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

# Kalkaroo Cu-Au, Portia Au and Shylock Au deposits of the Curnamona Province

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Geological Survey of South Australia

SOUTH AUSTRALIA

Government of South Australia
Department for Energy and Mining

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October 2024
Report Book 2024/00023


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**Acknowledgement of Country**
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.

**Preferred way to cite this publication**
Terrones M, Fabris A and Zivak D 2024. *Using geochemistry to assess the untapped critical minerals potential of South Australia's deposits: Kalkaroo Cu-Au, Portia Au and Shylock Au deposits of the Curnamona Province*, Report Book 2024/00023. Department for Energy and Mining, South Australia, Adelaide.

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*Kalkaroo deposit – sample 4362432*

# Associated data

Associated data files referred to throughout this report are available for download.

Download the zip file (234 MB)

## File structure

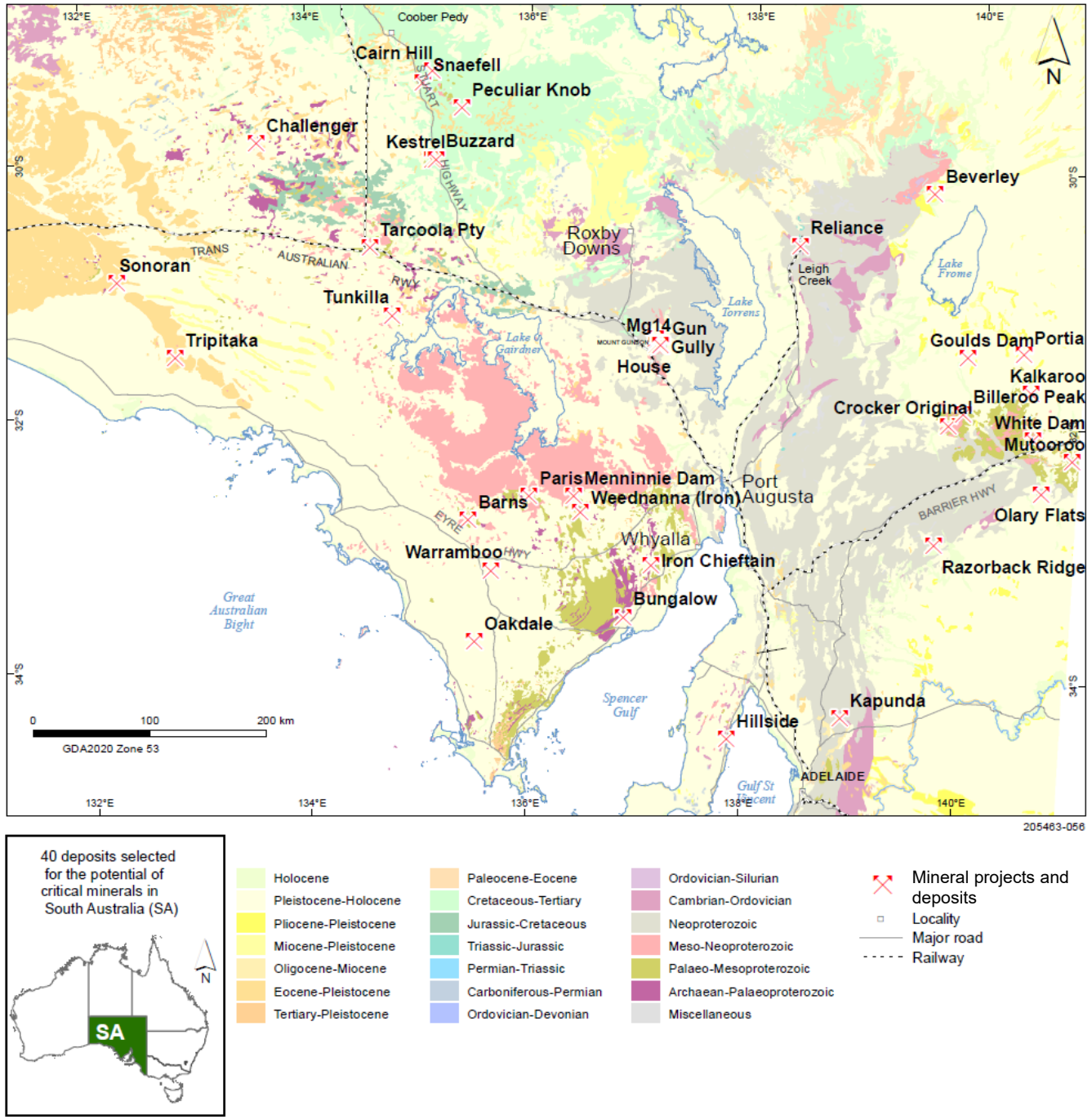
| | | |
|---|---|---|
| Complementary information | Critical minerals project overview.pdf | |
| | Sampling strategy overview.pdf | |
| Legacy data | Correlation-Kalkaroo.xlsx | Geochemistry |
| | Correlation-Portia.xlsx | Geochemistry |
| | Drillhole BE 7 legacy data-Portia.pdf | Geochemistry |
| | Drillholes SHAC035 and SHAC025-SA Geodata.JPG | Existing lithologies of the selected drillholes |
| | Havilah 2020_ADI-RD01-105-GP_App 3 Table 3.xlsx | 9 drillholes - geochemistry - REEs |
| | Legacy data-Kalkaroo.csv | Geochemistry |
| | Legacy data-Portia.csv | Geochemistry |
| | Summary Env 13321-Legacy data of Rare Earths-Kalkaroo.pdf | Summary of Kalkaroo REE study |
| New data | Correlation-all data.xlsx | |
| | Integrated Kalkaroo and Portia.xlsx | Lithologies, stratigraphic units and new geochemistry |
| Further reading | Env 03713.pdf | |
| | Env 11335.pdf | |
| | Env 13321.pdf | |

# Critical Minerals South Australia – project overview

Historically, most geochemical data collected from drillholes by explorers in the State comprised assays for target commodities and pathfinder elements, thus the potential for the full suite of critical minerals in existing deposits remains unknown. For this reason, re-sampling and re-assaying of existing drill material from major projects in South Australia was undertaken to assess their critical mineral potential.

40 deposits were selected for review of their critical mineral potential in South Australia, representing a variety of mineralisation styles. Reviews involved using historic company records and where necessary, sampling and re-assaying of relevant drillholes available in the South Australia Drill Core Reference Library.

More information in associated data:
- *Critical minerals project overview.pdf*



# Sampling strategy

Sample selection from drillholes focused on mineralised zones of selected deposits, as it these were deemed more likely to host elevated concentrations of critical minerals.

Observation of mineralisation and alteration guided sample selection and aided interpretation of newly collected geochemical data and mineral paragenesis.

