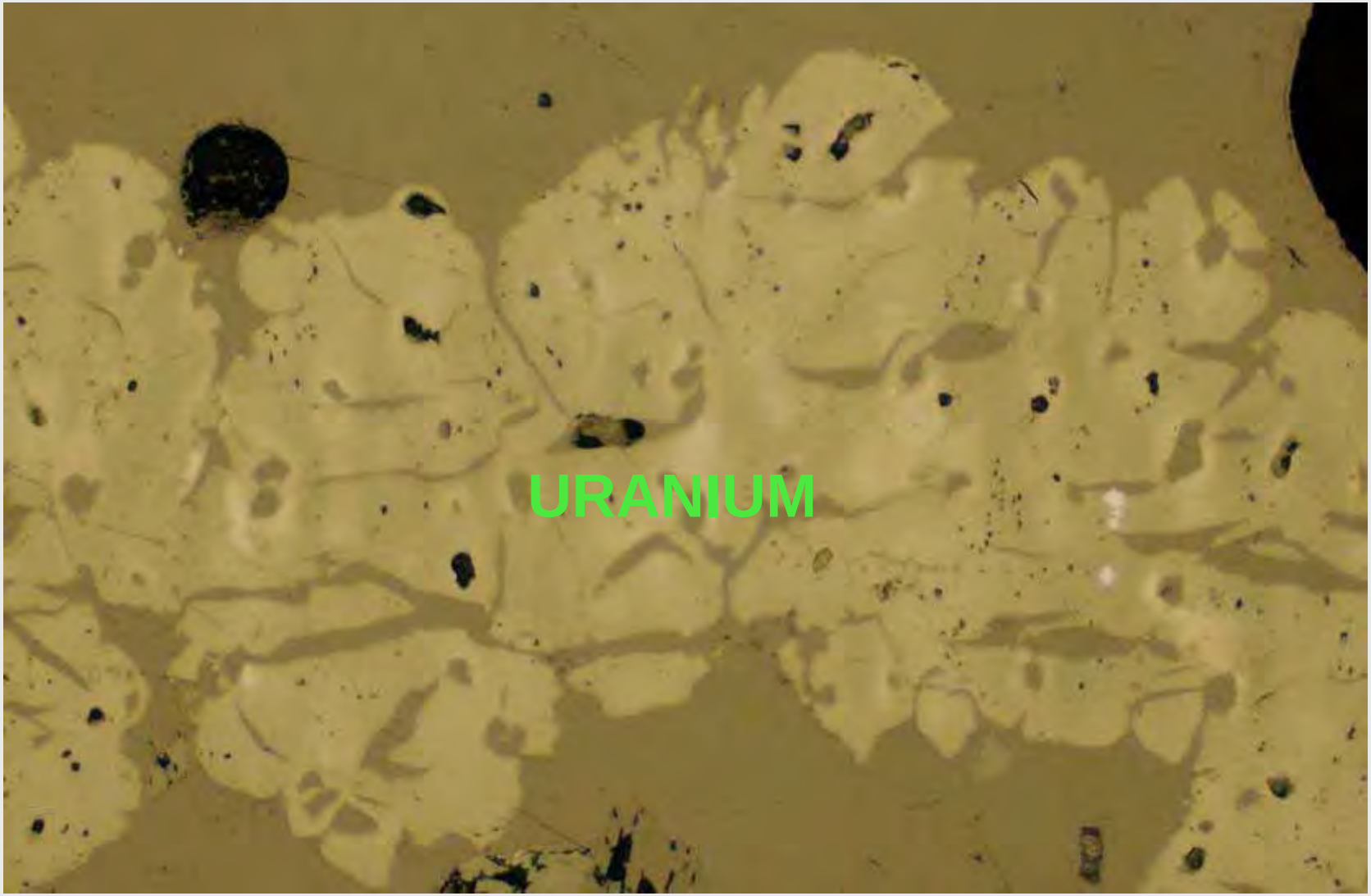
Details: zoned polymetallic mineralization, extending over 2km in length

