Using geochemistry to assess the untapped critical minerals potential of South Australia's deposits

Sediment-hosted copper deposits of the Mount Gunson district

Mirella Terrones, Adrian Fabris and Carmen Krapf

Geological Survey of South Australia

SOUTH AUSTRALIA

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Department for Energy and Mining

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As guests on Aboriginal land, the Department for Energy and Mining (DEM) acknowledges everything this department does impacts on Aboriginal country, the sea, the sky, its people, and the spiritual and cultural connections which have existed since the first sunrise. Our responsibility is to share our collective knowledge, recognise a difficult history, respect the relationships made over time, and create a stronger future. We are ready to walk, learn and work together.

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Content

Sampling at the South Australia Drill Core Reference Library at Tonsley – 2023

Associated data

- Complementary information
  - Critical minerals project overview.pdf
  - Sampling strategy overview.pdf
- LA-ICP-MS_Mt Gunson
  - Laser Ablation Photos
  - Sulphides_LA-ICP-MS_MtGunson.csv → LA-ICP-MS data
- Legacy data
  - Correlation_drillhole_legacydata_Moutn Gunson district.JPG → Elemental correlation of legacy data
  - Mount Gunson District_legacydata_export. 13_06_23.xlsx → Legacy geochemistry
- MLA_Mt Gunson
- New data
  - Integrating CM geochemistry_Mount Gunson.xls → New geochemistry, lithology, stratigraphy and mineralisation
- AusImm CM Conference poster - Mirella Terrones_MtGunson.pdf
- MLA and LA-ICP-MS.pdf
  - MLA and LA-CIP-MS presentation → MLA analysis and LA-ICP-MS of 6 samples
  - Poster presentation AusImm Critical Minerals Conference, Perth 2023: *Old mines - new potential: Assessing the Mount Gunson mineral district for critical minerals, South Australia*

Click to download the associated data zip file (495 MB).

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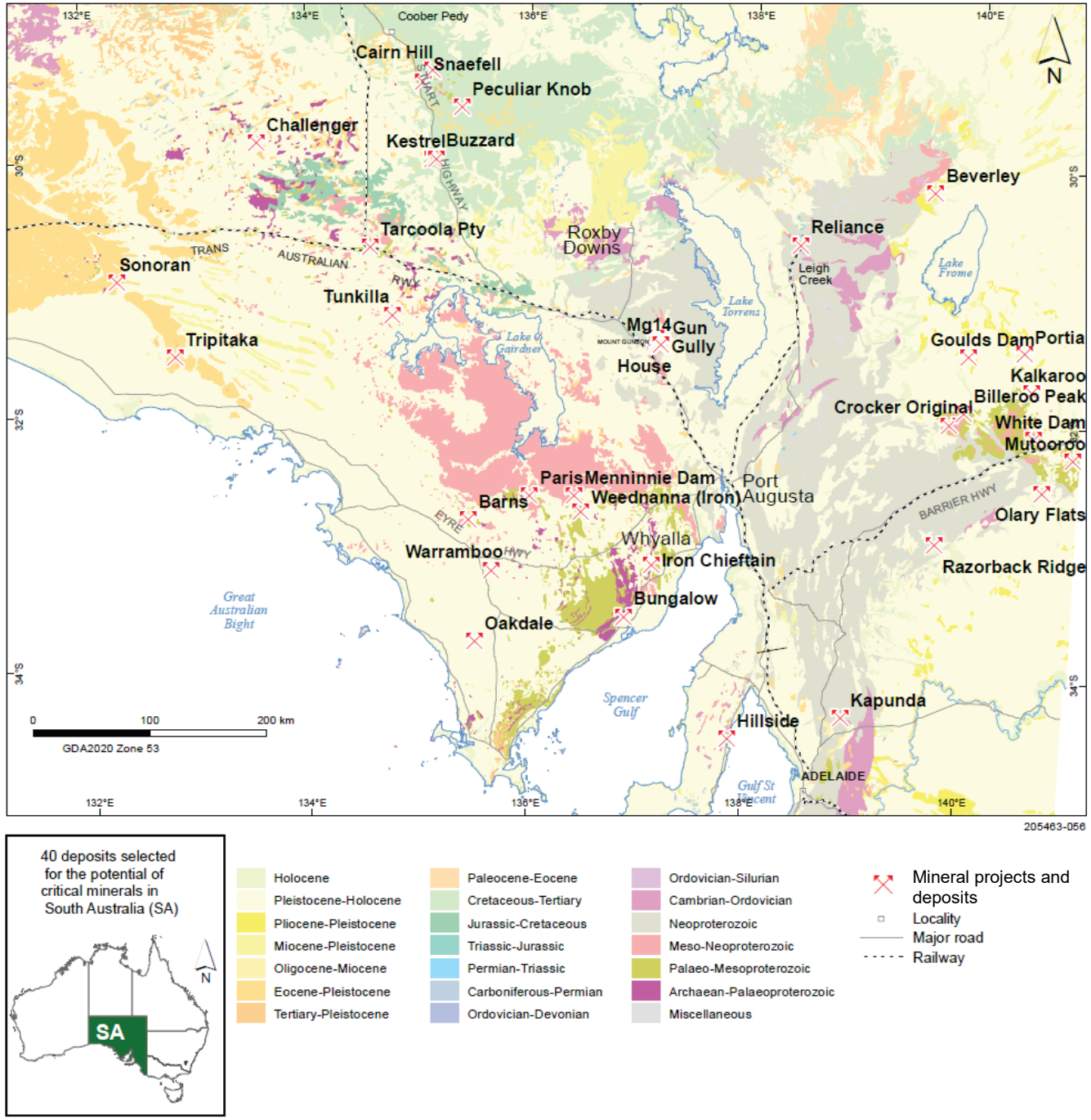
Critical Minerals South Australia – project overview

Historically, geochemical data collected from drillholes by explorers in the State comprised only drill core assays of the targeted commodity or commodities, thus the potential for other critical minerals in existing deposits remains unknown. For this reason, re-sampling and re-assaying of existing drill core from all major projects in South Australia was undertaken to assess their multi-commodity critical mineral prospectivity.

A total of 40 deposits were selected representing a variety of mineralisation styles to better define critical mineral potential across South Australia using historic company records and sampling drillholes from the South Australian Drill Core Reference Library in Tonsley.



Sampling strategy

Sample selection from drill core focused largely on the mineralised zone of the selected deposit as it is more likely to host elevated concentrations of critical minerals.

Mineralisation and alteration was logged and characterised to better understand and interpret the newly collected geochemical data and to better understand mineral paragenesis.

Further information on the sampling strategy see here.

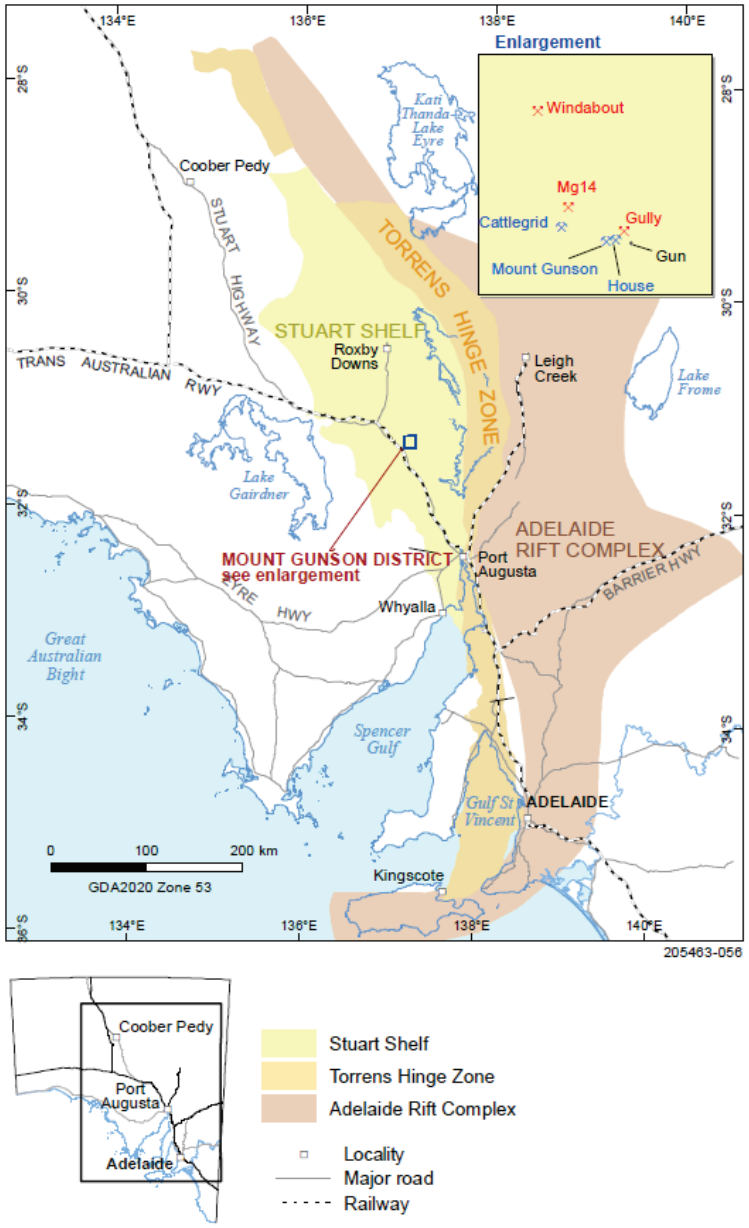
Sampling at the South Australia Drill Core Reference Library at Tonsley – 2023

Sediment-hosted copper deposits of the Mount Gunson district

Introduction

- Mount Gunson district is located in the Stuart Shelf overlying the eastern Gawler Craton, ~450 km north of Adelaide, ~145 km north-northwest of Port Augusta and ~110 km south of Olympic Dam.
- Has seven mineral deposits: Windabout, Mg14, Cattlegrid, Mount Gunson, Gun, Gully, and House (see map).
- Copper ore was discovered in 1875 and first production started by CSR Limited in 1899 at Mount Gunson deposit with an average grade of 1.7% Cu.
- Sporadic mining over the last 130 years has seen significant volumes of copper and cobalt extracted.
- Use link Quick Search (sarig.sa.gov.au) and Deposit number (MinDep) for further information:

Deposit name	Deposit number (MinDep)	Status
Windabout	3140	Deposit. Not worked
Mg14	3090	Depost. Not worked
Cattlegrid	3051	Deposit. Seasonal
Mount Gunson	3088	Deposit. Seasonal
Gun	3071	Occurrence. Abandoned
Gully	3034	Deposit. Not worked
House	3080	Deposit. Abandoned



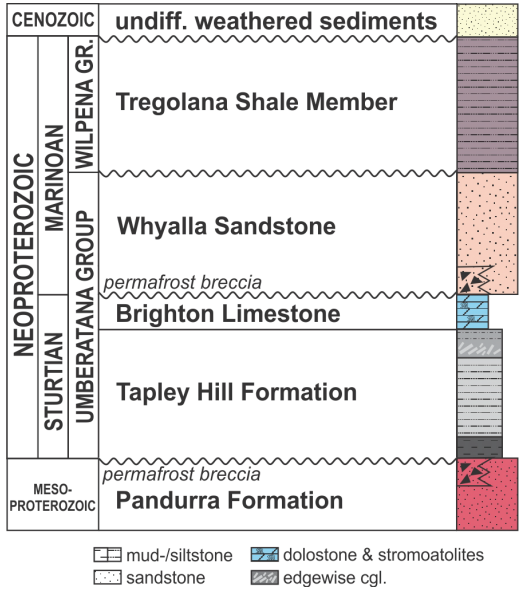
Location of the seven deposits of the Mount Gunson district.

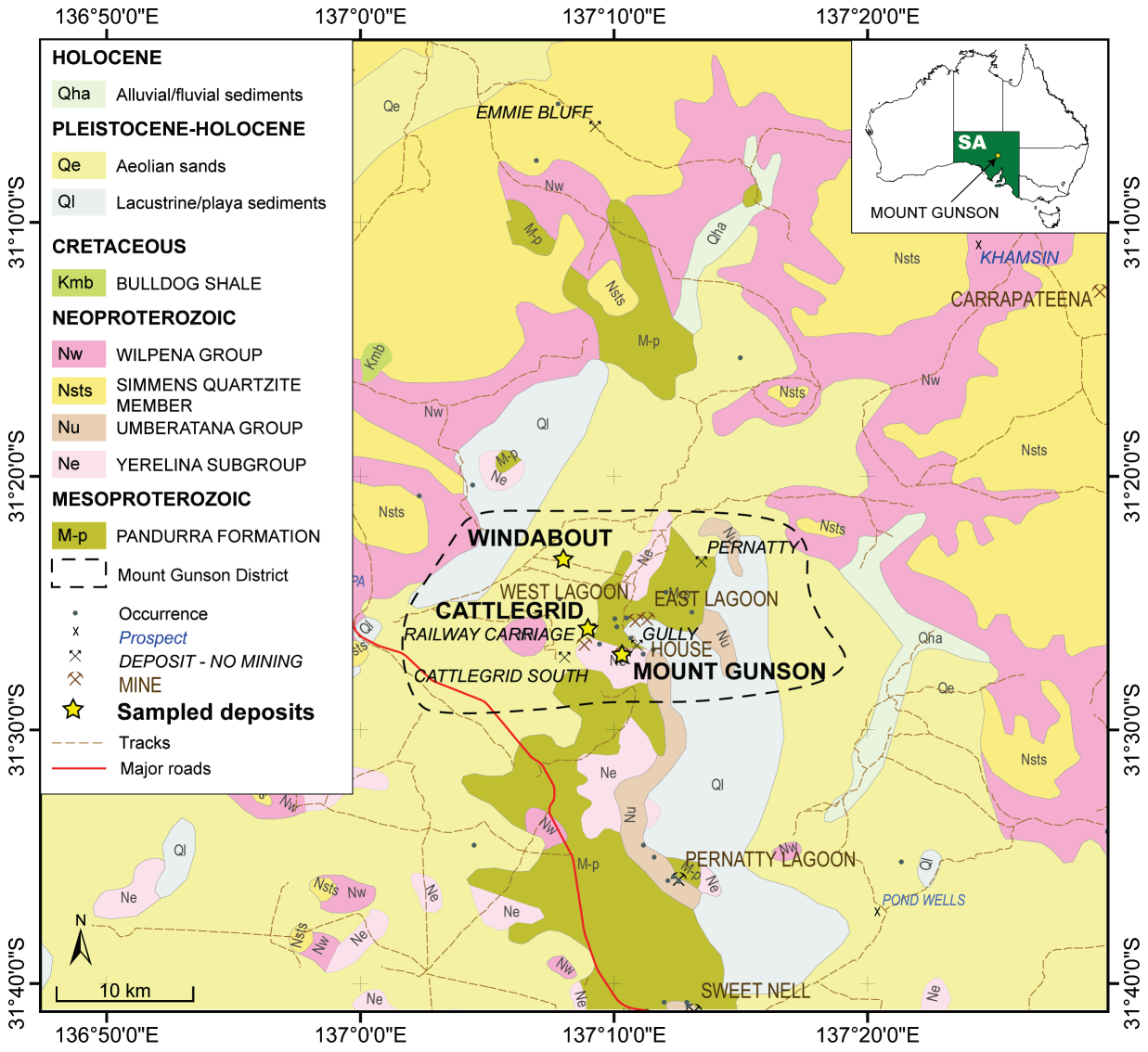
Sediment-hosted copper deposits of the Mount Gunson district

Introduction

- Mount Gunson district hosts several sediment-hosted copper deposits within Neoproterozoic sediments of the Stuart Shelf, Adelaide Superbasin (see map).
- Most of the area is covered by aeolian sands.
- The main host of the mineralisation is the Mesoproterozoic Pandurra Formation overlain by younger Neoproterozoic units.

Stratigraphic units logged and sampled





Local geology of the Mount Gunson district in the central Stuart Shelf, south of the Emmie Bluff prospect and Carrapateena copper deposit.

Sediment-hosted copper deposits of the Mount Gunson district

Resource information

- Cattlegrid is owned and operated by A&MJ Musolino since 2000. This deposit has the highest production in the Mount Gunson district with 7.2 Mt at 1.7% Cu and 3.3.g/t Ag.
- Head grade for ore delivered to the concentrator was about 2.0% Cu.
- Typical copper concentrate assayed are: 44.8% Cu, 10.6% Zn, 2.6% Pb, 1.0% Co, 0.15% Bi and 0.08% Ni.
- Production at Mount Gunson main pit was 830,000 t at 1.6% Cu.