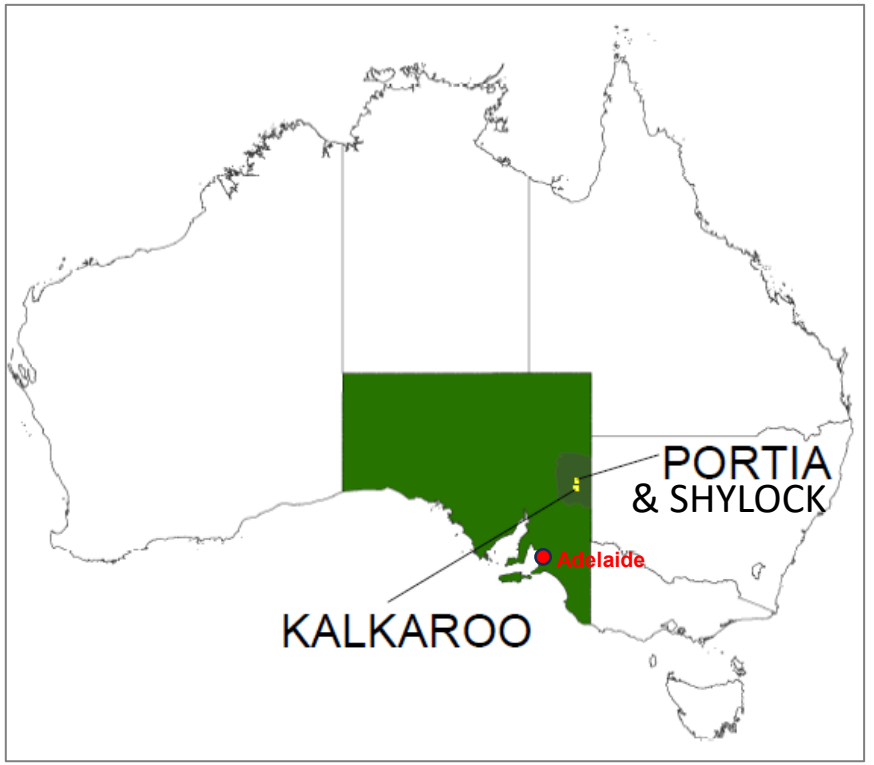
More information in associated data:
- *Sampling strategy overview.pdf*

*Sampling at the South Australia Drill Core Reference Library at Tonsley, 2023.*

# Kalkaroo, Portia and Shylock

## Introduction

- Kalkaroo, Portia and Shylock are located in the Curnamona Province, ~400 km north of Adelaide, South Australia, ~90 km west-northwest of Broken Hill, New South Wales.
- **Cu-Au-Mo-Co Kalkaroo deposit:** one of the larger undeveloped open pitable copper deposits in Australia on a 0.89 % CuEq Ore Reserve basis. Cu-Au-Mo-Co (As-F-LREE-U) mineralisation was discovered in the late 1970s below 50–60 m of Cenozoic sedimentary cover. The project is held by Kalkaroo Copper Pty Ltd, a wholly owned subsidiary of Havilah Resources Ltd.
- **Gold-rich Portia and Shylock deposits:** Benagerie Gold and Copper Pty Ltd (BGC) is the current owner of the Portia Mine. Portia and Shylock include basement-hosted Au-Cu and high grade eluvial/alluvial Au.
- Use link and MinDep number for further information:
  Quick Search (sarig.sa.gov.au)




*Location of Kalkaroo, Portia and Shylock deposits.*

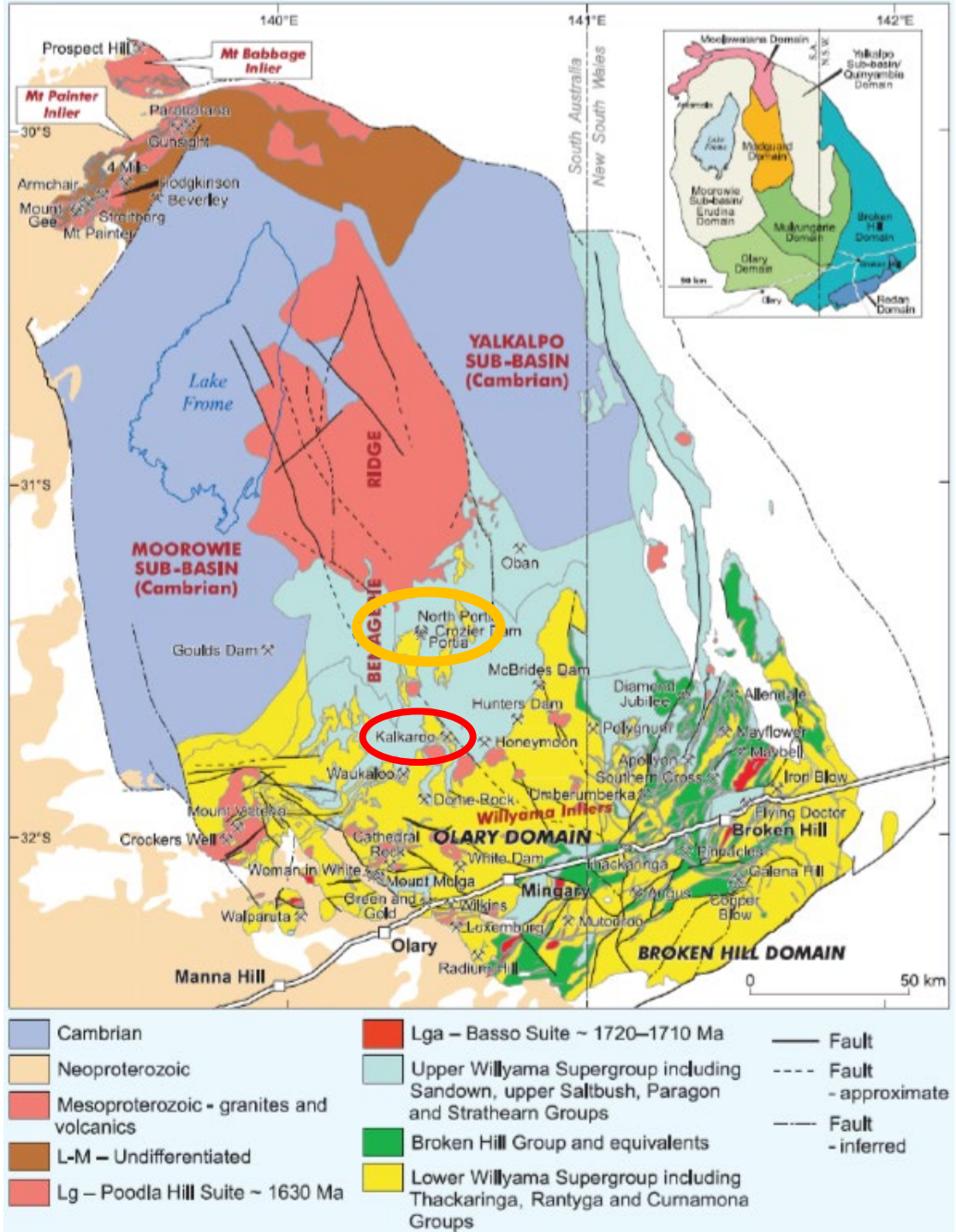
| Deposit name | Deposit number (MinDep) | Current status |
|---|---|---|
| Kalkaroo | 8455 | Deposit. Not worked. |
| Portia | 4504 | Deposit. Care and maintenance. |
| Shylock | 8471 | Occurrence. Not worked. |

# Kalkaroo, Portia and Shylock

## Introduction

**Kalkaroo:** located in the central Curnamona Province (red circle on map) with mineralisation mostly confined to a sequence of pyritic and carbonate-bearing metasediments of the Willyama Supergroup. The Kalkaroo deposit is located around the northern portion of a structural dome and along a cross-cutting fault. Ore zones include stratabound and breccia-hosted mineralisation.