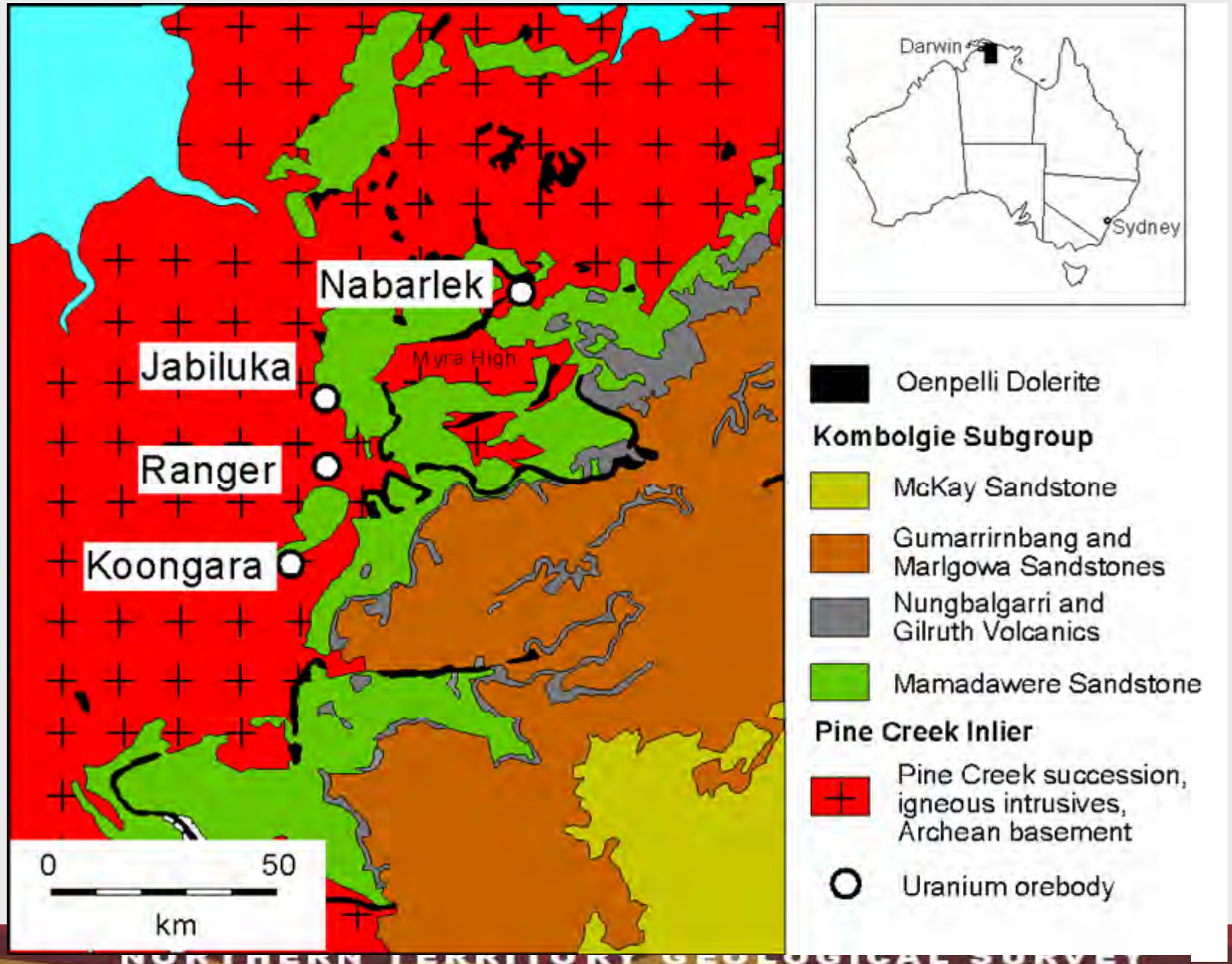
Grade: 70Mt @ 2.59% Pb, 0.81% Cu, 0.12% Co, 0.11% Ni & 10g/t Ag

Structure: southerly steeply-dipping sheet-like orebody, but near surface rolls over in a fold