Cattlegrid – Cu-Co-Ag-Zn-Bi

****Cattlegrid Production**

1974 - 1986		
Mt	Cu %	Ag g/t
7.2	1.7	3.3

****Cattlegrid Indicated Resources**

Cu Eq > 0.2 % cut off			
Mt	Cu %	Co ppm	Ag g/t
1.6	0.66	100	2

**Mount Gunson - Pernatty. Quarterly and annual reports for the period 14/2/87 to 15/4/94.', South Australia

Mount Gunson – Cu-Co-Zn

***Main Open pit Mount Gunson Production**

1984 - 1990		
t	Cu %	By-product
830,000	1.6	sandstone

****Mount Gunson Indicated Resources**

Cu Eq > 0.1 % cut off		
Mt	Cu %	Ag g/t
0.33	0.51	1

*Mined by Mount Gunson Mines Co. Ltd (SARIG).
**Bampton, K.F. (2003) 'Copper mining and treatment in South Australia.

Sediment-hosted copper deposits of the Mount Gunson district

Resource information

- Highest indicated resources are from Windabout deposit with 17.67 Mt at 0.77 % Cu and 492 ppm Co with Cu Eq > 0.5% cut off.
- Mg14 has an indicated resource of 1.83 Mt at 1.24% Cu and 334 ppm Co with Cu Eq > 0.5% cut off.

Windabout – Cu-Ag-Co-Zn

***Windabout Indicated Resources**

Cu Eq > 0.5% cut off				
Mt	Cu %	Co ppm	Ag g/t	Cu Eq%
17.67	0.77	492	8	1.41

Cu Eq > 1% cut off				
Mt	Cu %	Co ppm	Ag g/t	Cu Eq%
11.86	0.95	599	10	1.73

Mg14 – Cu-Co-Ag-Zn-Bi

***Mg14 Indicated Resources**

Cu Eq > 0.5% cut off				
Mt	Cu %	Co ppm	Ag g/t	Cu Eq%
1.83	1.24	334	14	1.67

Cu Eq > 1% cut off				
Mt	Cu %	Co ppm	Ag g/t	Cu Eq%
1.59	1.33	3.60	15	1.80

*Source: Mt Gunson project mineral resources estimate, January 2018. Have been estimated according to the guidelines of the 2012 edition of the JORC Code.

- Smaller prospects that surround Mount Gunson open pit include Gully, House and Gun.
- Gully has the highest inferred resources with 5.2 Mt at 0.4% Cu and 1 g/t Ag.

Gully, House and Gun – Cu-Co-Zn

***Gully Inferred Resources**

Mt	Cu %	Ag g/t
5.2	0.4	1

****House Production**

1987 - 1990		
t	Cu %	Ag g/t
209000	1.36	3.3

***Gun Production – 1920**

t	Cu %
75	15.6% Cu

* SARIG
**Mined by Adelaide Chemical Company Limited (SARIG)

Sediment-hosted copper deposits of the Mount Gunson district

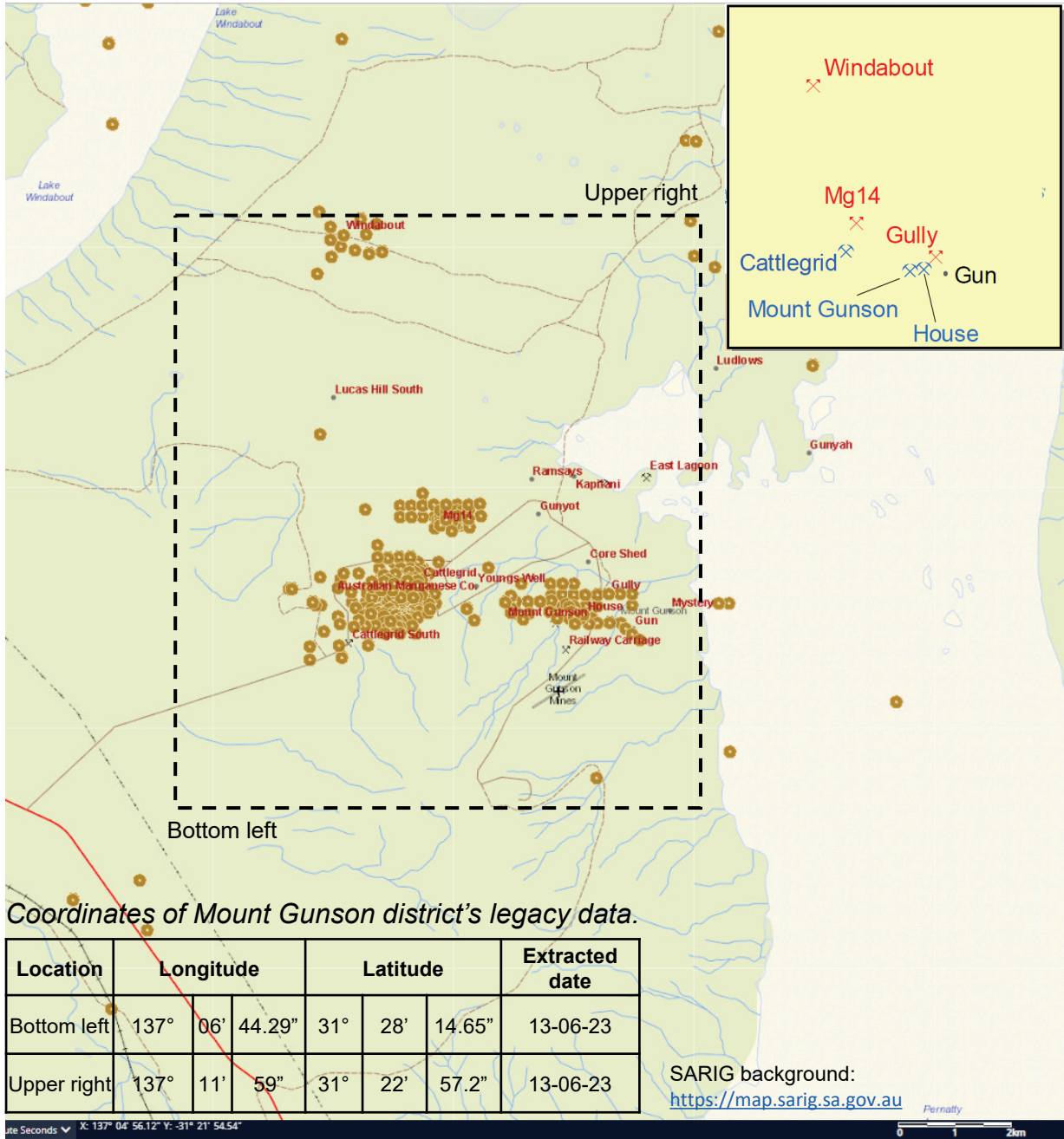
Legacy data - overview

- Only a limited suite of elements is available (major elements, and incomplete trace elements).
- Legacy data includes no information on laboratory used.
- Anomalous values of Zn, Pb, Co, Bi and Ni were identified in legacy data, but their host minerals are not well known.
- Elevated Co values are consistent with values from known sediment-hosted copper deposits (e.g. Central African copper belt).

A total of 478 drillholes were drilled at the Mount Gunson district:

- 213 drillholes available at the Core Library
- 108 drillholes have chemistry
- Drill core (DC): 8842 samples in total from 108 DHs
- Cuttings (CT): 486 samples in total
- Soil (SO): 161 samples in total

Download: See legacy data



Coordinates of Mount Gunson district's legacy data.

Location	Longitude			Latitude			Extracted date
Bottom left	137°	06'	44.29"	31°	28'	14.65"	13-06-23
Upper right	137°	11'	59"	31°	22'	57.2"	13-06-23

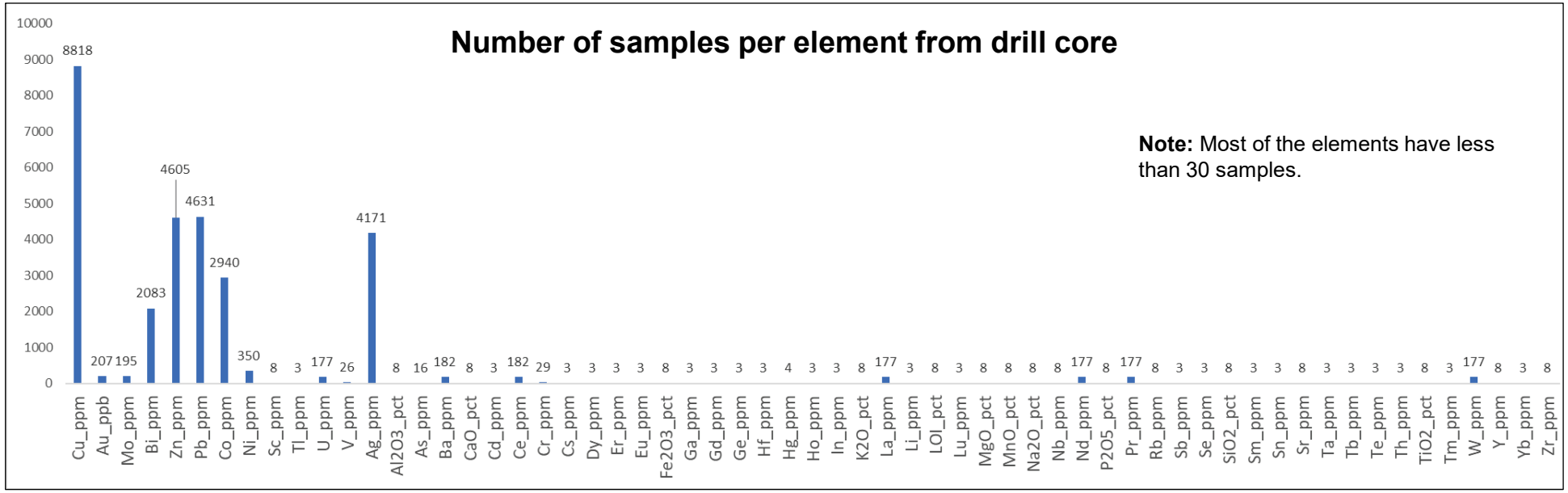
SARIG background: https://map.sarig.sa.gov.au

● Drillholes available at the South Australia Drill Core Reference Library at Tonsley

Sediment-hosted copper deposits of the Mount Gunson district

Legacy data: drill core geochemistry

- Only some method description available and no laboratory location available for analysis.
- 61 elements analysed by more than 5 methods from 1969 to 2017: Cu, Ag, Mo, Bi, Zn, Pb, Co, Ni, Sc, Tl, U, V, Ag, Al_2O_3, As, Ba, CaO, Cd, Ce, Cr, Cs, Dy, Er, Eu, Fe_2O_3, Ga, Gd, Ge, Hf, Hg, Ho, In, K_2O, La, Li, LOI, Lu, MgO, MnO, Na_2O, Nb, Nd, P_2O_5, Pr, Rb, Sb, Se, SiO_2, Sm, Sn, Sr, Ta, Tb, Te, Th, TiO_2, Tm, W, Y, Yb, and Zr (see histogram for number of samples by element).



Sediment-hosted copper deposits of the Mount Gunson district

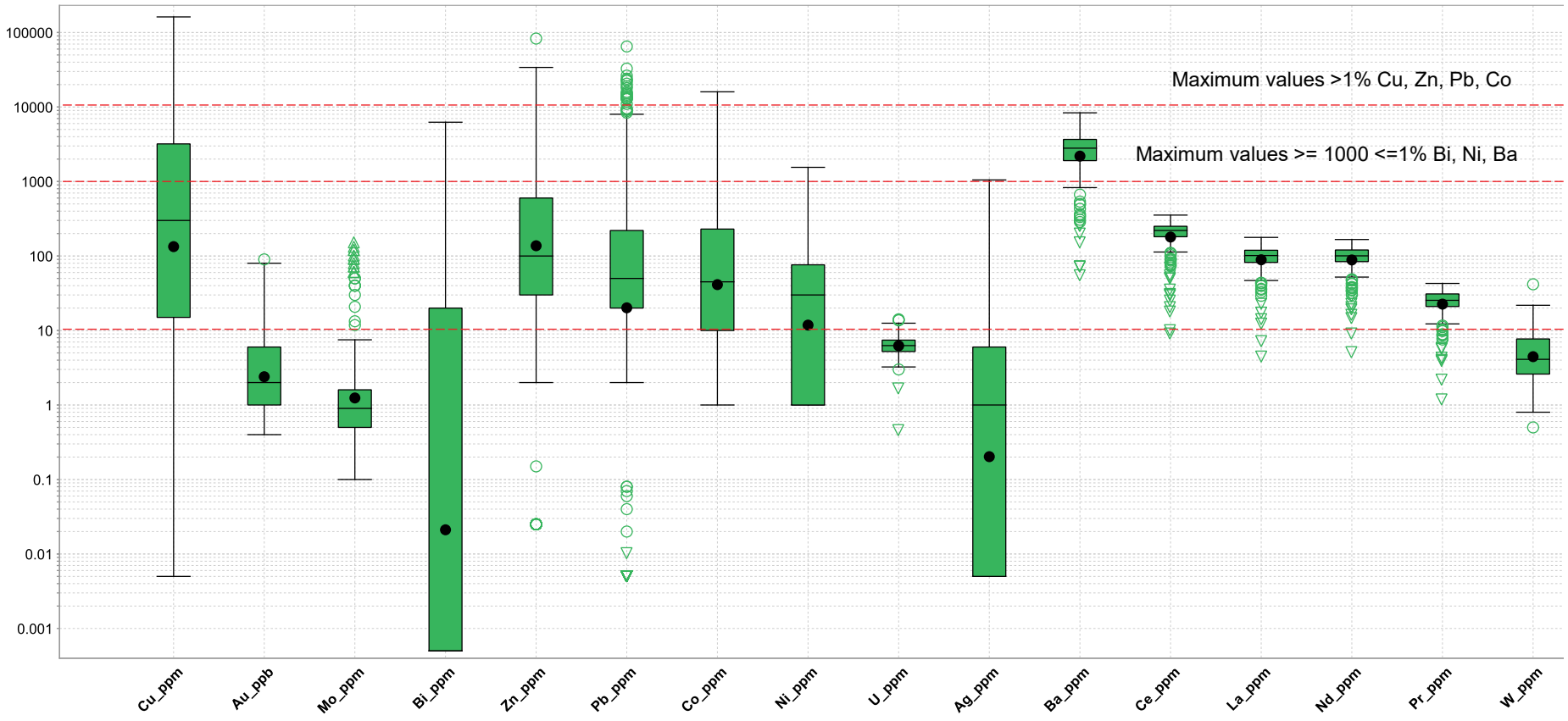
Legacy data: drill core geochemistry

More than 100 samples with 16 elements: Cu, Au, Mo, Bi, Zn, Pb, Co, Ni, U, Ag, Ba, Ce, La, Nd, Pr, and W.