**Portia and Shylock:** located in the central Curnamona Province and around the northern portion of the Benagerie Dome (orange circle on map). Gold mineralisation occurs in clay at the base of Cenozoic units (alluvial Au), within saprolite developed in Willyama Supergroup metasediments (eluvial Au), and as veins and associated with copper sulphides in highly altered metasediments of the Willyama Supergroup.




*After Conor 2006*

# Kalkaroo

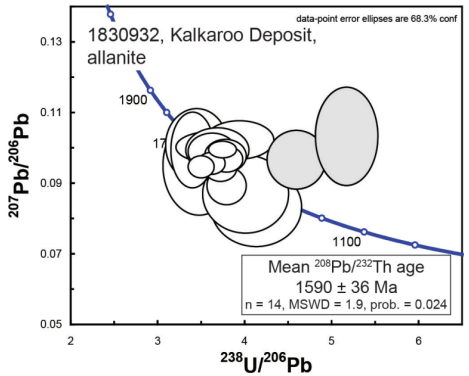
# Mineralisation and alteration

Primary mineralisation is chalcopyrite, pyrite, minor molybdenite and gold.

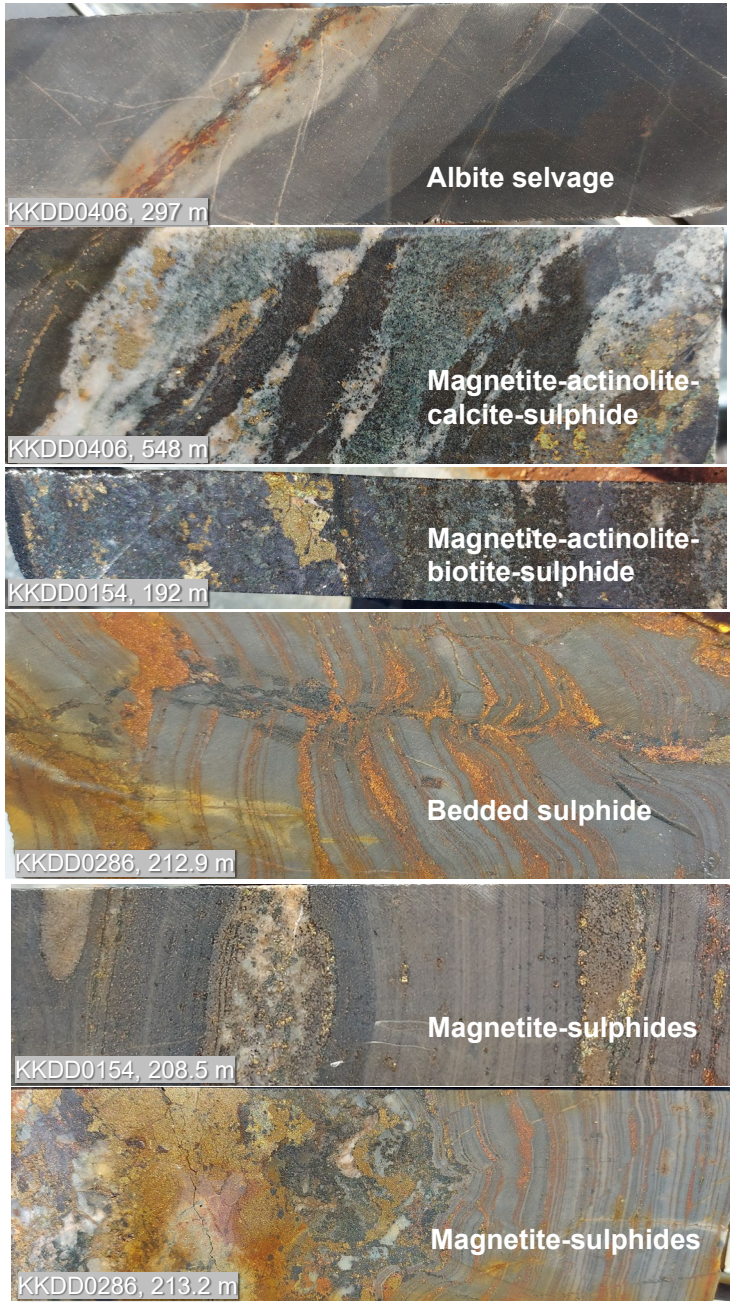
Multiple stages of veining and alteration: sodic (albite), potassic (biotite, k-feldspar), iron (magnetite), calc-silicate (epidote, hedenbergite, garnet). Copper-gold mineralisation is associated with bedded sulphides and quartz-carbonate (+/- magnetite, biotite, actinolite) filled breccia zones with related stockwork of sulphide-bearing veins, which are interpreted to be the conduit for the mineralising fluids (see drill core images).

Supergene mineralisation is developed in the weathering profile above the primary zone, in the form of chalcocite, native copper, gold and minor malachite commonly forming sub-horizontal blankets.

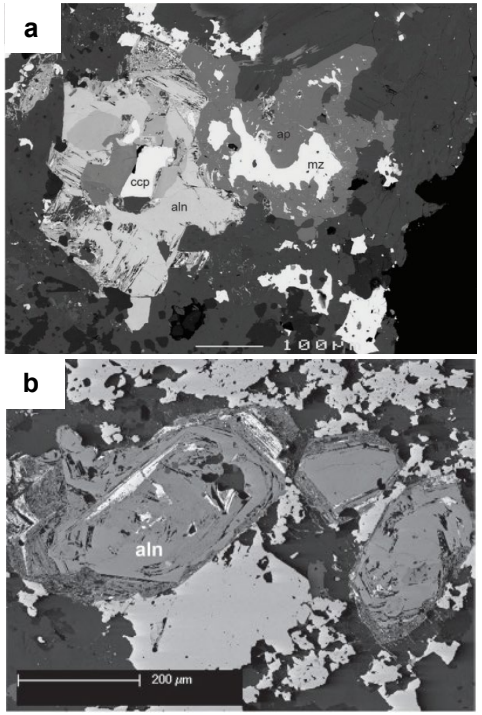
Copper mineralisation within the Kalkaroo deposit has an age of 1590 ± 36 Ma ($^{208}Pb/^{232}Th$ age) based on allanite intergrown with chalcopyrite (Reid and Jagodzinski 2012; see SEM images on the right).