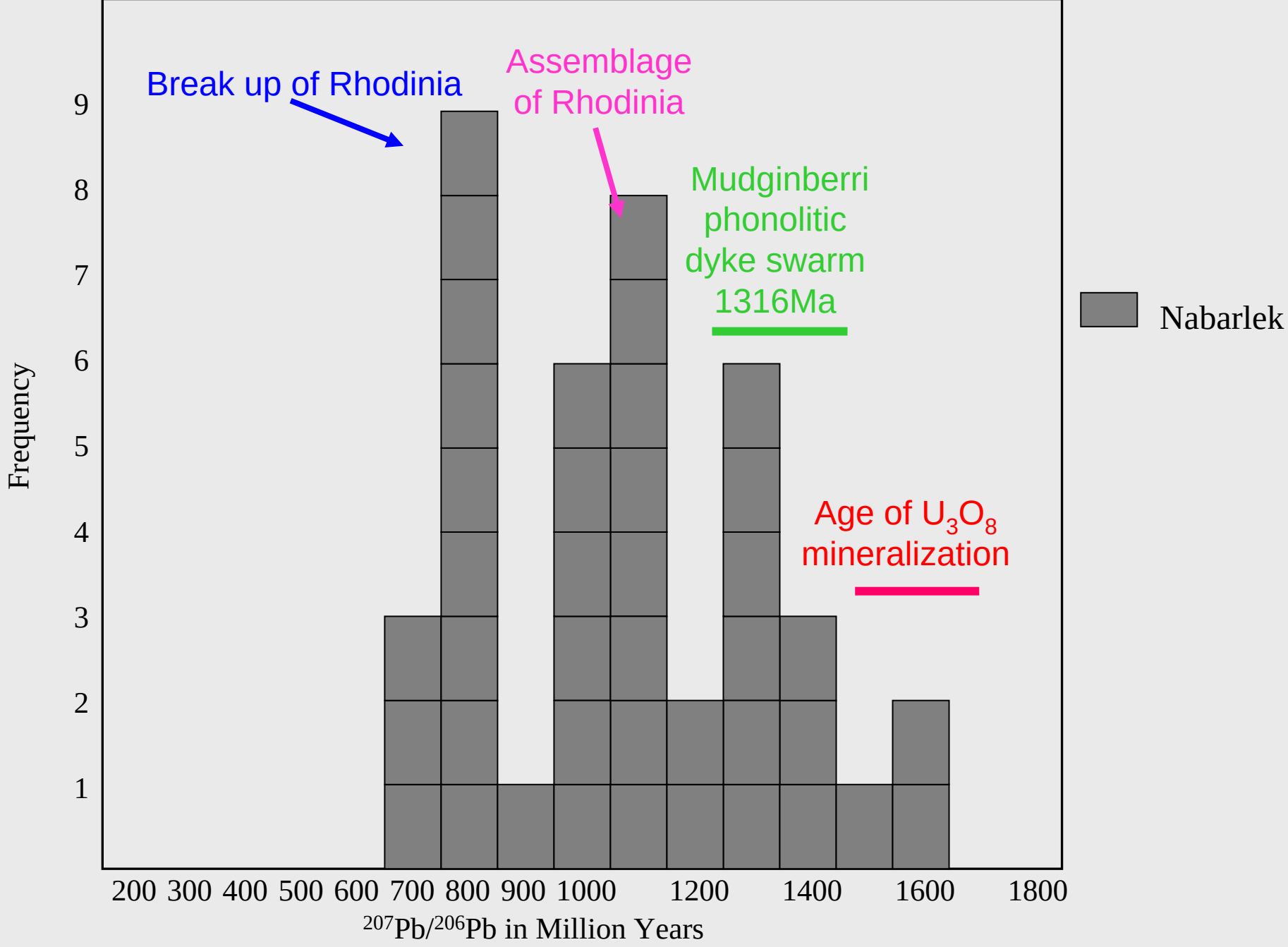


GENETIC PARAMETER	RESULTS	REMARKS
Main Metals and Minerals	Cu-Pb-Zn-Co-Ni Chalcopyrite, galena, sphalerite, siegenite, pyrite	Possible source may be underlying arenites and carbonates
Spatial association	Proximal to ~2500 Ma Archaean granite gneiss but in rocks about 300 Ma younger	Not specifically related to granite
Fluid Inclusions	High concentration of CO_2 andCH_4 ~ 23% eq NaCl 130-160^oC	Possibly metamorphic Possible saline brines Possible heated waters
Host Rock Setting	Black graphitic-pyritic shale Carbonate in the footwall Intracratonic rift basin, intertidal to anoxic subtidal conditions	Possibly syngentic or syndiagentic origin of base metal
Sulphur isotopes	Highly variable: $\delta^{34}S$ sulphides -5 to +15‰	Possible inorganic/organic sulphate reduction
Lead Isotopes	Variable but yield ages 500 Ma younger than the enclosing sediments. There is no difference between coarse cross cutting vein sulphides and stratiform sulphides	Possibly derived from the metasediments or Archaean basement