Cu intersection highlights:

- 0.5 m @ 16.2% Cu – R379203, M020-480, from 37 m; 1 m @ 13% Cu – R379842, 3-3-156P from 9 m
- Correlation: Cu vs Co = 0.4, Cu vs Bi = 0.33, Cu vs Ag = 0.28, Cu vs Pb = 0.42 and Cu vs Zn = 0.65. See table of correlation
- Ce, La, and Nd commonly >100 ppm

Note: *Some analyses are outliers and do not represent a normal distribution.*

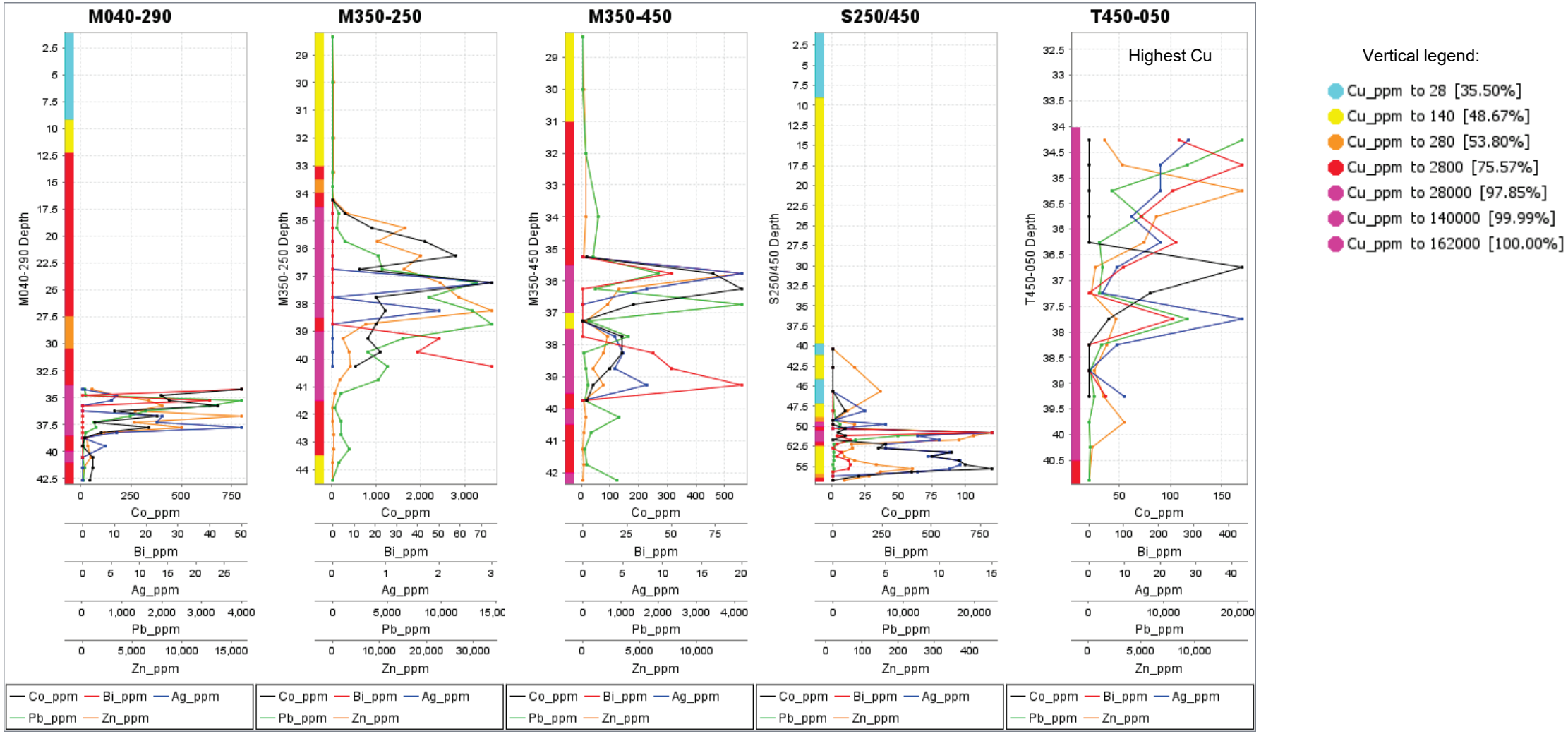


Box plots of representative elements for Mount Gunson district from drill core assays

Sediment-hosted copper deposits of the Mount Gunson district

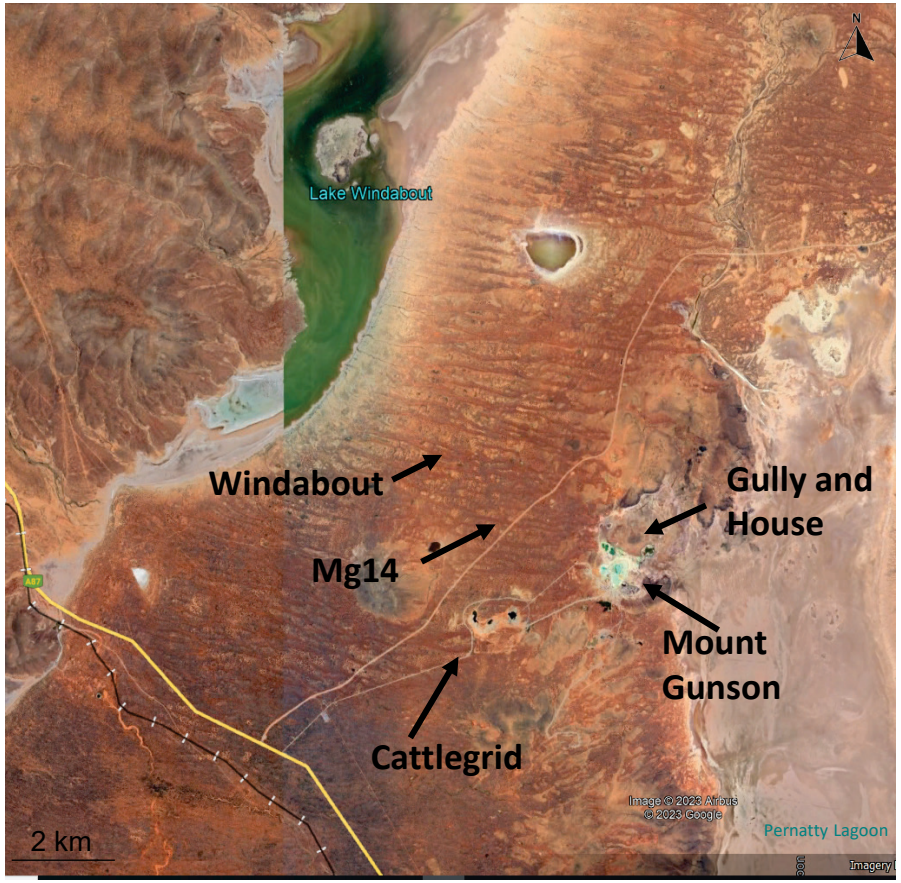
Legacy data: drill core - Cattlegrid

Downhole geochemistry showing the distribution of selected elements in the Pandurra Formation. Cobalt peak values broadly occur in copper mineralised domains.

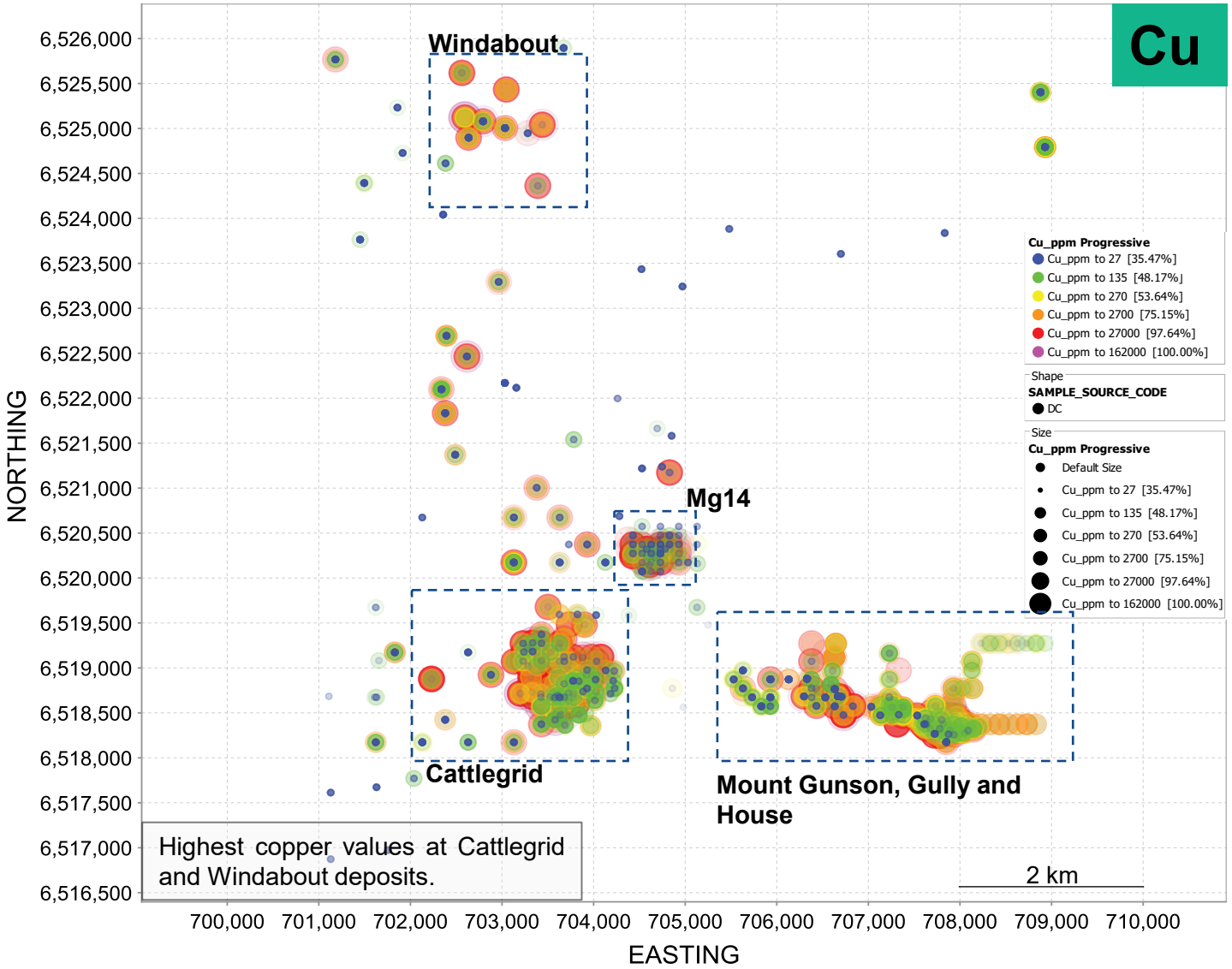


Sediment-hosted copper deposits of the Mount Gunson district

Legacy data: drill core and geochemical insights



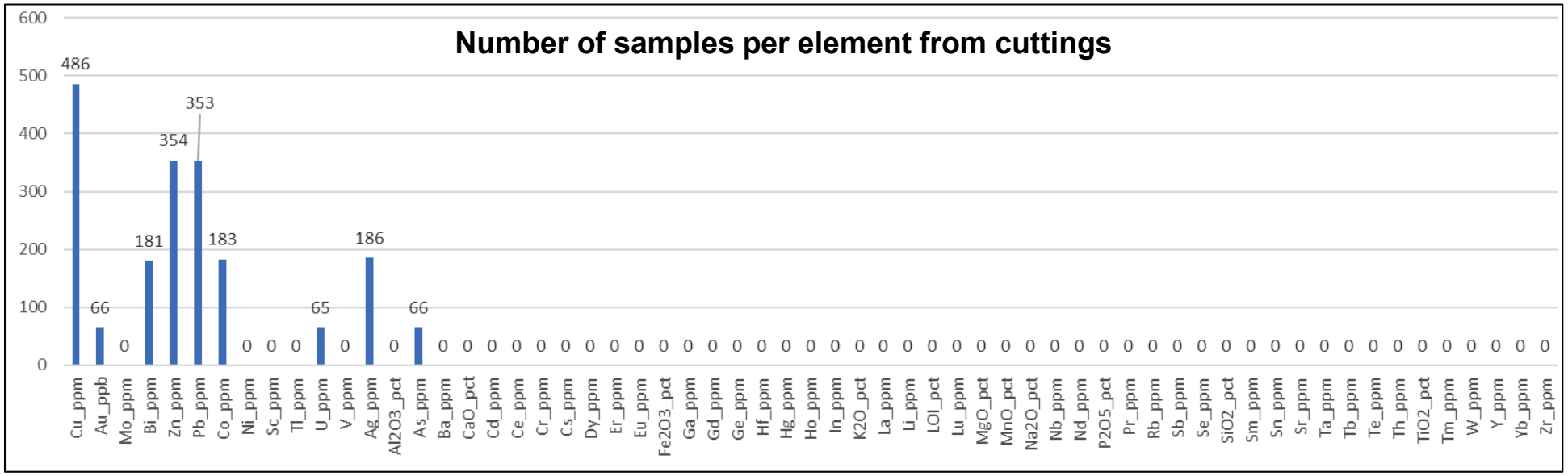
Reference location on satellite image (SARIG).



Sediment-hosted copper deposits of the Mount Gunson district

Legacy data: Rock chip cuttings geochemistry

- No record of laboratory where samples have been assayed.
- Some method descriptions available.
- 9 elements analysed by more than 5 methods from *1969 to 2017* : Cu, Au, Bi, Zn, Pb, Co, U, Ag and As (see histogram for number of samples by element).
- Limited suite of elements for major and trace elements.



Sediment-hosted copper deposits of the Mount Gunson district

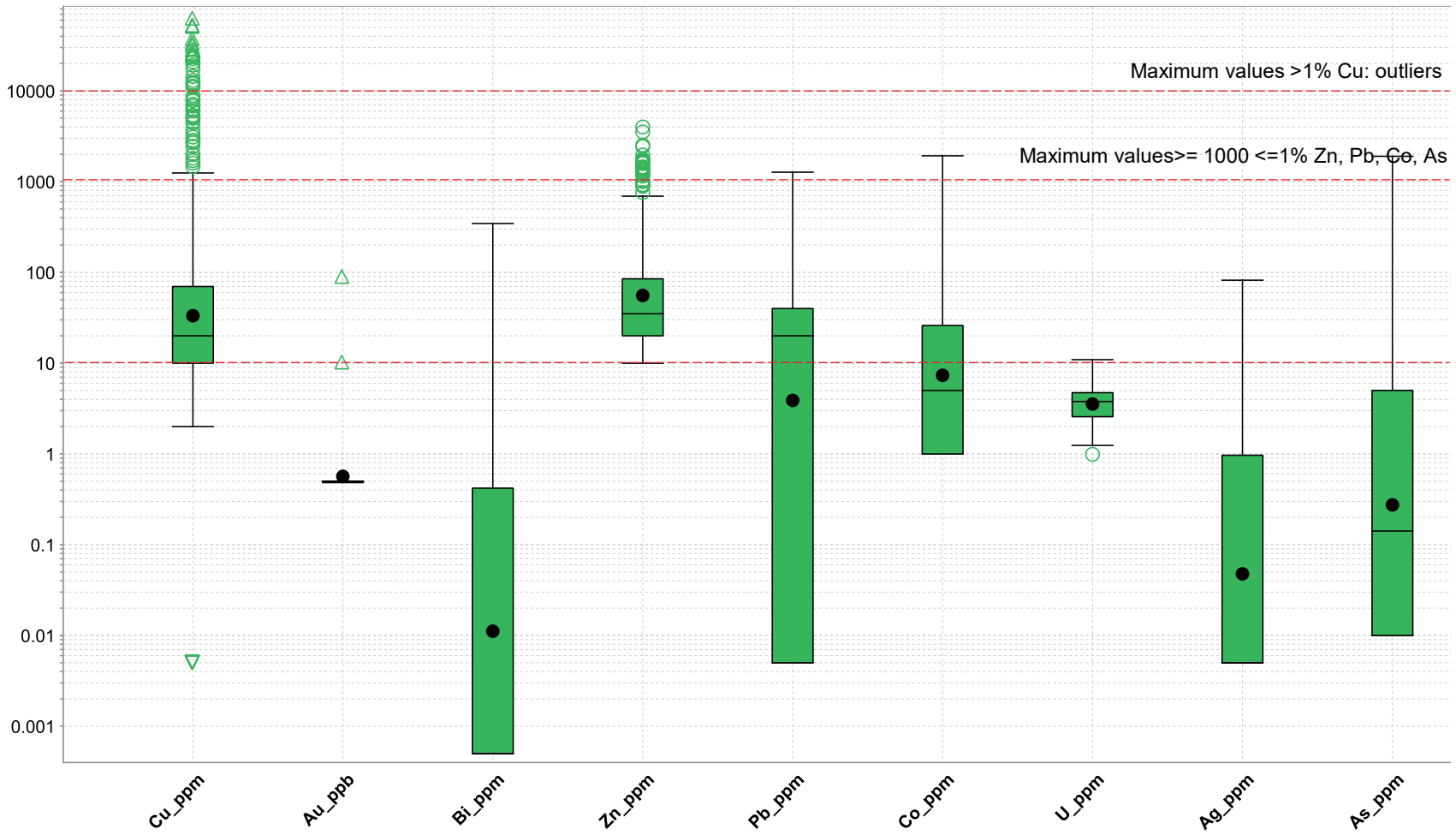
Legacy data: Rock chip cuttings geochemistry

50 samples with more than 9 elements : Cu, Au, Bi, Zn, Pb, Co, U, Ag and As

Cu intersection highlights:

- Max. intersect 61,400 ppm Cu
- Limited data for Au, U and As

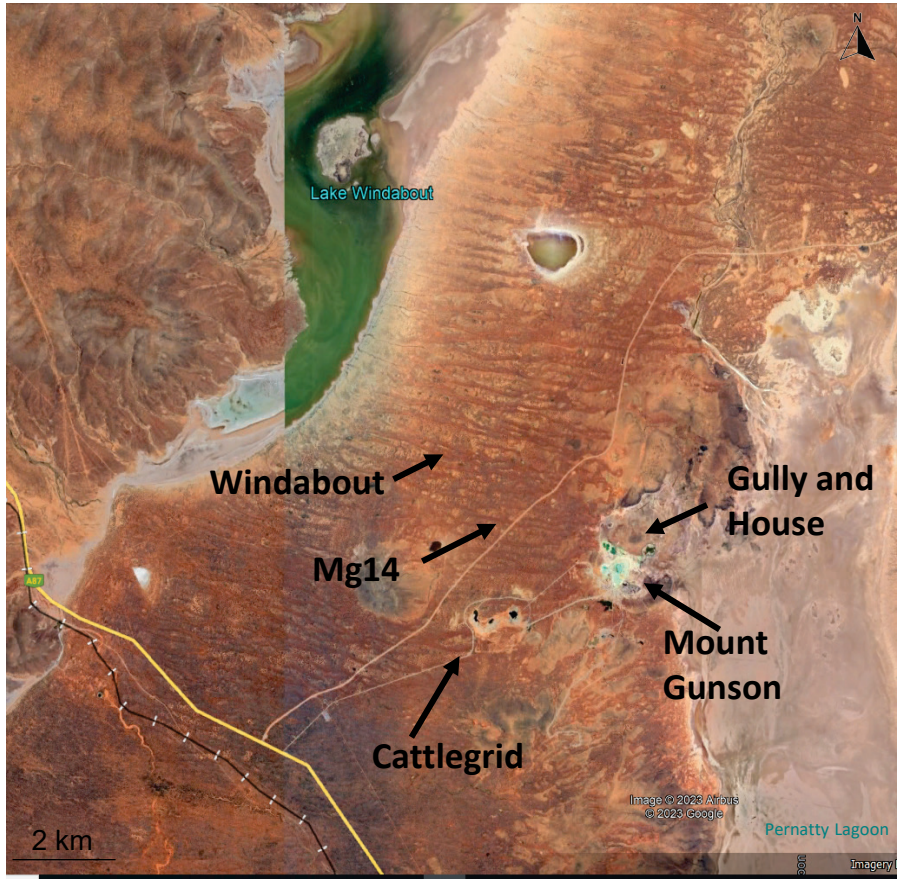
Note: *The outliers do not represent a normal distribution.*