*In situ SHRIMP (sensitive high resolution ion microprobe) U-Th-Pb geochronology for Kalkaroo deposit (Reid and Jagodzinski 2012).*




*Drill core images of mineralisation and alteration logged at Kalkaroo (images: A Fabris 2024).*




***a.*** *Back-scatter electron image of sample 1830932 showing monazite (mz) grain inter-grown with apatite (ap).* ***b.*** *Allanite (aln) from sample 1830932, KND001, 265.64–265.65 m (Reid and Jagodzinski 2012).*

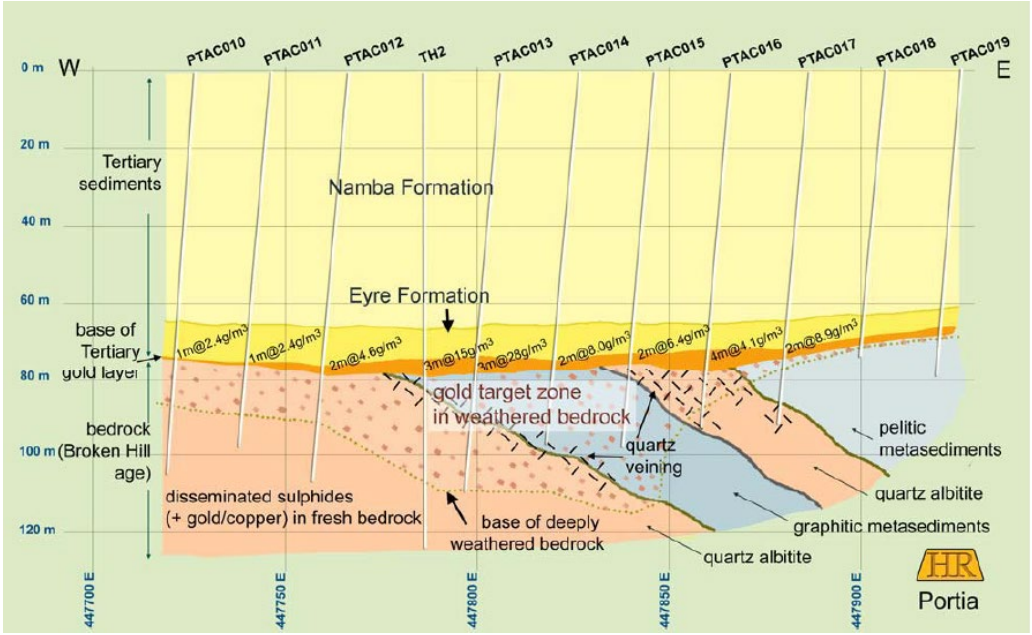
# Portia and Shylock

## Mineralisation and alteration

At Portia, gold mineralisation predominantly occurs in a distinctive grey, friable clayey layer of the latest Paleocene to Middle Eocene Eyre Formation that occurs between the underlying saprolite and overlying Early Miocene to Pliocene Namba Formation clays (see cross section).

High-grade gold also occurs in veins in basement rocks (grades of >200 g/t) and as secondary mineralisation at the top of weathered basement and the base of Cenozoic sediments.

Shylock is located to the northwest of the Portia deposit and hosts similar styles of mineralisation to Portia, with very high-grade gold intersections reported including 23 m of 79 g/t Au in drillhole BEN 677.




*Cross section of Portia deposit by Havilah Resources (HR).*

# Kalkaroo

# Resource information

- Total mineral resource – JORC mineral resource: 245 Mt at 0.49 % Cu and 120 ppm Co and 0.36 g/t Ag (7 March 2018).
- Measured JORC resources: 62.5 t @ 0.52 % Cu, 0.48 g/t Au, containing 325,000 t Cu and 967,742 oz Au and an inferred resource of 4.5 Mt @ 615 ppm Mo containing 2,767,500 kg Mo (May 2011).

| Project | Classification | Tonnes (Mt) | Copper % | Gold g/t | Copper tonnes (Kt) | Gold ounces (Koz) |
|---|---|---|---|---|---|---|
| Kalkaroo [1] | Proved | 90.2 | 0.48 | 0.44 | 430 | 1,282 |
| | Probable | 9.9 | 0.45 | 0.39 | 44 | 125 |
| | **Total** | **100.1** | **0.47** | **0.44** | **474** | **1,407** |

| Project | Classification | Resource Category | Tonnes | Copper % | Cobalt % | Gold g/t | Copper tonnes | Cobalt tonnes | Gold ounces |
|---|---|---|---|---|---|---|---|---|---|
| Kalkaroo [2] | Measured | Oxide Gold Cap | 12,000,000 | | | 0.82 | | | |
| | Indicated | Oxide Gold Cap | 6,970,000 | | | 0.62 | | | |
| | Inferred | Oxide Gold Cap | 2,710,000 | | | 0.68 | | | |
| | **Total** | **Oxide Gold Cap** | **21,680,000** | | | **0.74** | | | **514,500** |
| | Measured | Sulphide Copper-Gold | 85,600,000 | 0.57 | | 0.42 | | | |
| | Indicated | Sulphide Copper-Gold | 27,900,000 | 0.49 | | 0.36 | | | |
| | Inferred | Sulphide Copper-Gold | 110,300,000 | 0.43 | | 0.32 | | | |
| | **Total** | **Sulphide Copper-Gold** | **223,800,000** | **0.49** | | **0.36** | **1,096,600** | | **2,590,300** |
| | | **Total Kalkaroo** | **245,480,000** | | | | **1,096,600** | | **3,104,800** |
| | Inferred | Cobalt Sulphide[3] | 193,000,000 | | 0.012 | | | 23,200 | |

1. *Details released to ASX: 18 June 2018 (Kalkaroo) – 31 Jul – Havilah's 2021 annual report.*
2. *Details released to the ASX: 30 January 2018 and 7 March 2018 (Kalkaroo) – 31 Jul – Havilah's 2021 annual report.*
3. *Note that the Kalkaroo cobalt Inferred Resource is not added to the total tonnage – 31 Jul – Havilah's 2021 annual report.*

# Portia

# Resource information

- Production expressed as metal in doré (source: Major Mines & Projects | Portia Mine (miningdataonline.com)):

| Commodity | Units | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| Gold | OZ | 4,962 | 19,315 | 8,626 |

- Operation metrics:

| Metrics | 2016 | 2017 | 2018 |
|---|---|---|---|
| Ore tonnes mined | 164,000 t | 19,315 | 203,000 t |
| Waste | 5,206,000 bcm | 341,000 t | 567,000 bcm |
| Tonnes processed | 32,000 wmt | 3,886,000 bcm | 339,000 wmt |