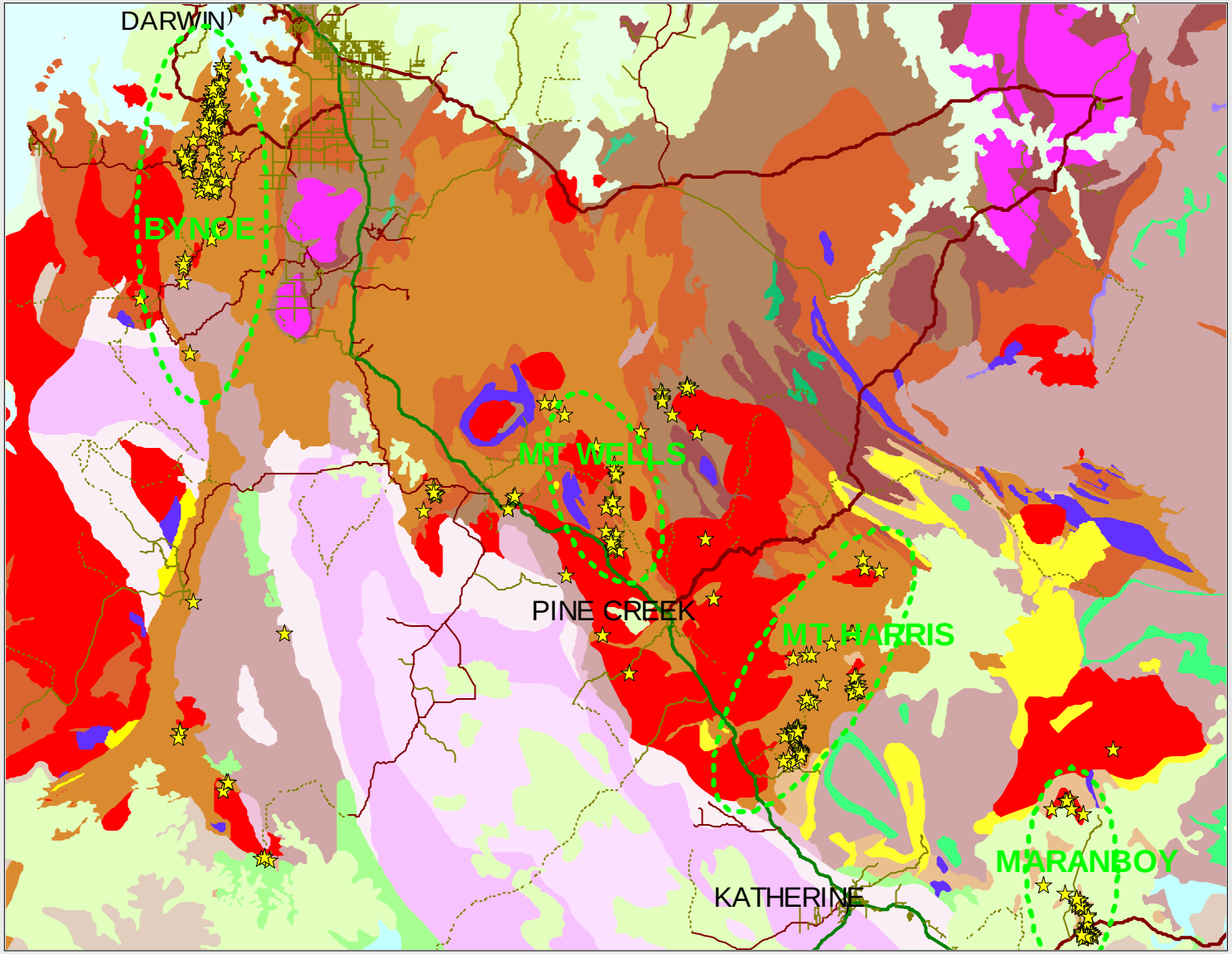

URANIUM


Darwin
Sydney
Nabarlek
Jabiluka
Myra High
Ranger
Koongara
0
50
km
Oenpelli Dolerite
Kombolgie Subgroup
McKay Sandstone
Gumarrirnbang and Marlgowa Sandstones
Nungbalgarri and Gilruth Volcanics
Mamadawere Sandstone
Pine Creek Inlier
Pine Creek succession, igneous intrusives, Archean basement
Uranium orebody