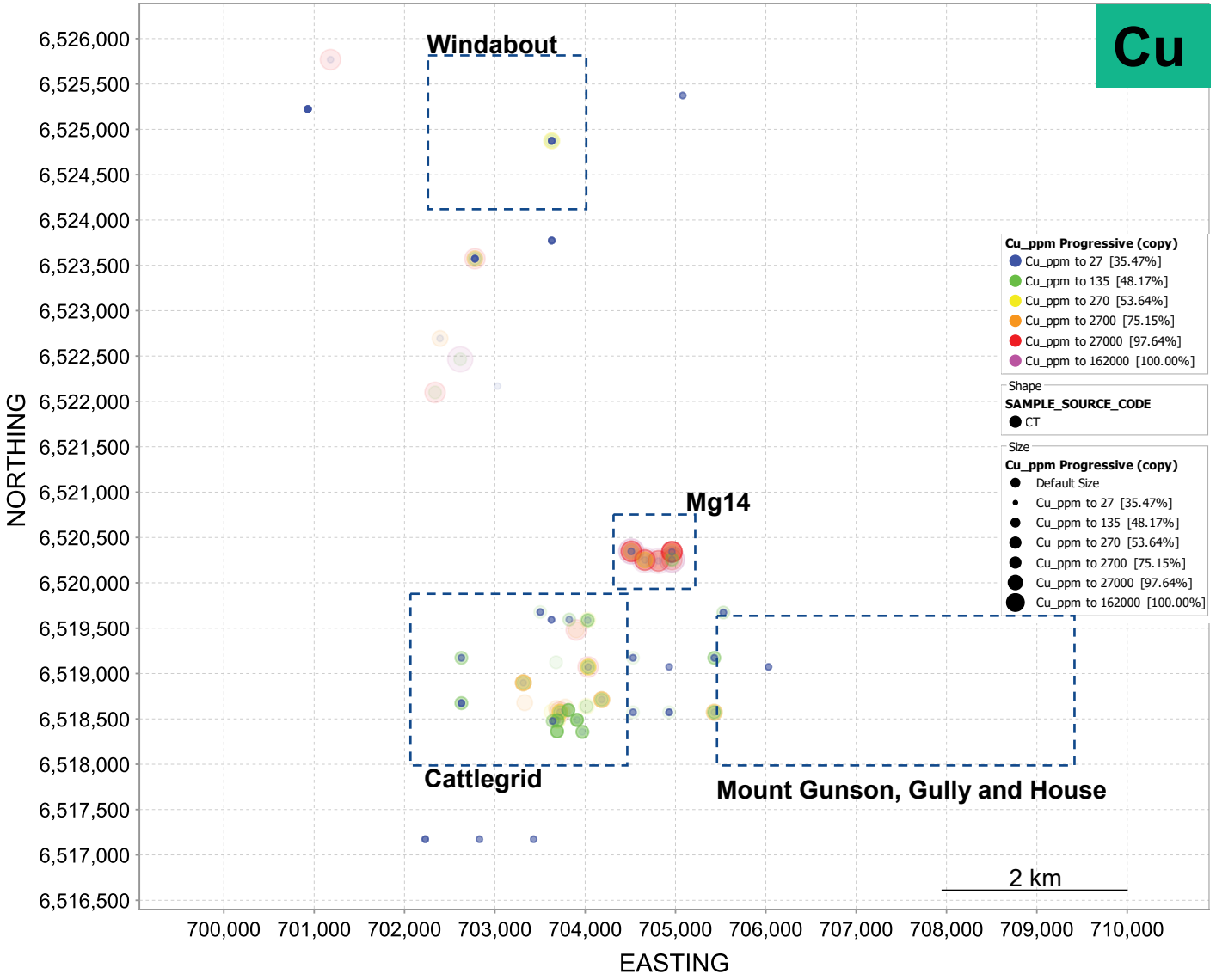
Box plots of representative elements for Mount Gunson district of RC chip cuttings chemistry data.

Sediment-hosted copper deposits of the Mount Gunson district

Legacy data: cutting samples and geochemical insights



Reference location on a satellite image (SARIG).



Resampling data delivery strategy

- Geochemistry is the main new data type collected (see 'Methods' graphic) which has been complemented with additional data to achieve a fully **integrated geochemistry data set** (containing coordinates of the drill holes, sample location, lithologies, stratigraphy, mineralisation, alteration, observations, and the new geochemistry data).
- 167 newly collected samples were re-assayed for a full suite of major and trace element geochemistry to characterise the critical mineral potential. Sample preparation was done by ALS Geochemistry (Adelaide) and analysis by Bureau Veritas Laboratory (Perth).
- In addition, six samples were selected for Mineral Liberation Analysis (MLA) and Laser Ablation Inductively Coupled Plasma Mass Spectroscopy (LA-ICP-MS) from the altered and mineralised zone of the Pandurra and Tapley Hill Formations (see poster 205814-002 PDF 551 KB).

For details of the characterisation information click on the **LINKS** provided below:

click to download

- Integrated Geochemistry
- MLA and Laser ablation presentation
- MLA photos and MLA data
- Laser ablation data
- Laser ablation photos
- Poster

Methods used on Mount Gunson district samples

pXRF
- Spot analysis
- 1 cm spot size
- Only used for sample selection

Geochemistry
- Integrated geochemistry
- Multi-elemental data (see details)
- Identify critical minerals

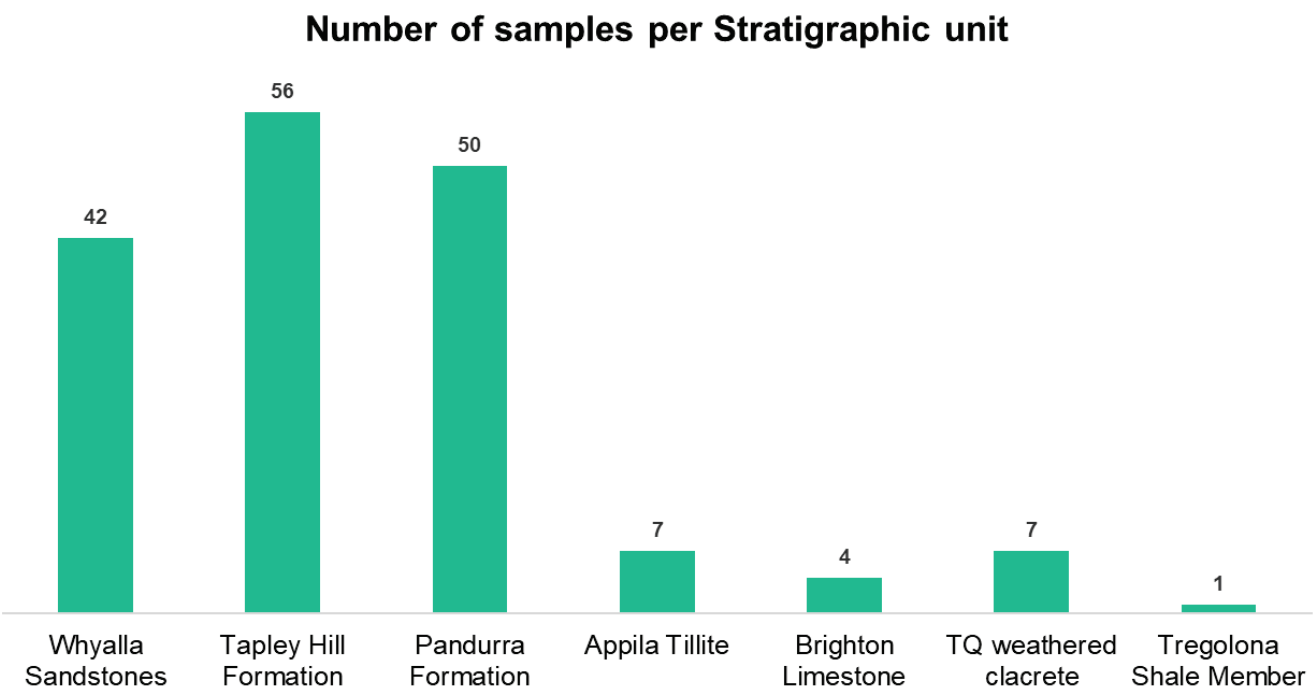
MLA-EDS
- Mineral distribution maps
- 400 um resolution in round mounts
- Laser ablation reference

LA-ICP-MS
- Mineral deportment
- Spot analysis
- Anomalous CM identification

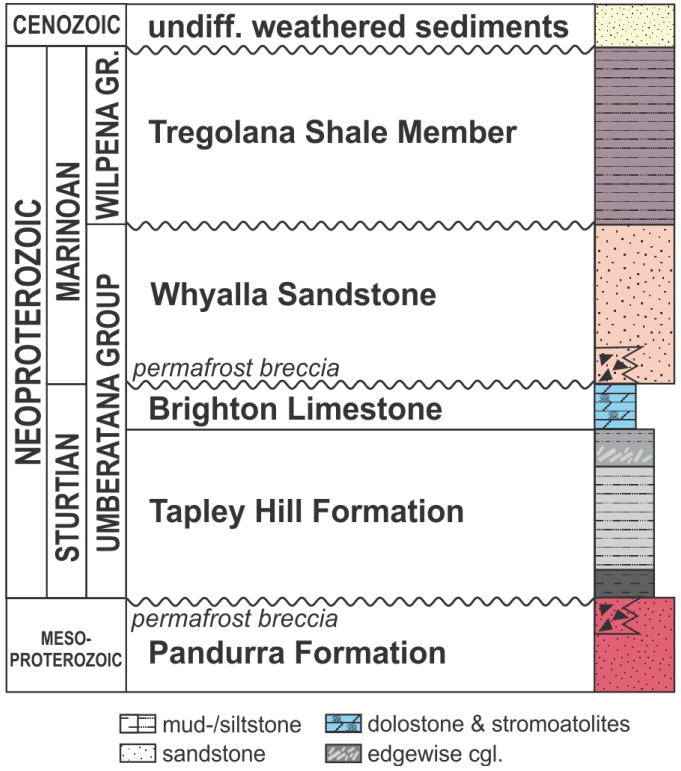
New geochemistry **Summary** *1 of 2*

The new geochemistry for Mount Gunson district is restricted largely to the deposits mineralised-altered zones to assess the potential for critical minerals in association with their primary commodity.

The main stratigraphic mineralised units are: Tapley Hill Formation, Pandurra Formation and Whyalla Sandstone (see stratigraphic column).

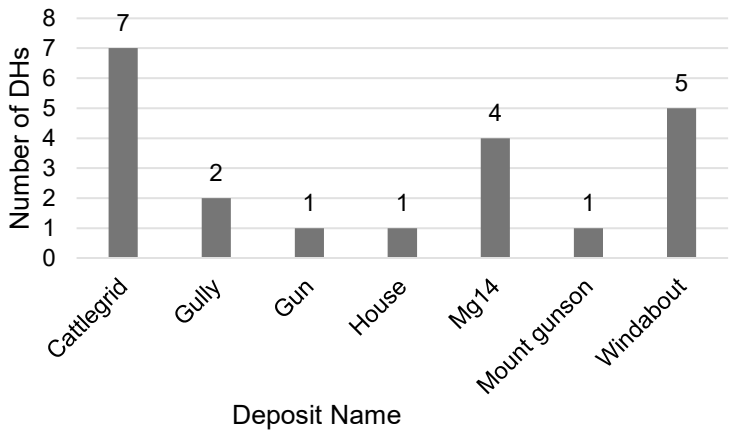


Stratigraphic units sampled and logged



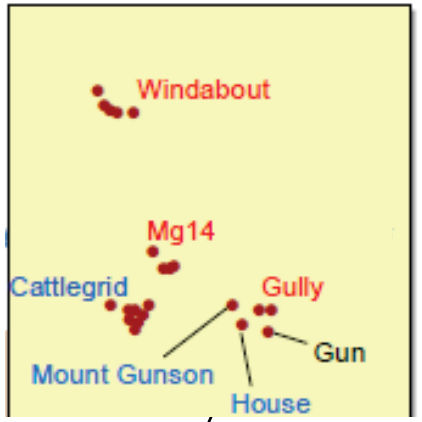
New geochemistry **Summary** *2 of 2*

- Laboratory batch: EX3604 (GSSA database number).
- 21 drillholes (DHs) sampled (see histogram).
- 167 samples collected: 35 (Cattlegrid), 17 (Gully), 5 (Gun), 4 (House), 27 (Mg14), 6 (Mount Gunson), and 73 (Windabout); 11 QC samples.
- 5 drillholes HyLogged with HyLogger™.
- 19 drillholes with new stratigraphic logs.
- Total drill core metres reviewed: 595.32 m.



Number of selected drillholes per deposit

Drillhole number	Drillhole name	Deposit anme
379530	LW 61	Windabout
379529	LW 60	Windabout
179955	CW006RD 6	Windabout
179952	CW003D 3	Windabout
179950	CW001D 1	Windabout
373242	MG 61	Mg14
379233	MG 23/2	Mg14
379242	MG 69/1	Mg14
379256	MG 93	Mg14
379222	M350-450	Cattlegrid
376865	N450-350	Cattlegrid
379280	N190-210B	Cattlegrid
379219	M350-250	Cattlegrid
379139	83/108	Cattlegrid
376879	T450-050	Cattlegrid
379315	S250/450	Cattlegrid
379148	840-670	House
184730	GY 1	Mount gunson
184731	GY 13	Gully
293680	GY 15	Gully
379138	820-750	Gun



Mineralisation and alteration

Logged main lithologies include (from young to old):

- Whyalla Sandstone (sandstone with secondary sulphides and manganese oxides).
- Tapley Hill Formation (black shales with microgranular sulphides and more than 2% Cu).
- Pandurra Formation (red sandstone with sigmoidal structures infilled with coarse-grained sulphides [1 to up to 2 cm in size]).

- **<u>Mineralisation:</u> bornite, chalcocite, galena, chalcopyrite, carrollite, pyrite, emplectite, sphalerite, malachite and manganese oxides.**

- **<u>Alteration:</u> mainly quartz, muscovite and chlorite.**

Drillhole M350-250, 39 m, Cattlegrid deposit.

Mineralisation and alteration
Whyalla Sandstone

- Quartz-, illite-alteration?
- Secondary minerals: malachite, +/- chalcocite and manganese oxides.
- Other minerals: clays.

Drillhole 840/670 – 5.60 m

Right: hand sample showing malachite vein and disseminated chalcocite, with black manganese oxides.