wmt = wet metric tonnes
bcm = billion cubic metres

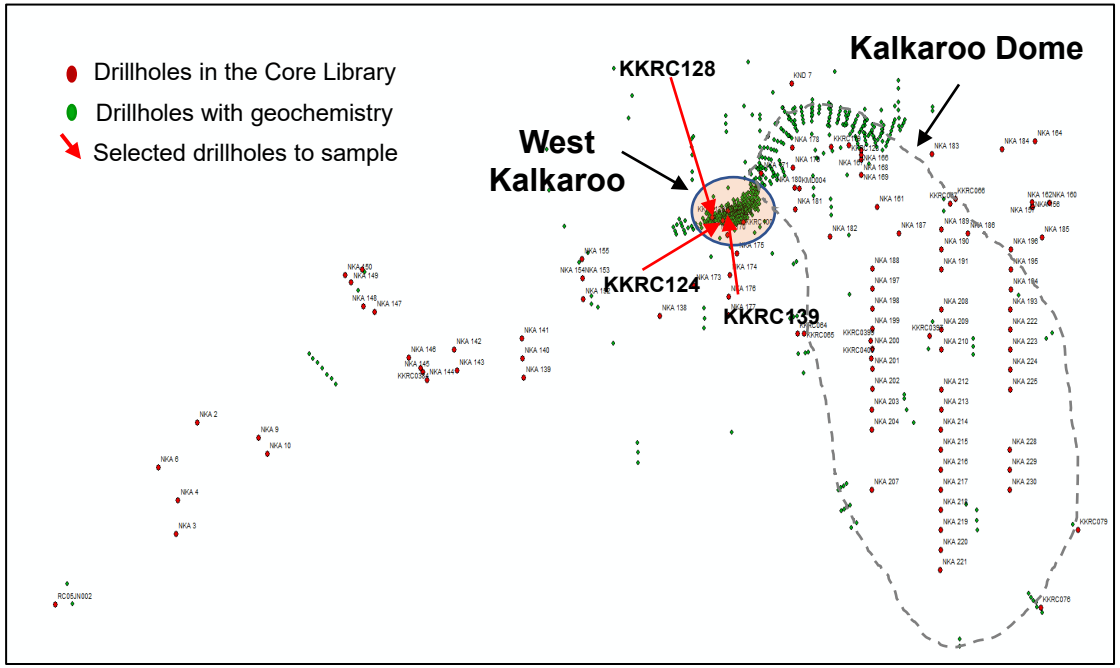
- JORC inferred resources by 2010:

| Category | Tonnage | Commodity | Grade | Contained Metal |
|---|---|---|---|---|
| Inferred | 720,000 t | Gold | 2.9 g/t | 67,000 oz |

# Kalkaroo

## Legacy data - overview

- Extensive assay results for Ag, As, Au, Bi, Co, Cu, Mo, Ni, Pb, S, Sb, U, Zn. Additional elements Ba, Be, Cd, Cr, Ga, La, Sc, Sr, Te, Th, Tl, V and W for West Kalkaroo. Occasional assay results for Ce and Y.
- Main missing elements are major elements, complete REEs and the critical minerals Li, Ge, Hf, He, In, Nb, Pd, Pt, Re, Ta and Zr.
- **Findings:** Copper mineralisation is associated with Au, Ag, As, Bi, Co, Mo, Ni, Pb, Sb, U, W and Zn. The median value of La (only REE with a significant number of assays; West Kalkaroo) is 45 ppm with a maximum of 5,540 ppm indicating the potential for significant REE enrichment.
- **Note:** Recent evaluation of the REE potential at West Kalkaroo was undertaken by Havilah Resources (ENV13321) based predominantly on portable XRF element values. REE results indicate TREE values of up to ~0.66% within the saprolite zone at West Kalkaroo. REE mineralisation was found to be associated with bastnasite ((Ce, La, Y) $CO_3F$).
  More information in associated data:
  *- Env 13321.pdf*
  *- Summary Env 13321-Legacy data of Rare Earths-Kalkaroo.pdf*
  *- Havilah 2020_ADI-RD01-105-GP_App 3 Table 3.xlsx*




*Drillhole location for the Kalkaroo deposit.*
*Note: Limited drillholes intersecting high-grade mineralisation are available at the South Australia Drill Core Reference Library.*

- **Focus of further analysis:** REE, Ge, Hf, In, Li, Nb, Pd, Pt, Re, Ta.

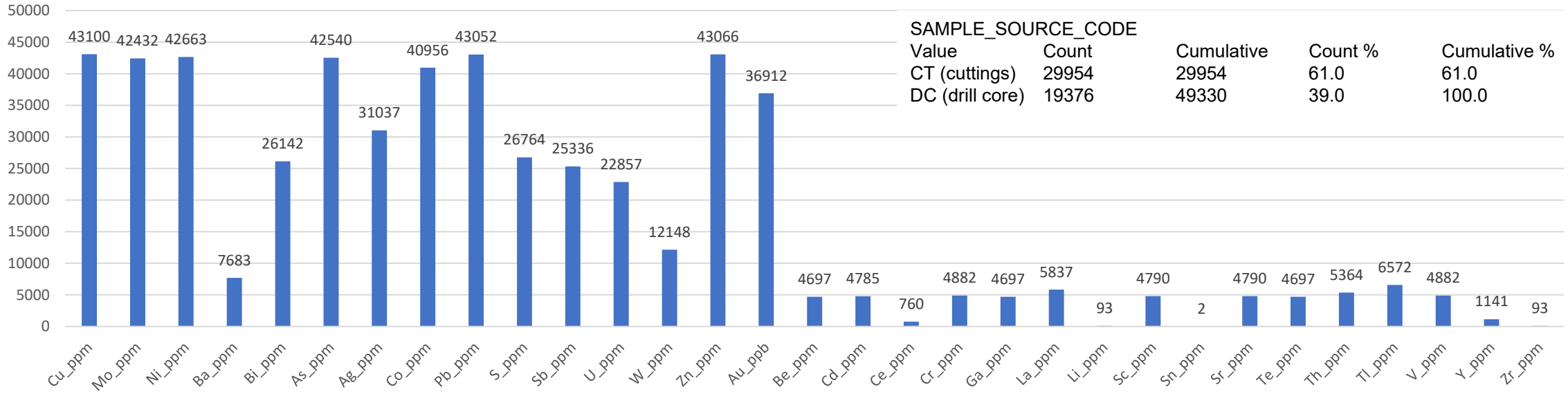
# Kalkaroo

# Legacy data: drillhole geochemistry

- 49,330 geochemical samples from drill core (DC) and drill cuttings (CT) collected between 1989 to 2020.
- Drill cuttings (CT): 421 drillholes; drill core (DC): 199 drillholes.
- 31 trace elements available: copper, molybdenum, nickel, barium, bismuth, arsenic, silver, cobalt, lead, sulphur, antimony, uranium, tungsten, zinc, gold, beryllium, cadmium, cerium, chromium, gallium, lanthanum, lithium*, scandium, tin*, strontium, tellurium, thorium, thallium, vanadium, yttrium, and zirconium*.