NORTHERN TERRITORY GEOLOGICAL SURVEY

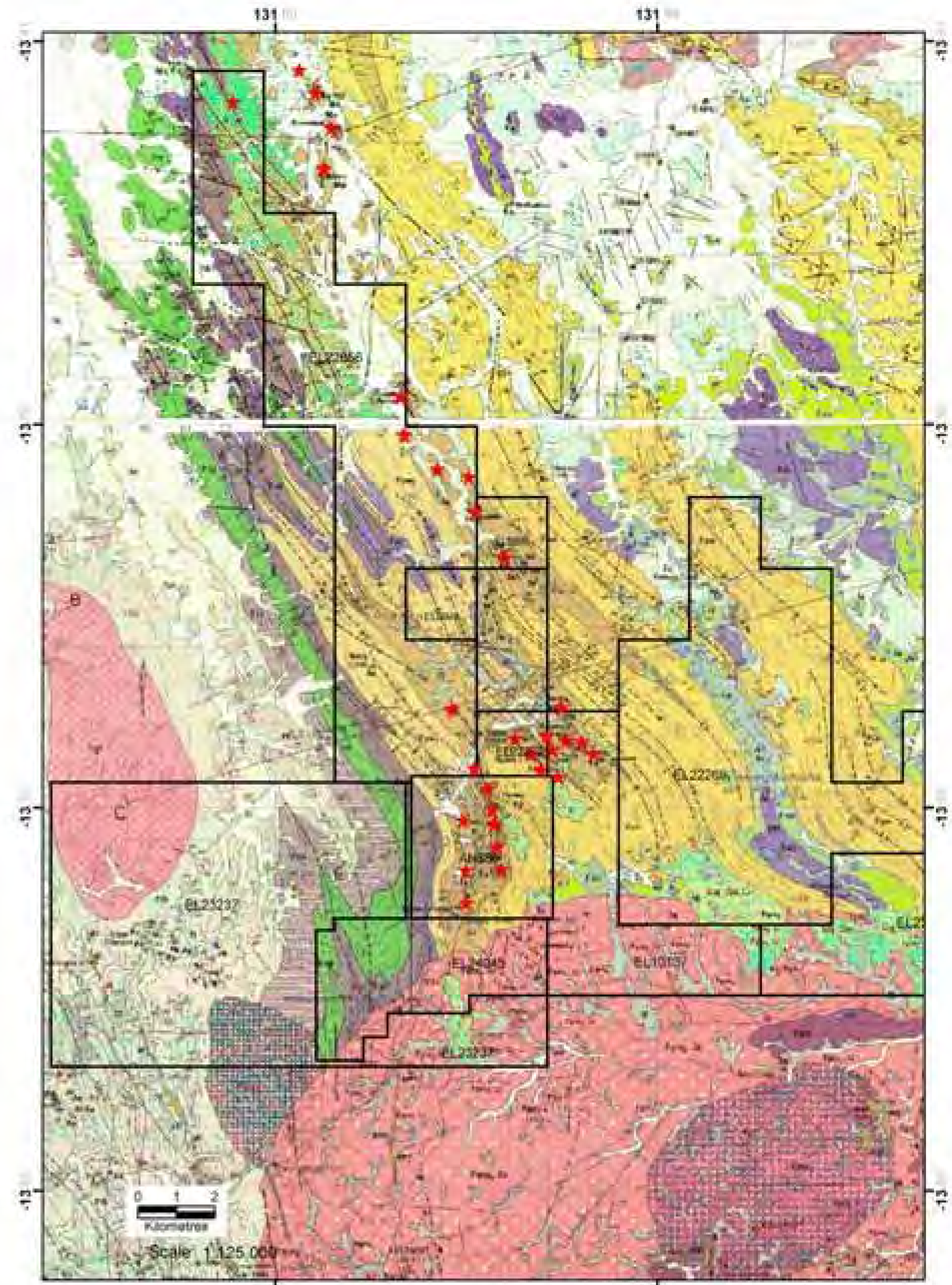

Break up of Rhodinia
Assemblage of Rhodinia
Mudginberri phonolitic dyke swarm 1316Ma
Age of U_3O_8 mineralization
Nabarlek
Frequency
1
2
3
4
5
6
7
8
9
200 300 400 500 600 700 800 900 1000 1200 1400 1600 1800
$^{207}Pb/^{206}Pb$ in Million Years