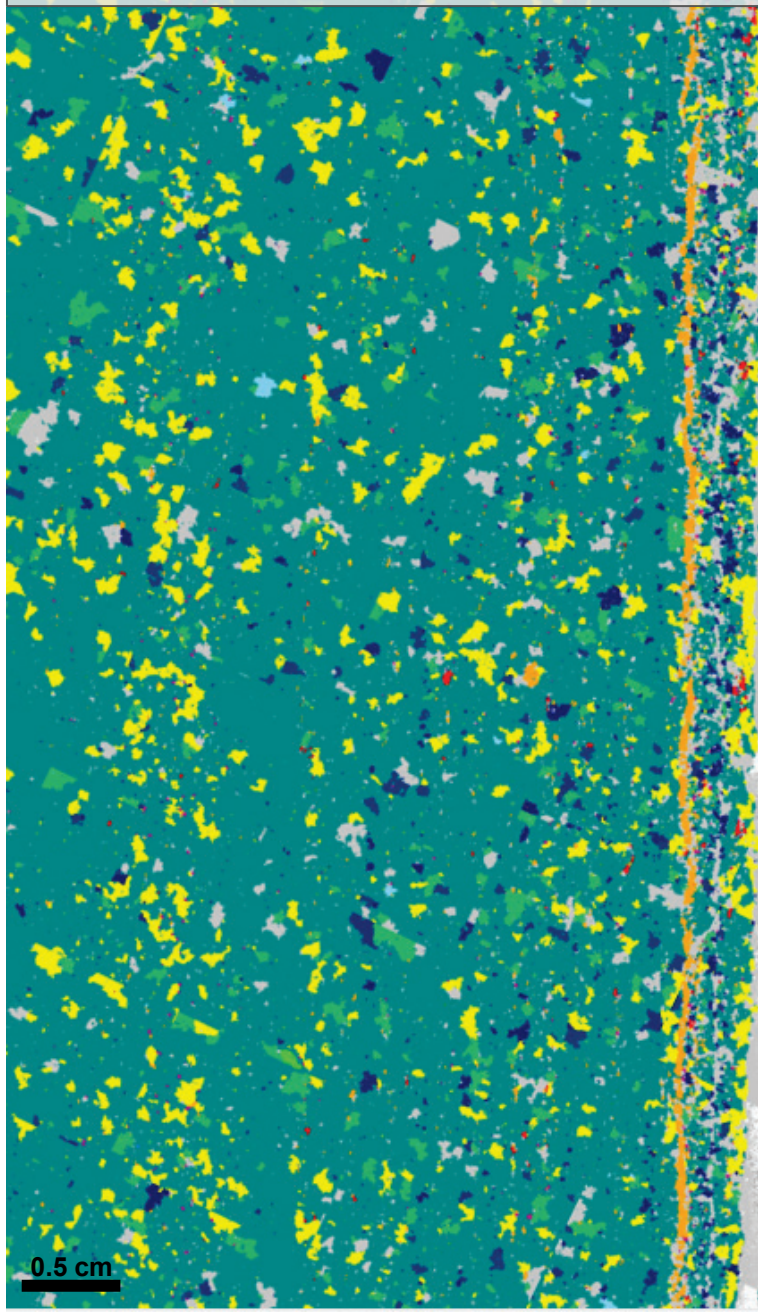
Mineralisation and alteration
Tapley Hill Formation

- Alteration: muscovite, quartz, chlorite
- Sulphide mineralisation: chalcopyrite, carrollite, micro pyrite and sphalerite.
- Not identified: bornite, chalcocite, carrollite, emplectite, galena and sphalerite.
- Other minerals: rutile, albite?, halite and zircon.


Drillhole MG 23/2 - 30 m (Mg14 deposit)

- Muscovite
- Quartz
- Chlorite
- Halite
- Chalcopyrite
- Carrollite
- Sphalerite
- Pyrite
- Rutile
- Albite

Drillhole CW003D3 - 92.94 m. MLA image showing muscovite, quartz, chlorite with chalcopyrite vein, carrollite and micro pyrite and sphalerite.



Mineralisation and alteration

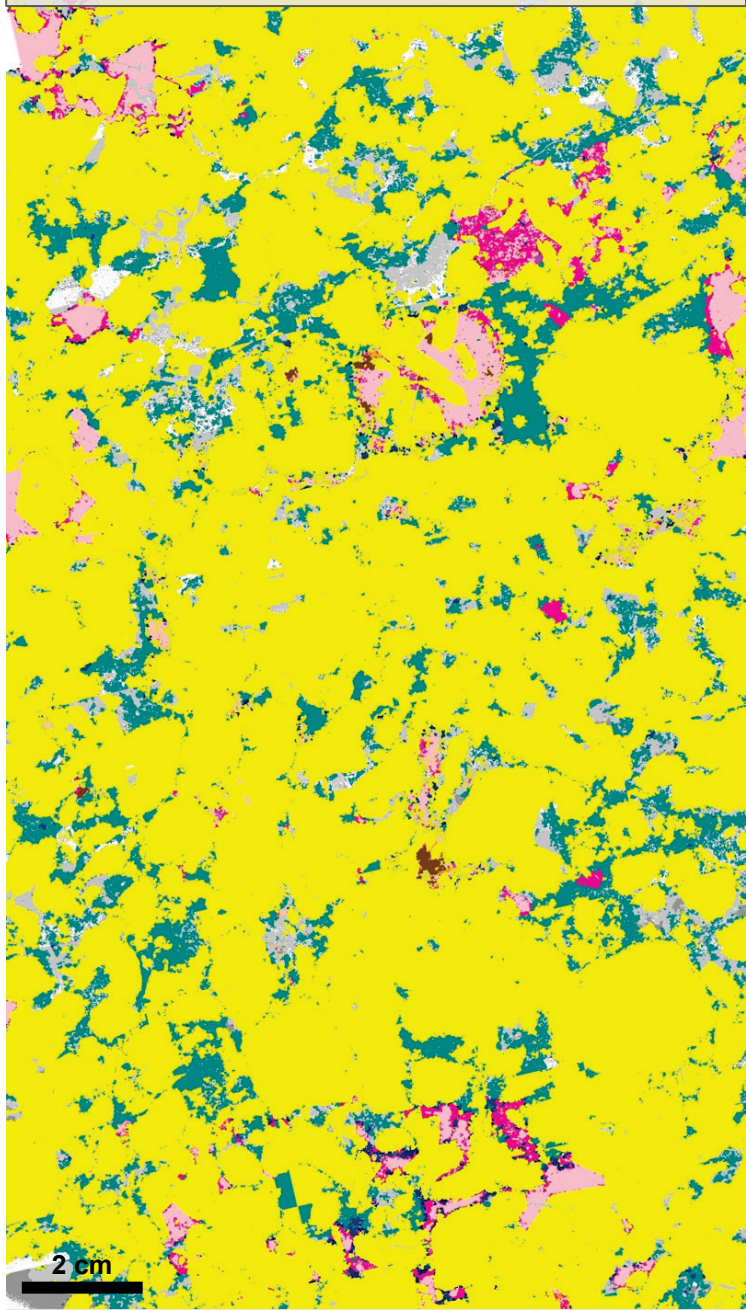
Pandurra Formation

- Alteration: quart-muscovite
- Sulphide mineralisation: bornite, chalcocite, galena, chalcopyrite, carrollite, pyrite, emplectite and sphalerite.
- Other minerals: halite, rutile and zircon.

Drillhole N450/350 - 38 m (Cattlegrid deposit)

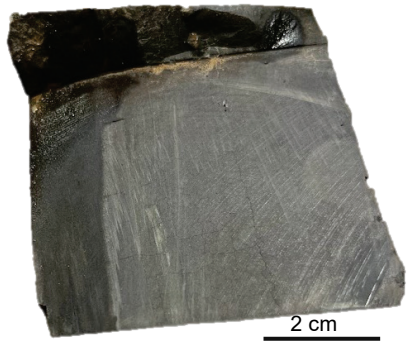
Quartz
Muscovite
Chalcocite
Galena
Emplectite
Sphalerite
Halite
Zircon
Bornite
Chalcopyrite

Drillhole S250/450 - 52.90 m. *MLA image showing quartz-muscovite with chalcocite, emplectite, galena, sphalerite and +/- bornite.*



Mineralisation and alteration

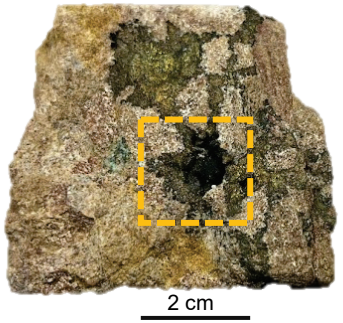
Photos *1 of 4*



Micro sulphides (not visible). Tapley Hill Formation at 32.1 m from MG 23/2 (Mg14 deposit)

Micro sulphides (not visible). Tapley Hill Formation at 31 m from GY 13 (Gully deposit)

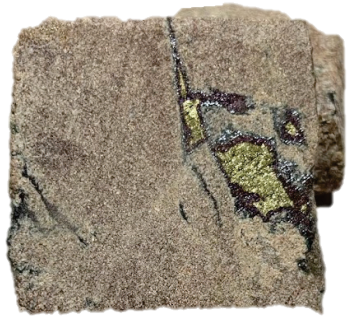
Patches of sulphides. Pandurra Formation at 38 m from M040-290 (Cattlegrid deposit). Not sampled. No analysis



In-fill sulphides. Pandurra Formation at 35 m from M350-250 (Cattlegrid deposit)

Micro sulphides and oxidized sulphide veins. Tapley Hill Formation at 32.4 m from MG 23/2 deposit (Mg14 deposit)

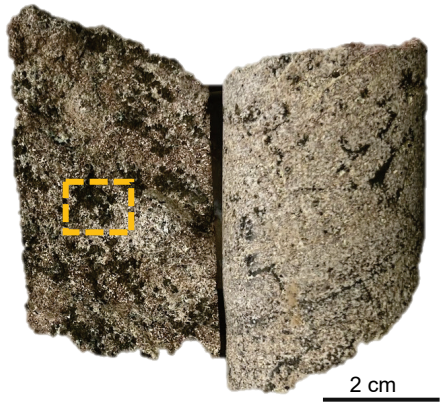
Micro sulphides (not visible). Tapley Hill Formation at 31.8 m from MG 93 (Mg14 deposit)



Sigmoidal vein with infill sulphides. Pandurra Formation at 38 m from N450-350 (Cattlegrid deposit)

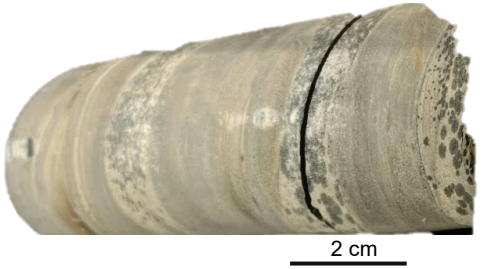
Mineralisation and alteration

Photos *2 of 4*

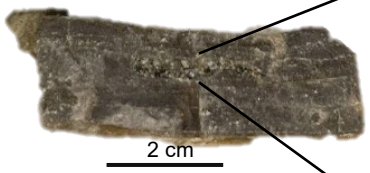


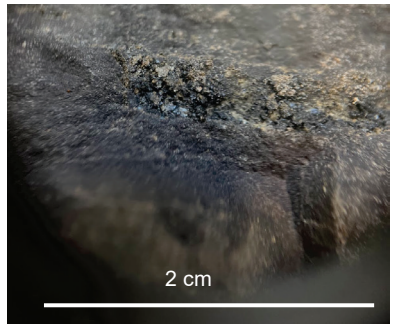
Wormy chalcocite. Pandurra Formation at 52.90 m from S250/450 (Cattlegrid deposit)

Disseminated sulphides not visible to eye. Tapley Hill Formation at 77.50 m from CW003D 3 (Windabout deposit)



Sulphide oxidation not easily visible. Tapley Hill Formation at 81.2 m from CW003D 3 (Windabout deposit)





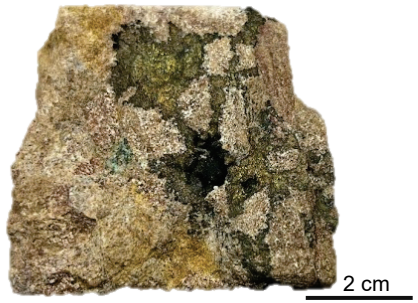
Cavity of chalcocite?. Tapley Hill Formation at 31 m from MG 61 (Mg14 deposit)

Mineralisation and alteration

Photos *3 of 4*

Red Sandstone with micro cavities infilled with clays. Whyalla Sandstone at 17.7 m from 840/670 (House deposit)

Crackle punctual breccia Sandstone with kaolinite and secondary sulphides infill. Whyalla Sandstone at 12.8 m from 820-750 (Gun deposit)



Limonite with chalcocite-chalcopyrite-bornite crackle veins. Pandurra Formation at 35 m from M350-250 (Cattlegrid deposit)

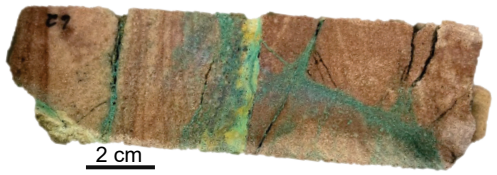
Tapley Hill Formation at 84.80 m from LW60 (Windabout deposit)

Malachite staining veins between black shales. Tapley Hill Formation at 98 m from CW006RD 6 (Windabout deposit)

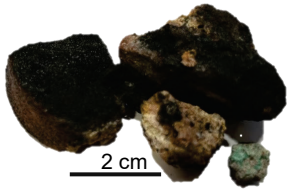
Soft sandstone with disseminated manganese oxides. Whyalla Sandstone at 68 m from LW 60 (Windabout deposit)

Mineralisation and alteration

Photos *4 of 4*



Malachite veins with manganese oxides. Whyalla Sandstone at 5.60 m from 840/670 (House deposit)



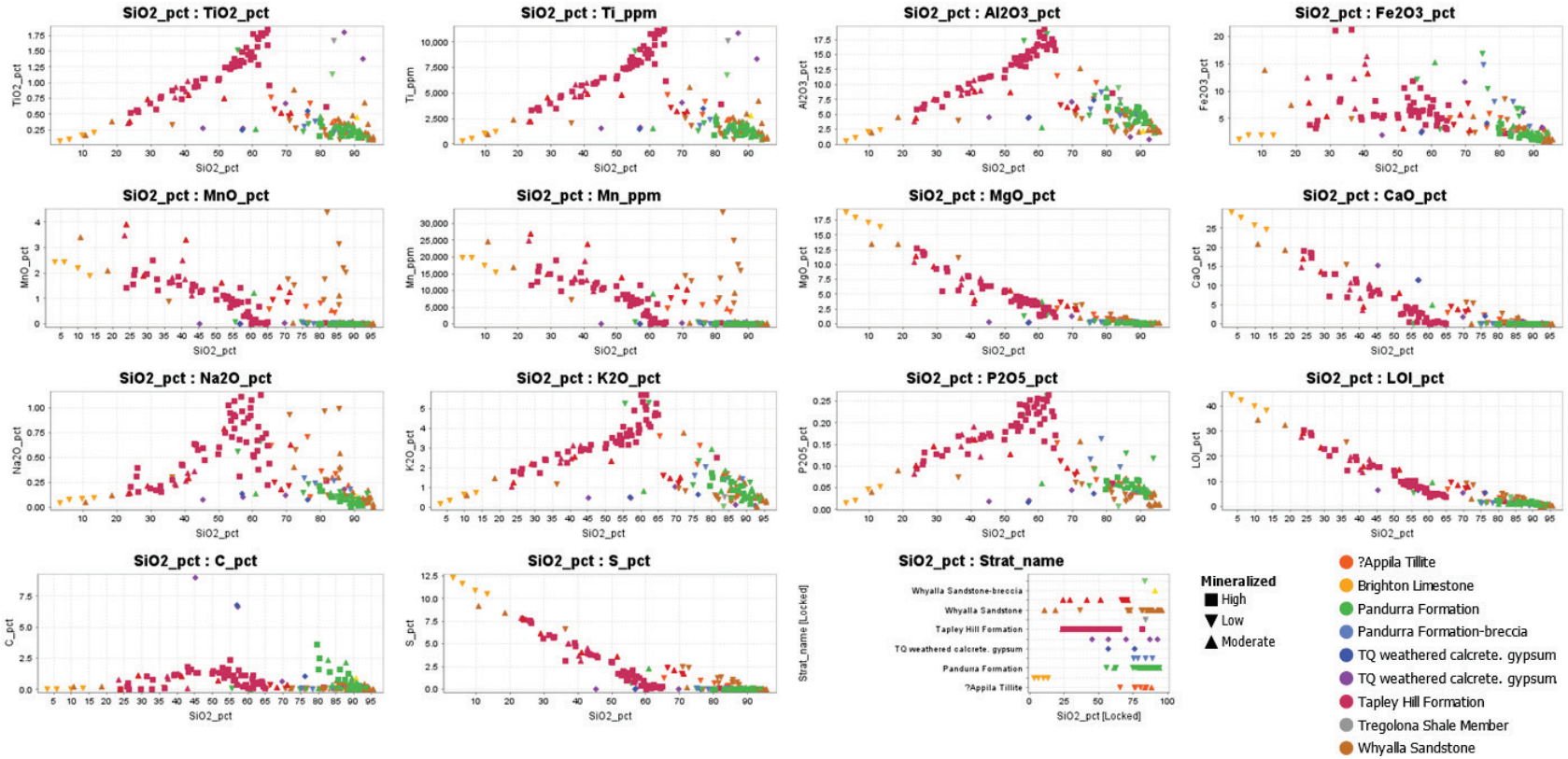
Manganese oxides and malachite. Whyalla Sandstone at 6.20 m from 840/670 (House deposit)

Malachite staining and manganese oxides. Tapley Hill Formation at 98 m from CW006RD 6 (Windabout deposit)

Muscovite and chalcocite vein. Whyalla Sandstone at 28 m from 820-750 (Gun deposit). Red line representing the closeup of the photo bellow

Major element distribution

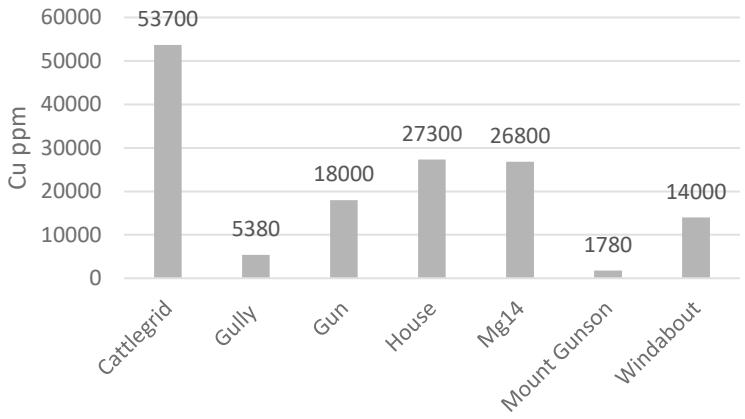
- Major element biplots discriminate silica- and carbonate-rich lithologies. For example, shales contain higher Al_2O_3, TiO_2, K_2O, Na_2O, and P_2O_5 than Sandstone (see correlations). Consequently, SiO_2 content is higher in Sandstone than shales.
- Tapley Hill Formation (shales) yields less than 65% SiO_2, Pandurra Formation (Sandstone) contains > 55% SiO_2; Brighton Limestone has under 15% SiO_2. Breccias and weathered zones yield highly variable SiO_2 contents.