  * Assays distal to Kalkaroo deposit

**Number of samples per element**



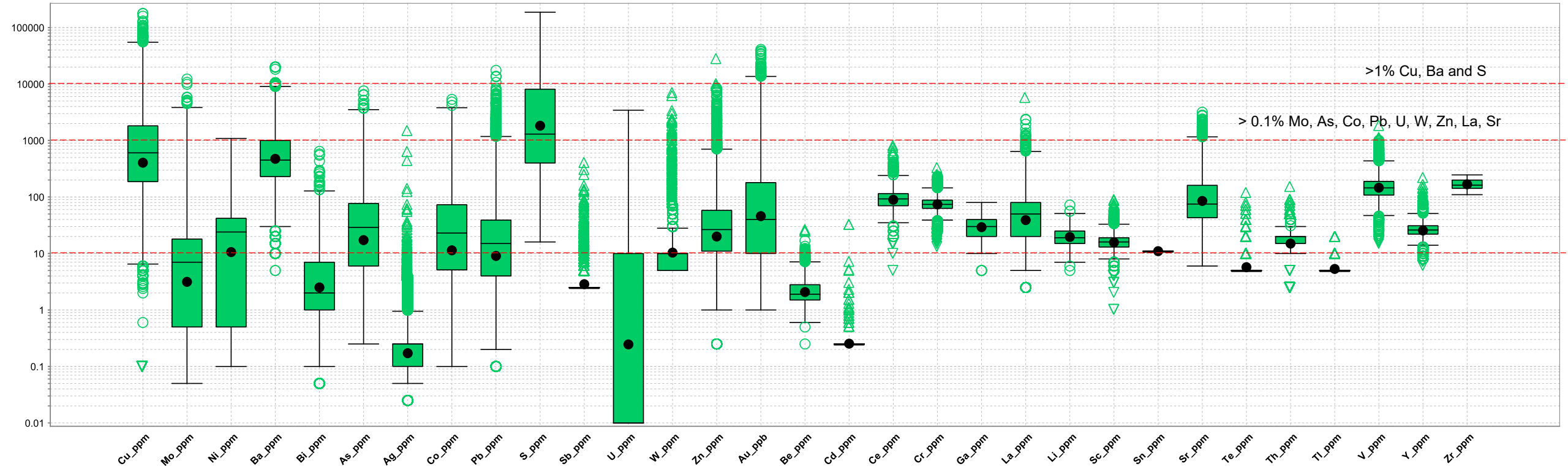

SAMPLE_SOURCE_CODE

| Value | Count | Cumulative | Count % | Cumulative % |
|---|---|---|---|---|
| CT (cuttings) | 29954 | 29954 | 61.0 | 61.0 |
| DC (drill core) | 19376 | 49330 | 39.0 | 100.0 |

# Kalkaroo

## Legacy data: drillhole geochemistry

- 31 elements with more than 500 results (excluding Li, Sn and Zr where data is distal to Kalkaroo deposit).
- Correlation coefficient: Cu vs Co = 0.21, Cu vs Bi = 0.03, Cu vs Ag = 0.041, Cu vs Pb = 0.006 and Cu vs Zn = 0.018.
  More information in associated data: *Legacy data-Kalkaroo.csv; Correlation-Kalkaroo.xlsx*
- The critical minerals Bi, Co, Mo, Sb, W show significant values (>100 times crustal abundance) at Kalkaroo.
- La and Ce show outliers of ≥1000 ppm.