GENETIC PARAMETER	RESULTS	REMARKS
Main Metals	U±Au±PGE	Possible source may be oxidised arenites
Spatial association	Proximal to the underlying Archaean granite complexes and ~1730 Ma arenites of the basal McArthur Basin; unconformity at top and bottom	Metal source may be Archaean, basal PCO sediments or basal McArthur arenites
Fluid Inclusions	High concentration of CO_2 andCH_4, solid inclusions of NaCl, Hematite, chlorite, dolomite and chlorite Temp 100-160^{o}C	Relationship of inclusions to uranium mineralisation is uncertain
Host Rock Setting	Black graphitic shale; Carbonate in the foot wall; sandstone in the hanging wall; Intracratonic rift basin, intertidal to anoxic subtidal conditions	Possibly syngentic or syndaigentic precipitation of uranium precursor
Sulphur isotopes	Host rock sulphides: $\delta^{34}S$ ~2.2‰ Ore zone sulphides: $\delta^{34}S$ -6 to +7‰	No bacterial sulphate inorganic/organic sulphate reduction
Oxygen & Hydrogen Isotopes	$\delta^{18}O$ fluid: +1 to + 5‰ δD fluid: -15 to -35 ‰	Possible modified meteoric water


DARWIN
BYNOE
MT WELLS
PINE CREEK
MT HARRIS
MARANBOY
KATHERINE

GENETIC PARAMETER	RESULTS	REMARKS
Main Metals	Sn, Ta, W	
Spatial association	Proximal to the 1865-1840 Allia Creek Suite S-type granites in the Bynoe area and to the fractionated reduced I (granodiorite) type phases of the Cullen Supersuite in the Central PCO	Granitic metal source
Fluid Inclusions	High concentration of CO_2 andCH_4, solid inclusions of NaCl, Hematite, chlorite, dolomite and chlorite Temp 100-380^{o}C, Bimodal salinity modes at at 4-12% and 28-36% eq NaCl	Both magmatic and metamorphic fluids are present
Geochronology	SHRIMP Cassiterite 1717, 1754, 1762 and 1702 Ma SHRIMP Tantalite 1723 Ma Ar-Ar Muscovite 1727 and 1681 Ma	Significance of these ages is not clear.
Oxygen & Hydrogen Isotopes	$\delta^{18}O$ fluid: +5.6 to + 8.6‰ δD fluid: -19 to -55 ‰	Possible magmatic source


IRON


131
131
-13
-13
-13
-13
EL23237
EL1013
0 1 2
Kilometres
Scale 1:125,000

SUMMARY

- GOLD: Possibly intrusion related; mixing of magmatic and metamorphic fluids; I-type granite event at ~1825 Ma.
- POLYMETALLICS: Possible syngenetic in black shale but significant later remobilasition.
- URANIUM: Meteoric water leaching either from the hanging wall arenites or from the underlying Archaean or basal PCO arenites.
- TIN-TANTALUM: undoubtedly associated with S-type granitoids.
- Iron: Sedimentary modified by hydrothermal processes

WHAT MAKES PCO DIFFERENT FROM OTHER OROGENIC DOMAINS OF THE NORTH AUSTRALIAN CRATON

	McARTHUR BASIN	VICTORIA BIRRINDUDU	DAVENPORT ASHBURTON	SOUTH NICHOLSON	AILERON	WARUMPI	MUSGRAVE	Age Ma
P9	Roper	Auvergne	Renner	Nicholson			Tjauwata Musgravian	1200
P8	Nathan	Wattie -Bullita		Doomadgee G		Chewings		
P7	McArthur	Limbunya	Namerini	Fickling		Liebig Maddern Yard Yaya		1650
P6	Katherine River	Birrindudu	upper Hatches Creek	Peters Creek Volcanics	Strangways Reynolds Range			1730
	PINE CREEK	TANAMI	WARRAMUNGA	MURPHY				
P5	Cullen Edith River ElSherana	Tanami Ware Killi Killi	Murchison Event Oooradigee Flynn	Nicholson Cliffdale Volcanics	Stafford Lander Rock			1825
P4	Nimbuwah Finniss River	Dead Bullock	Tennant Event Warramunga	Murphy Mtm				1845
P3	South Alligator	????	????					1860
P2	Mt Partridge							2025
P1	Namoona							

THANK YOU