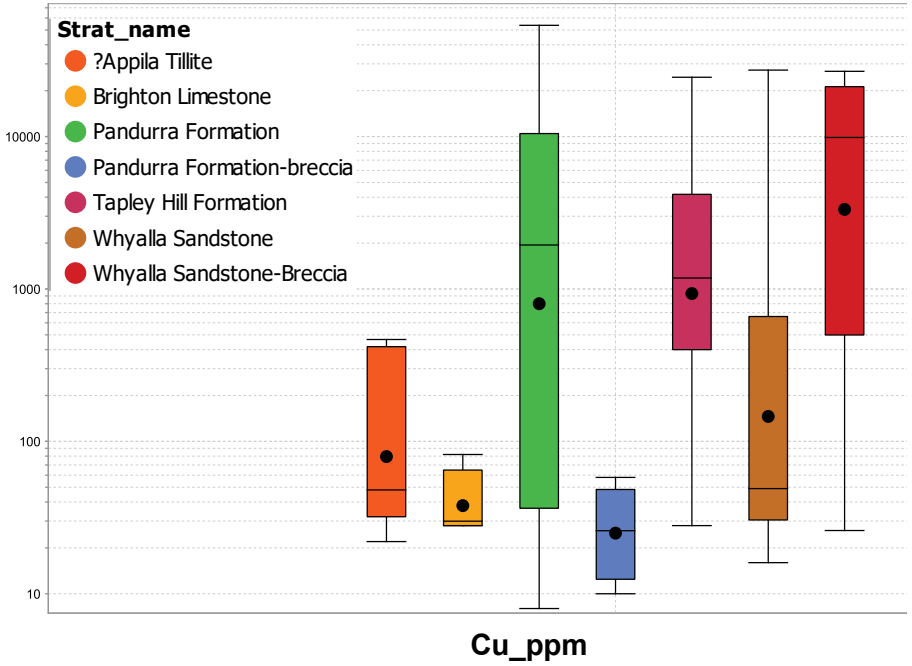
Correlation of major elements of Mount Gunson district.

Trace element overview

- Critical minerals such as Co, Bi and Ni and pathfinders such as Pb, Zn have been identified with the new geochemistry.
- The results were assessed for the mineralised zones of each deposit from the available lithologies:
  - Cattlegrid (only Pandurra Formation sampled).
  - Windabout (only Tapley Hill Formation sampled).
  - Mg14 (mostly Tapley Hill Formation and Whyalla Sandstone).
  - Gun and House (only Whyalla Sandstone sampled).
- Samples from Gully and Mount Gunson deposits have less copper content than the other deposits.
- Pandurra Formation, Tapley Hill Formation and brecciated Whyalla Sandstone are the main hosts of Cu ore (see box plot). The highest Cu grades are at Cattlegrid (Pandurra Formation) (see histogram).
- Selenium (Se) was partially volatilized and could not be measured with certainty.
- Au (gold), Pt (platinum), and Pd (palladium), tellurium (Te), thallium (Tl), rhenium (Re), indium (In), boron (B), lithium (Li), chlorine (Cl), sulphur (S). are near and below detection limit (DL). These elements were not used for analysis or interpretation.



Mount Gunson district deposits

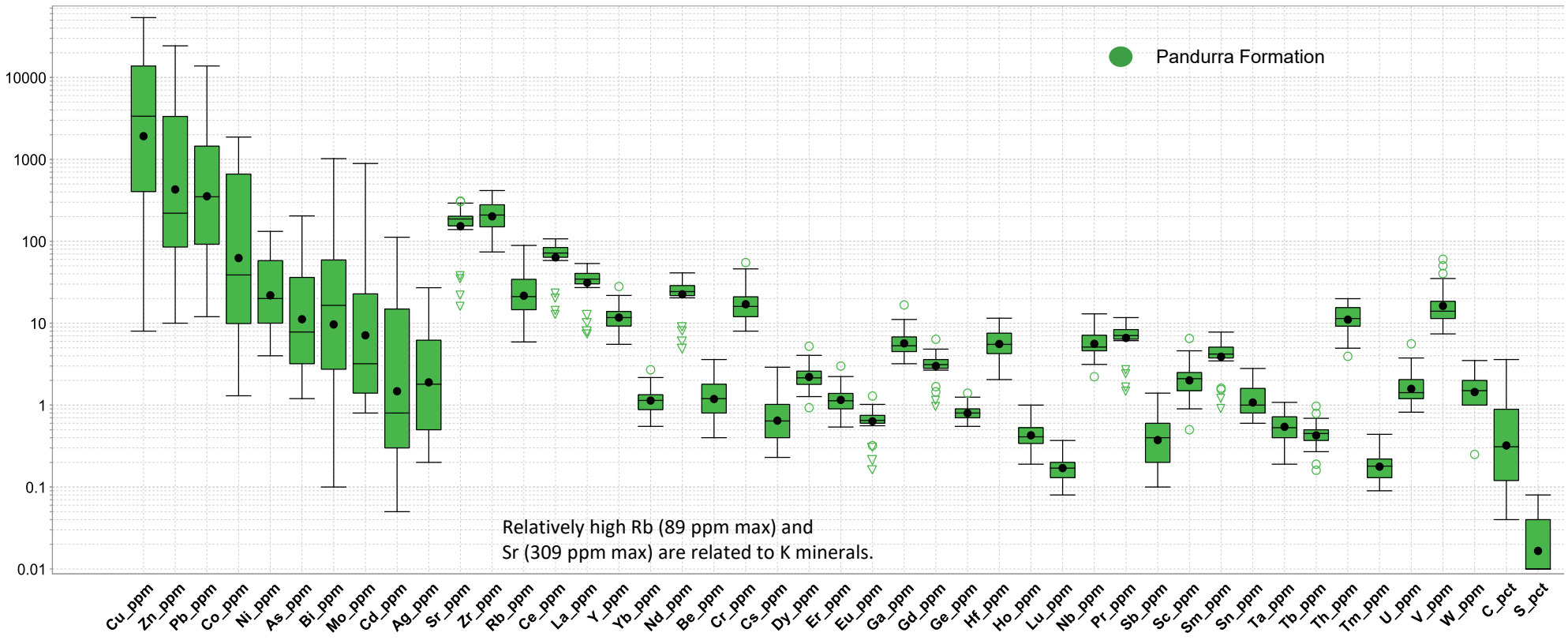


Trace elements - Cattlegrid

35 samples from 7 drillholes intersecting Pandurra Formation with cm-scale sulphides: chalcocite, chalcopyrite, bornite, galena, sphalerite, carrollite, and pyrite. Cattlegrid deposit yields the highest Cu grades. Maximum values of different elements listed to the left of the Box and Whisker plot.

Pandurra Formation

- 5.37 % Cu
- 2.43 % Zn
- 1.38 % Pb
- 1870 ppm Co
- 132 ppm Ni
- 204 ppm As
- 27.1 ppm Ag
- 1020 ppm Bi
- 890 ppm Mo
- 112 ppm Cd
- 60.4 ppm V



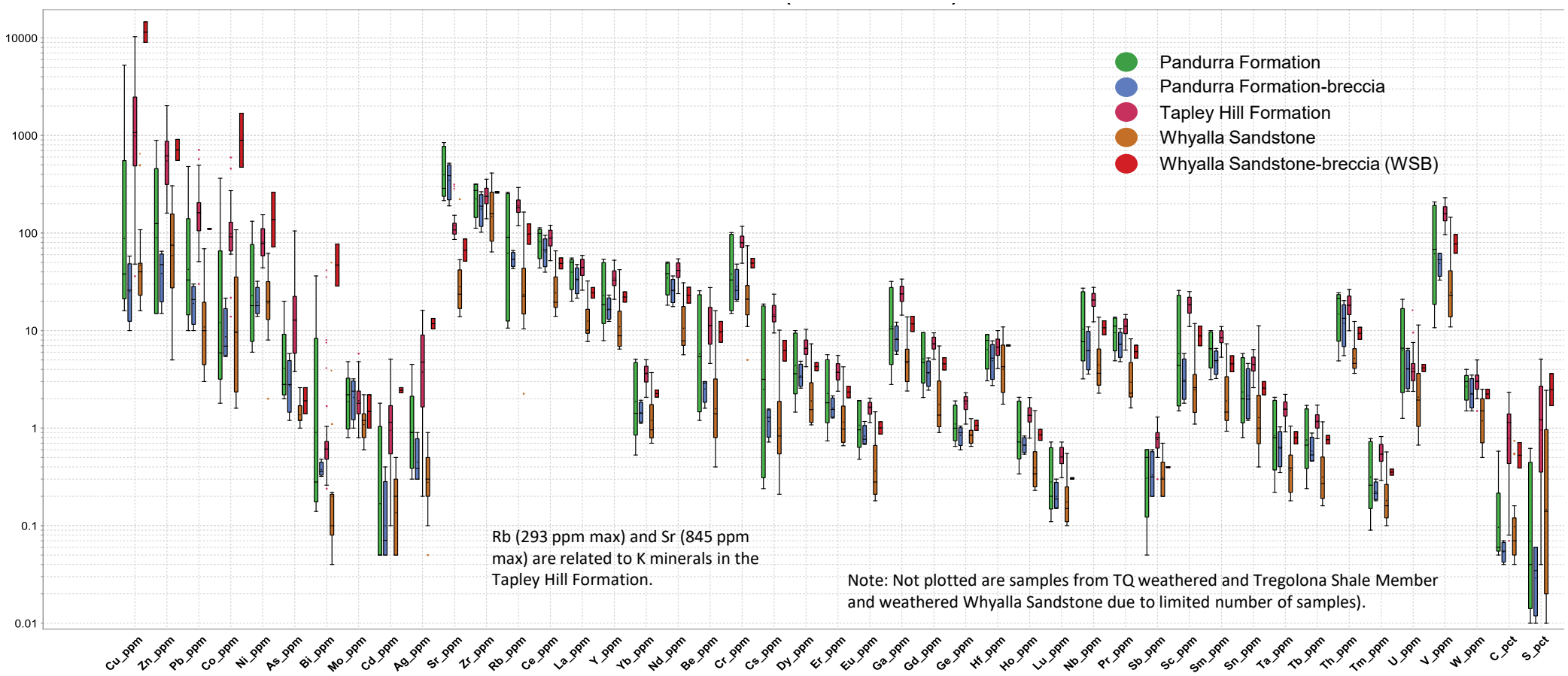
Box and Whisker plot showing trace element concentrations determined by whole rock fusion LA-ICP-MS. The central box represents 50% of the data from quartile 1(Q1) to quartile 3 (Q3); outlier circles and triangles indicate the data that is further than 1.5 (Q3-Q1) from the box. The whiskers include the extreme outlier values.

Trace elements - Windabout

73 samples in total, 9 Pandurra Formation, 7 TQ weathered, 36 Tapley Hill Formation, 1 Tregolana Shale Member and 20 Whyalla Sandstone. The highest Cu grades are within the Tapley Hill Formation. Maximum values for different elements are listed to the left of the Box and Whisker plot.

Tapley Hill Formation

- 1.4 % Cu (WSB)
- 2020 ppm Zn
- 496 ppm Pb
- 1690 ppm Co (WSB)
- 262 ppm Ni (WSB)
- 105 ppm As
- 16.1 Ag ppm
- 71.1 ppm Bi (WSB)
- 4.8 ppm Mo
- 5.1 ppm Cd
- 230 ppm V



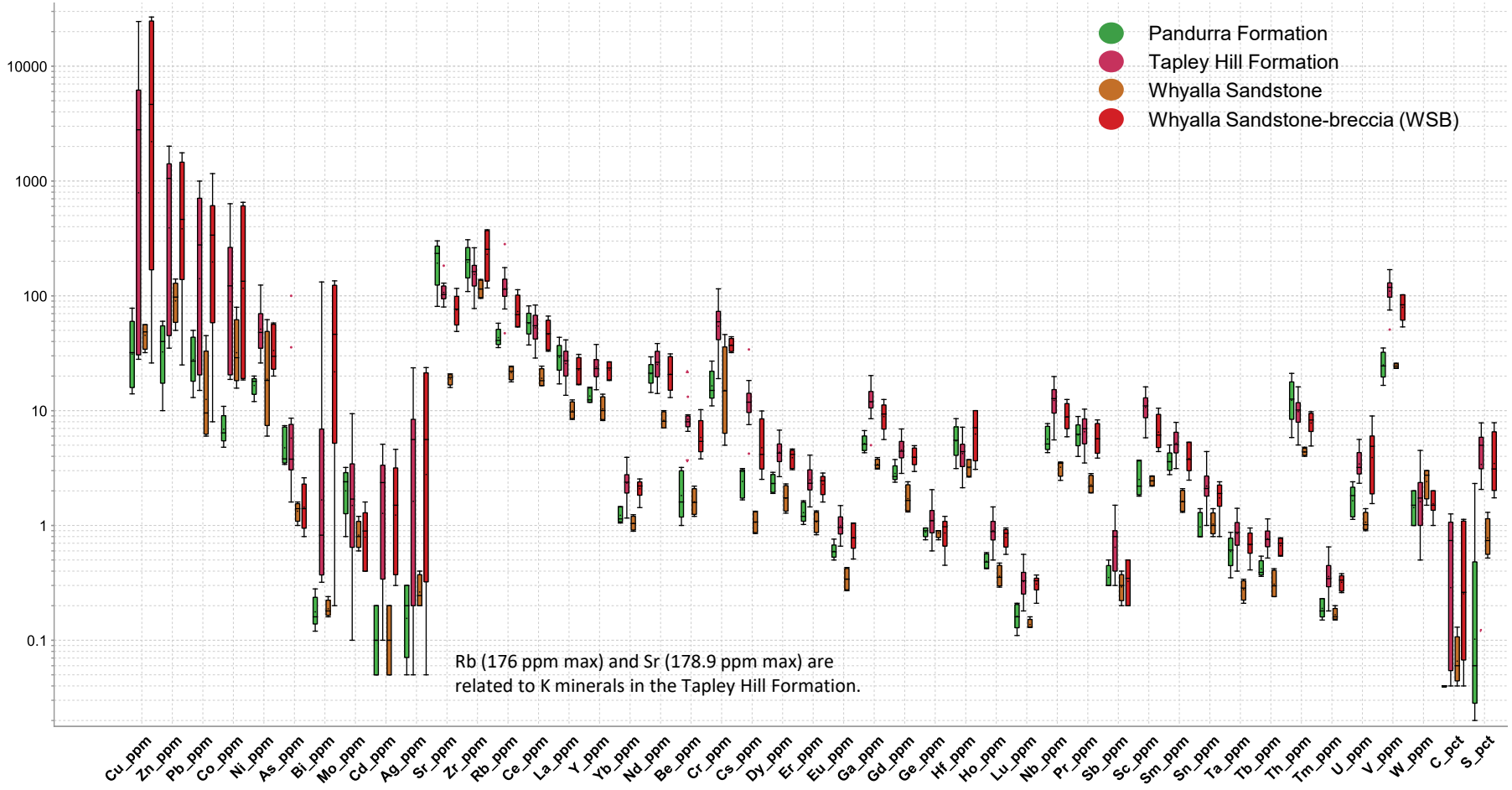
Box and Whisker plot showing trace element concentrations determined by whole-rock geochemistry. The central box represents 50% of the data from quartile 1(Q1) to quartile 3 (Q3); outlier circles and triangles indicate the data that's is further than 1.5 (Q3-Q1) from the box. The whiskers include the extreme outlier value.