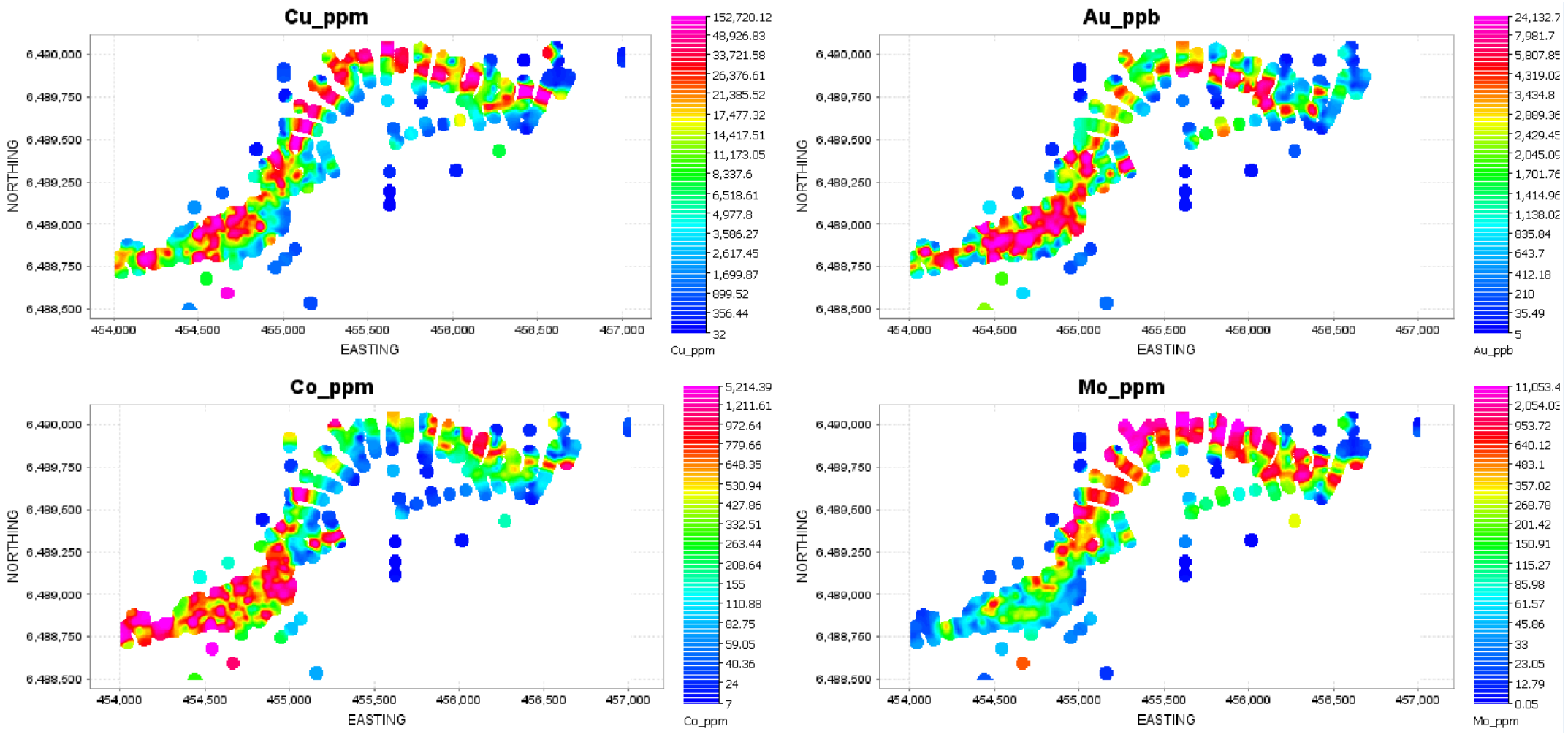



*Box plots of Kalkaroo legacy geochemical data.*

# Kalkaroo

## Legacy data: main commodities

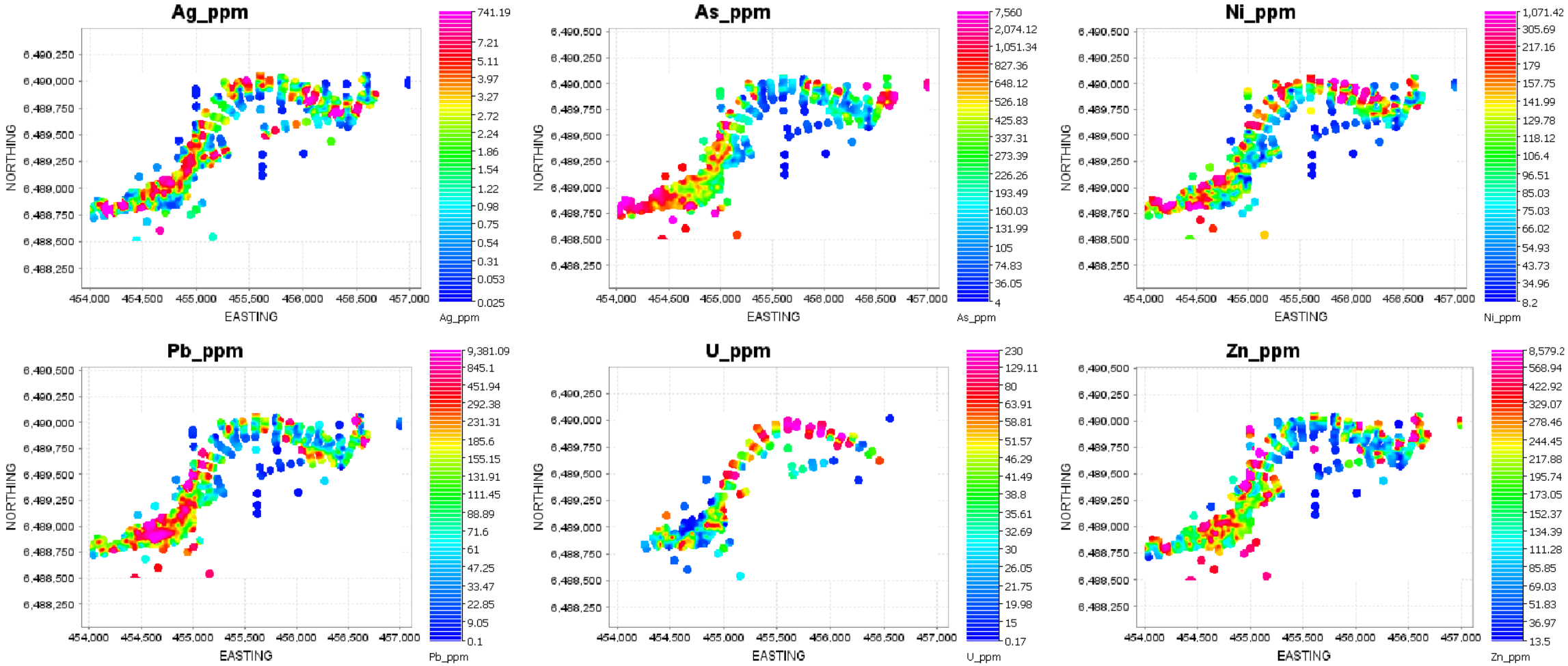
- Gold shows a moderate spatial relationship to Cu but with highest values clustered at West Kalkaroo and the northeast portion of the Kalkaroo Dome. Cobalt values are highest at West Kalkaroo. High Mo values are associated with the northern Kalkaroo Dome.



# Kalkaroo

## Legacy data: trace elements

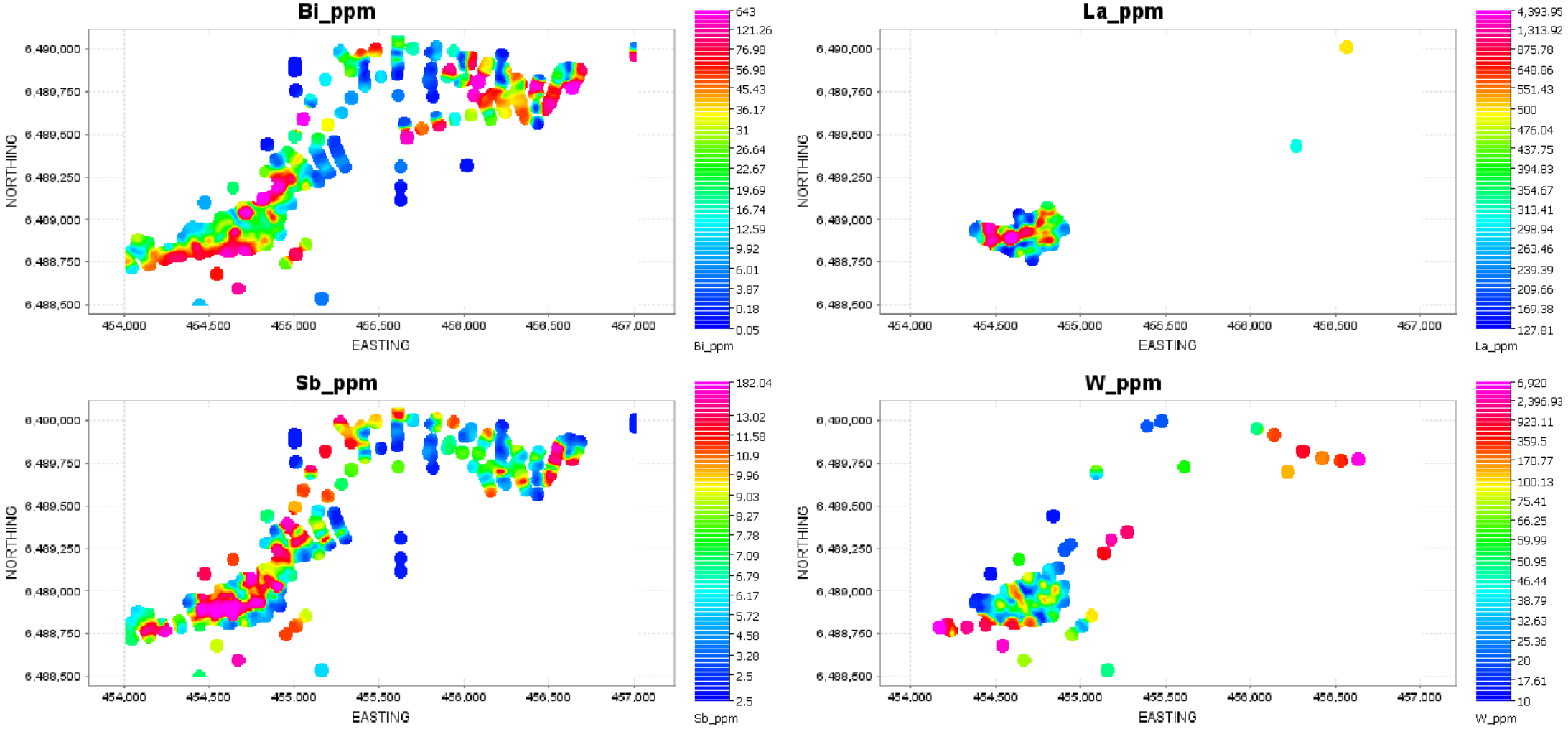
- Highest As and Pb values are associated with West Kalkaroo. The distribution of Zn is similar to Pb however highest values occur around the northwest of the Kalkaroo Dome. Elevated Ag and Ni values occur around the Kalkaroo Dome but are highest at West Kalkaroo and the northeast section of the Kalkaroo Dome. Uranium is associated with the Kalkaroo Dome.