Trace elements - Mg14

27 samples in total, 5 Pandurra Formation, 12 Tapley Hill Formation, and 10 Whyalla Sandstone. Maximum values for different elements are listed to the left of the Box and Whisker plot.

Tapley Hill Formation

- 2.68 % Cu (WSB)
- 2010 ppm Zn
- 1160 ppm Pb (WSB)
- 634 ppm Co
- 124 ppm Ni
- 8.6 ppm As
- 23.6 Ag ppm
- 135 ppm Bi (WSB)
- 9.4 ppm Mo
- 5.1 ppm Cd
- 169 ppm V



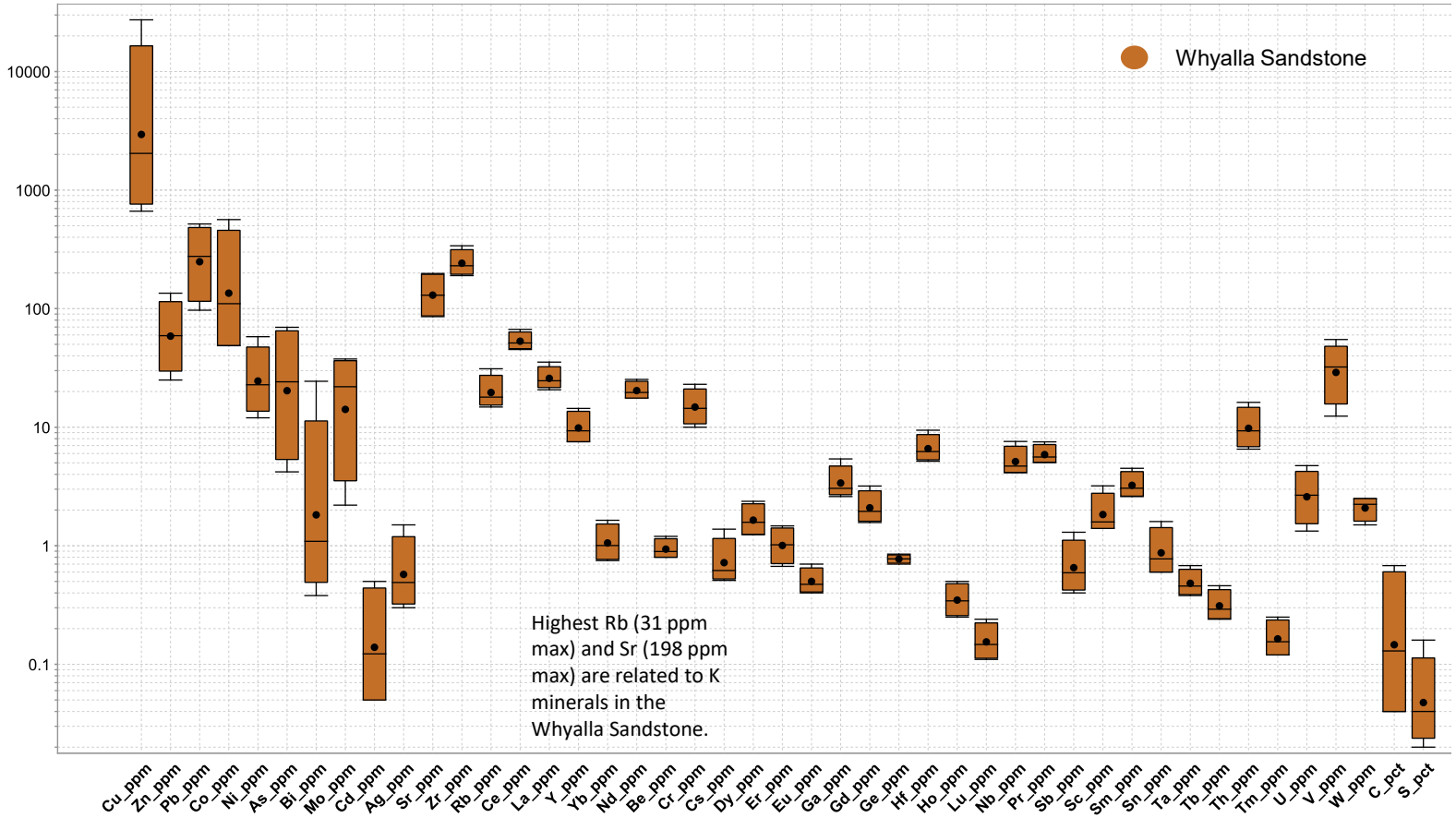
Box and Whisker plot showing trace element concentrations determined by whole-rock geochemistry. The central box represents 50% of the data from quartile 1(Q1) to quartile 3 (Q3); outlier circles and triangles indicate the data that's is further than 1.5 (Q3-Q1) from the box. The whiskers include the extreme outlier value.

Trace elements - House

4 samples in total, all from Whyalla Sandstone. Secondary sulphides such as malachite, chalcocite and other sulphides such as pyrite and micro chalcopyrite, carrollite? and bornite. Maximum values for different elements are listed to the left of the Box and Whisker plot.

Whyalla Sandstone

- 2.73 % Cu
- 135 ppm Zn
- 518 ppm Pb
- 564 ppm Co
- 58 ppm Ni
- 69.6 ppm As (breccia)
- 1.5 Ag ppm
- 24.4 ppm Bi
- 37.6 ppm Mo
- 0.5 ppm Cd
- 54.9 ppm V



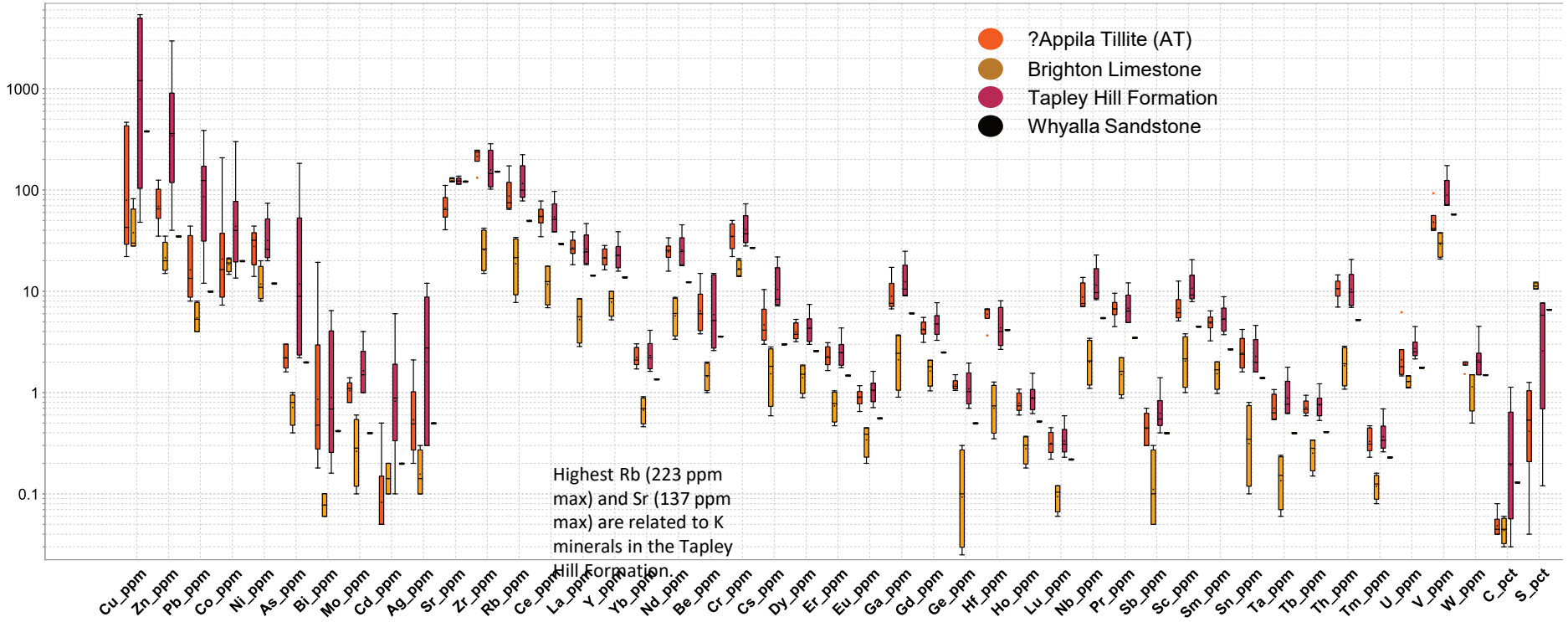
Box and Whisker plot showing trace element concentrations determined by whole-rock geochemistry. The central box represents 50% of the data from quartile 1(Q1) to quartile 3 (Q3); outlier circles and triangles indicate the data that's is further than 1.5 (Q3-Q1) from the box. The whiskers include the extreme outlier value.

Trace elements - Gully

17 samples in total, 6 Appila Tillite(?), 4 Brighton Limestone, 6 Tapley Hill Formation and 1 Whyalla Sandstone. Highest grade in Tapley Hill Formation with disseminated sulphides: chalcopyrite, pyrite, +/- sphalerite, carrollite, and pyrite. Maximum values for different elements are listed to the left of the Box and Whisker plot.

Tapley Hill Formation

- 5380 ppm Cu
- 2960 ppm Zn
- 387 ppm Pb
- 300 ppm Co
- 74 ppm Ni
- 183 ppm As
- 12 ppm Ag
- 19.3 ppm Bi (AT)
- 4 ppm Mo
- 6 ppm Cd
- 174 ppm V



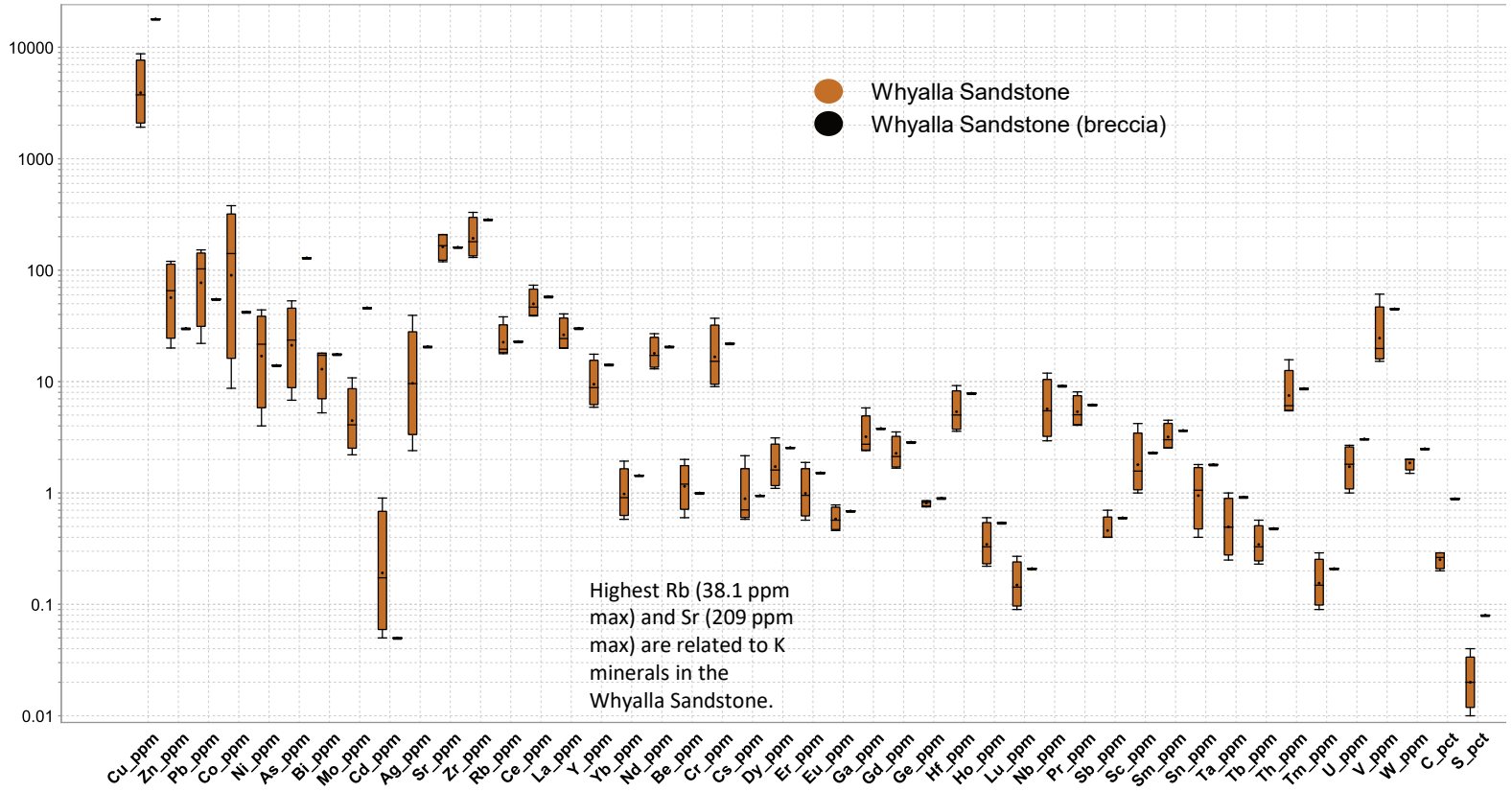
Box and Whisker plot showing trace element concentrations determined by whole-rock geochemistry. The central box represents 50% of the data from quartile 1(Q1) to quartile 3 (Q3); outlier circles and triangles indicate the data that's is further than 1.5 (Q3-Q1) from the box. The whiskers include the extreme outlier value.

Trace elements - Gun

5 samples in total, all from Whyalla Sandstone. Secondary sulphides such as malachite, chalcocite and other sulphides such as pyrite and micro chalcopyrite. Maximum values for different elements are listed to the left of the Box and Whisker plot.

Whyalla Sandstone

- 1.8 % Cu (breccia)
- 120 ppm Zn
- 152 ppm Pb
- 379 ppm Co
- 44 ppm Ni
- 129 ppm As (breccia)
- 39.3 Ag ppm
- 18 ppm Bi
- 46 ppm Mo (breccia)
- 0.9 ppm Cd
- 174 ppm V



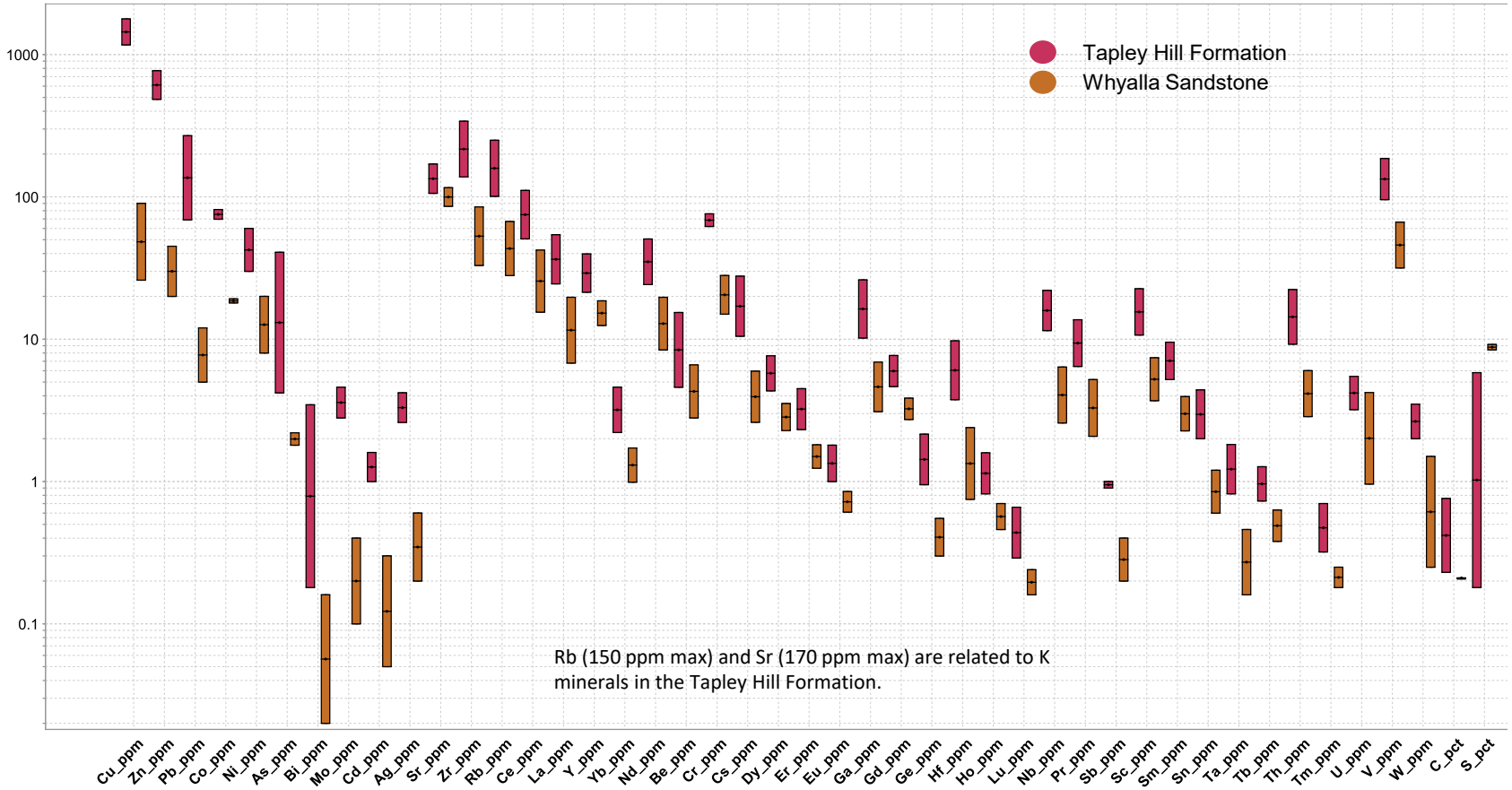
Box and Whisker plot showing trace element concentrations determined by whole-rock geochemistry. The central box represents 50% of the data from quartile 1(Q1) to quartile 3 (Q3); outlier circles and triangles indicate the data that's is further than 1.5 (Q3-Q1) from the box. The whiskers include the extreme outlier value.

Trace elements - Mount Gunson

6 samples in total, 1 Appila Tillite(?), 1 Pandurra Formation, 2 Tapley Hill Formation and 2 Whyalla Sandstone. Maximum values for different elements are listed to the left of the Box and Whisker plot.

Tapley Hill Formation

- 1780 ppm Cu
- 770 ppm Zn
- 269 ppm Pb
- 81.5 ppm Co
- 60 ppm Ni
- 40.8 ppm As
- 4.2 Ag ppm
- 3.46 ppm Bi (WSB)
- 4.6 ppm Mo
- 1.6 ppm Cd
- 186 ppm V

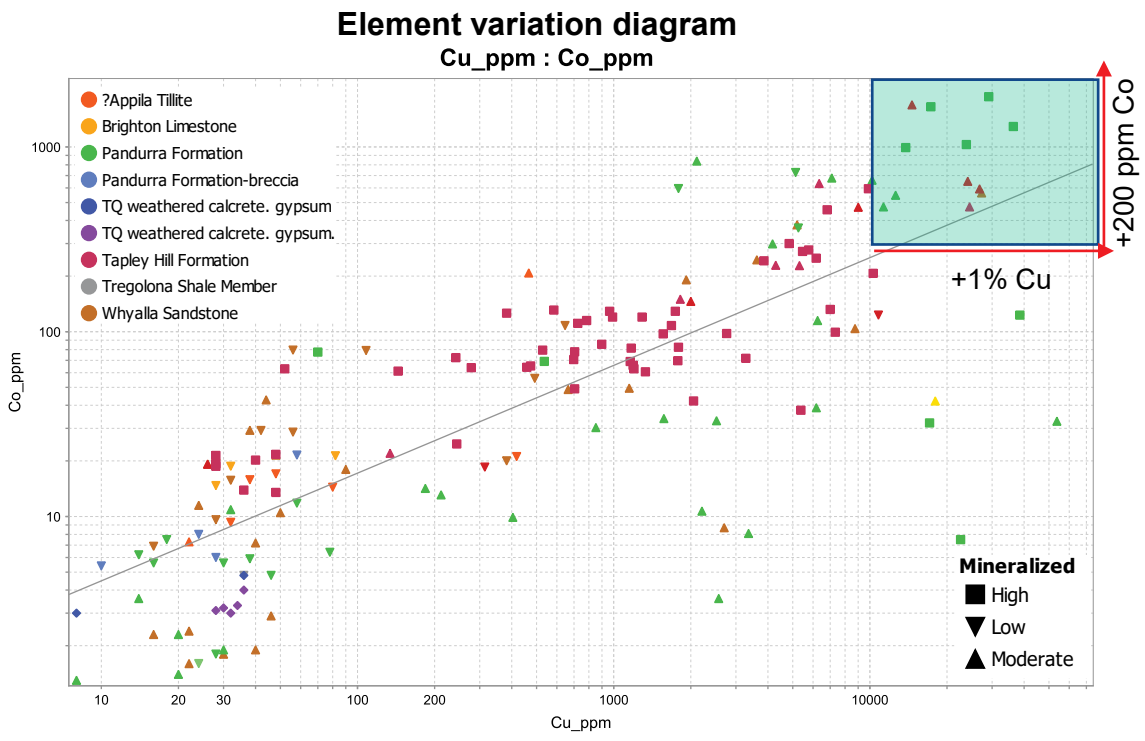


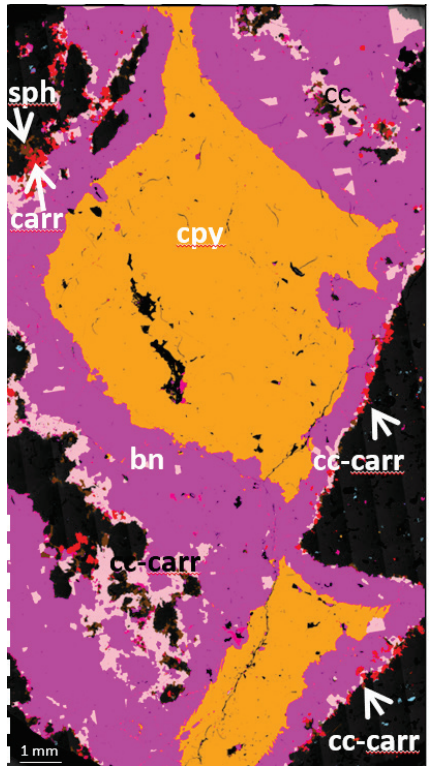
Box and Whisker plot showing trace element concentrations determined by whole-rock geochemistry. The central box represents 50% of the data from quartile 1(Q1) to quartile 3 (Q3); outlier circles and triangles indicate the data that's is further than 1.5 (Q3-Q1) from the box. The whiskers include the extreme outlier value.

Trace elements - Correlation

Copper shows a strong correlation (Spearman) with Pb (0.85), Ag (0.83), Bi (0.82), Co (0.81) and Zn (0.77). >1% Cu and >200 ppm Co, chalcopyrite, carrollite, bornite and chalcocite are typically found in Tapley Hill Formation (shales) and Pandurra Formation (Sandstone); >1000 ppm in Zn is likely from sphalerite intergrown with Cu sulphides (see MLA image).

Gold is not correlated with Cu mineralisation and has a maximum value of 24 ppb (Cattle grid). Mineralisation in the shales is disseminated and in the Sandstone is typically found in sigmoidal veins in the form of infills and filling cracks/fractures.

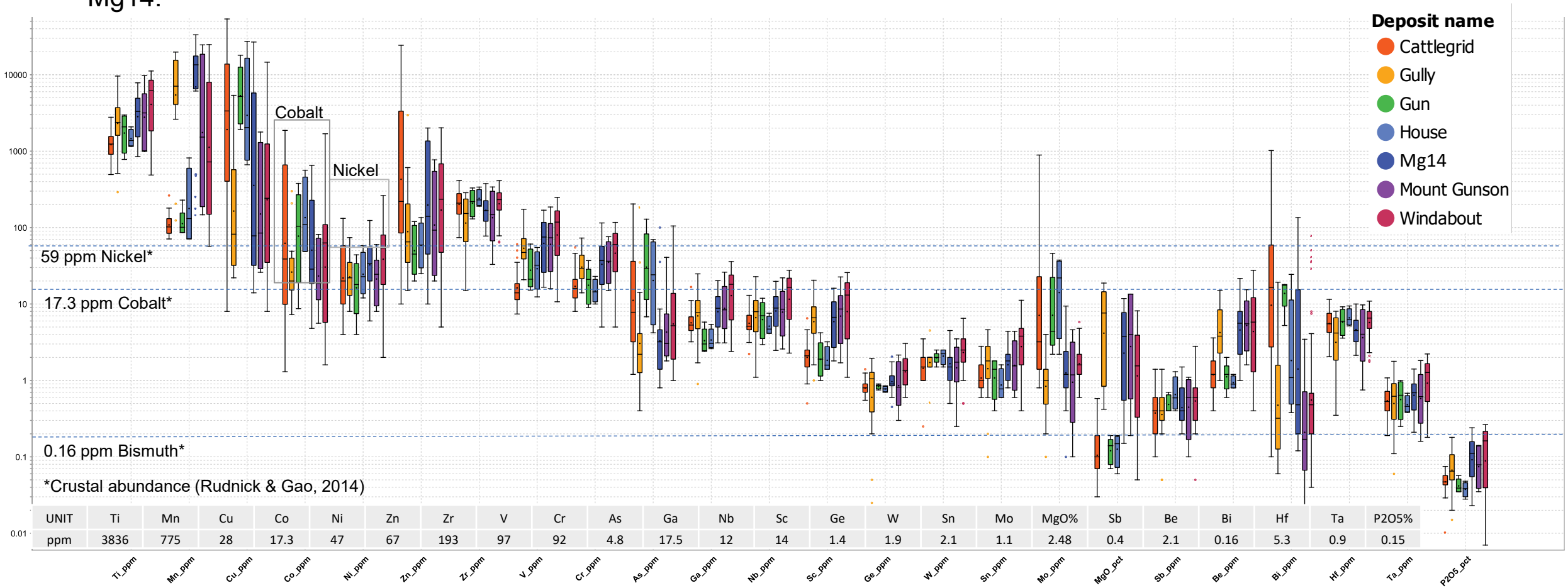




N450/250, 41.20 m. MLA image. *Infill of chalcopyrite (cpy) surrounded by bornite (bn) with chalcocite (cc)-carrollite (carr) halo and bornite intergrown with sphalerite (sph).*

Critical Minerals potential

- Deposits of the Mount Gunson district contain more than 15 times crustal abundance of **copper, cobalt, bismuth, molybdenum and manganese.**
- Elevated values of Cu, Co, Ni, Zn, As, Mo, Pb, and Bi are widely present with highest outliers in the breccia at Cattlegrid deposit (see box plot).
- Ti, Mn, V, Cr, Ga, Nb, Sc, Be, P, and Mg at the Cattlegrid deposit is lower compared to the shale units from Windabout and Mg14.



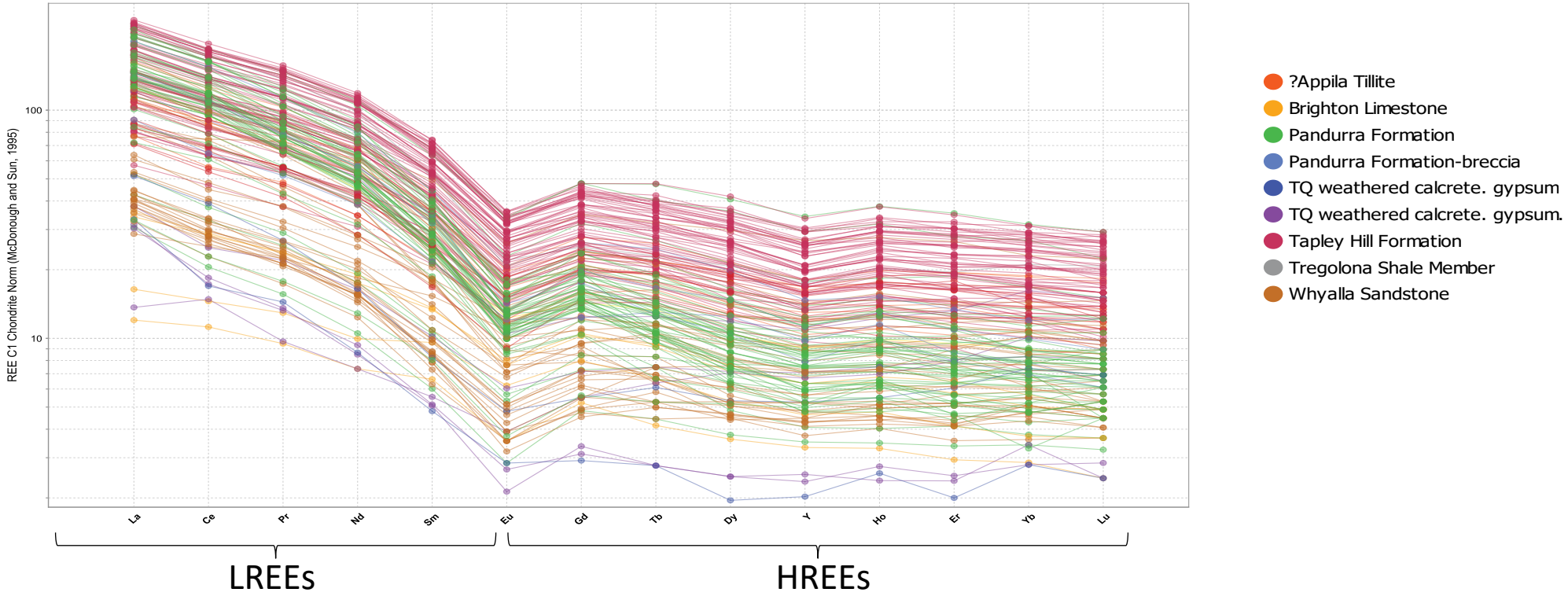
UNIT	Ti	Mn	Cu	Co	Ni	Zn	Zr	V	Cr	As	Ga	Nb	Sc	Ge	W	Sn	Mo	MgO%	Sb	Be	Bi	Hf	Ta	P2O5%
ppm	3836	775	28	17.3	47	67	193	97	92	4.8	17.5	12	14	1.4	1.9	2.1	1.1	2.48	0.4	2.1	0.16	5.3	0.9	0.15

Rare earth element potential

The Mount Gunson district yields relatively low concentrations of rare earth elements (REE) (see spider diagram). REEs are marginally more elevated in the Tapley Hill and the Pandurra formations and therefore REE values can be used to differentiate different lithologies. These units are characterised by

- >100 ppm light rare earths (LREEs)
- Heavy rare earths (HREEs) between 10 to 50 ppm

Other stratigraphic units show less than 80 ppm LREEs and less than 20 ppm HREEs.



Conclusions

- The Mount Gunson region is prospective for the critical minerals Cu, Co, Bi with elevated concentrations of Ag, Zn, Pb, Mo, Ni and Mn.
- Cobalt and bismuth in the Mount Gunson district are hosted by carrollite and emplectite respectively rather than solely with pyrite.
- High copper grades in the Pandurra Formation come from sigmoidal veins infilled with chalcopyrite, chalcocite, carrollite, pyrite, emplectite, and sphalerite; similar mineralisation occurs in the Whyalla Sandstone but is more disseminated and contains moderately high copper values.
- Micro disseminated chalcopyrite, pyrite, carrollite, and micro thin chalcopyrite veins in the Tapley Hill Formation, and disseminated chalcopyrite and pyrite at Windabout deposit.
- Malachite and chalcocite occur in veins within the Whyalla Sandstone but less so than in the Pandurra Formation.
- Download the data for the 6 drill holes: GY 1, GY 13, MG 61, 83/108, T450-050, S250/450.
- Six samples have been taken from the mineralised parts of the Pandurra and Tapley Hill formations from the Cattlegrid and Windabout deposits and analysed using Mineral Liberation Analysis (MLA) and LA-ICP-MS (see summary in poster).
- Element deportment using LA-CIP-MS: Co, Ni are more than 100 ppm, and Cu more than 1% in pyrite and sphalerite. Copper is more than 100 ppm in galena with Co and Ni reaching values of more than 100 ppm in bornite.
- Halite was identified by MLA analysis as matrix infill the Tapley Hill Formation at the Windabout deposit (see MLA photos).
- Eight sulphide minerals confirmed using MLA analysis: chalcopyrite, chalcocite, bornite, carrollite, emplectite, pyrite, galena, and sphalerite.
- REE concentrations in the Pandurra and Tapley Hill formations are typically more than 100 ppm for light rare earths (LREEs) and between 10 to 50 ppm heavy rare earths (HREEs).
- Ti, Mn, V, Cr, Ga, Nb, Sc, Be, P, and Mg at the Cattlegrid deposit are in lower concentrations than at the other deposits, compared to the shale units from Windabout and Mg14 deposits.
- Cu, Co, Ni, Zn, As, Mo, Bi values are higher at the Cattlegrid deposit compared to the other deposits.
- Samples with more than 1% Cu are associated with high Co (max. 1870 ppm), Ag (max. 27.1 ppm), Bi (max. 1020 ppm), Mo (max. 61.6 ppm), Mn (max. 2.38 %), Ni (max. 262 ppm), Pb (max. 1.38 %) and Zn (max. 2.43 %); see new integrated whole-geochemistry (see data).
- The highest maximum Ag value of 39 g/t comes from the Gun deposit, followed by Cattlegrid deposit with 27 g/t Ag (see data).

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