# Kalkaroo

## Legacy data: critical minerals

- The distribution of high Bi values are similar to regions with high Au. Highest Sb results occur at West Kalkaroo and along the far northern extent of the Kalkaroo Dome. Lanthanum assays are restricted to West Kalkaroo with high values indicating potential for REE mineralisation.

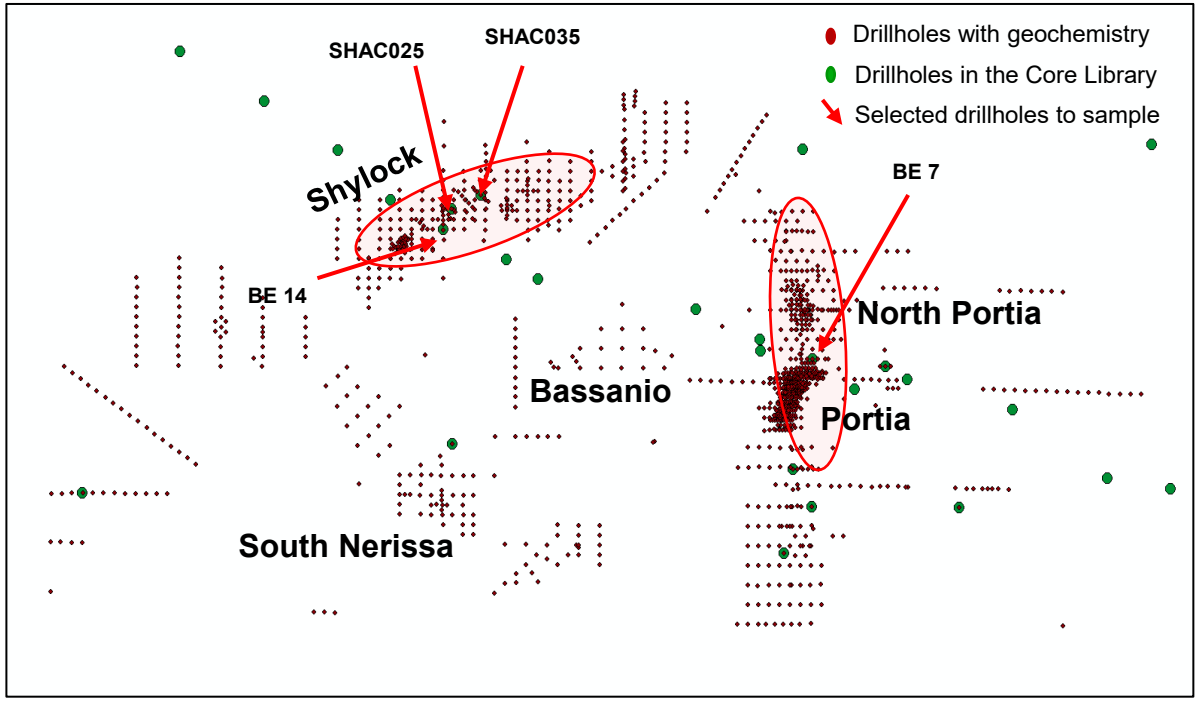


# Portia region

## Legacy data - overview

- **Portia:** Extensive assay results for Ag, As, Au, Bi, Cd, Co, Cu, Mo, Ni, Pb, Sb, V and Zn. Moderate coverage of assay results for Ba, La, S, Se, Tl, U and W. Limited assay results for Be, Ce, La, Cr, Ga, Hg, La, Nb, Sc, Sr, Sn, Ta, Te and Th.
- **Shylock:** Extensive assay results Ag, As, Au, Cu, Mo, Pb and Zn. Moderate coverage of assay results for Ba, Be, Bi, Cd, Ce, Co, La, Nb, Ni, S, Sb, Sc, Se, Sr, Ta, Th, V and W. Limited assay results for U.
- Main missing elements are major elements, complete REEs and the critical minerals Li, Ge, Hf, He, In, Nb, Pd, Pt, Re, Ti and Zr.
- 4 of 29 drillholes in the core library have HyLogger™ data.
  Geochemistry: 10 of 109 drillholes in the core library have geochemistry.
- Portia and Shylock are multi-commodity occurrences.
- **Findings:** Copper mineralisation is associated with Au, Ag, As, Bi, Co, Mo, Ni, Pb and Zn, with a moderate association with elevated Sb, V and W; Moderate LREE anomalism identified but insufficient available data to assess REE potential.
- **Focus of further analysis:** REE, Ge, Hf, In, Li, Nb, Pd, Pt, Re.

More information in associated data:
- *Drillhole BE 7 legacy data-Portia.pdf*
- *Drillholes SHAC035 and SHAC025-SA Geodata.jpg*

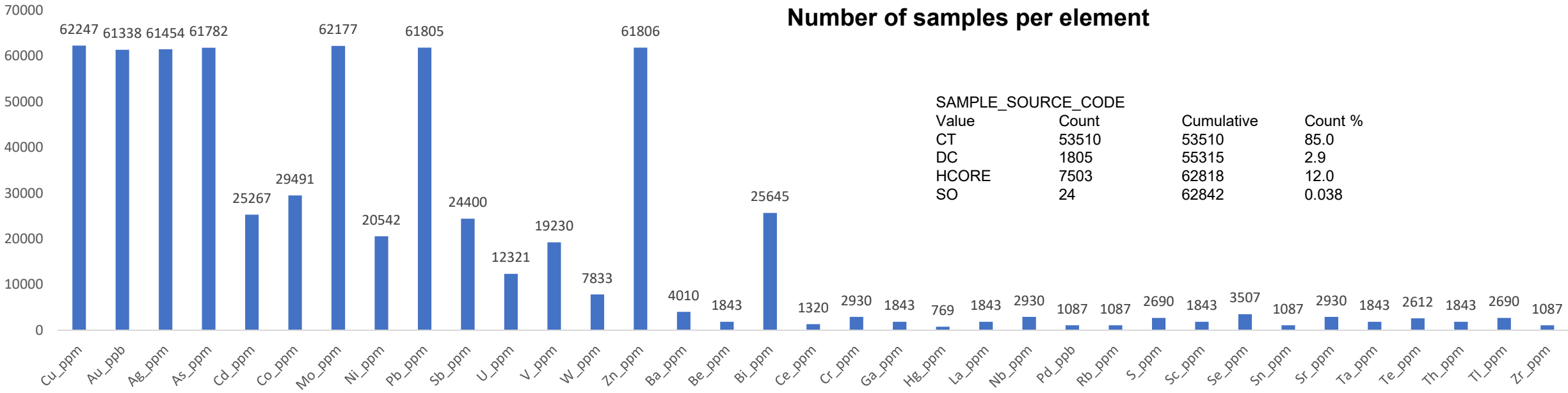



*Drillhole location in Portia region.*
*Note: Limited drillholes intersecting high-grade mineralisation are available at the South Australia Drill Core Reference Library.*

# Portia region

## Legacy data: geochemistry

- 62,818 geochemical samples from drill core (DC), cuttings (CT) and half core (HCORE) from 1992 to 2017.



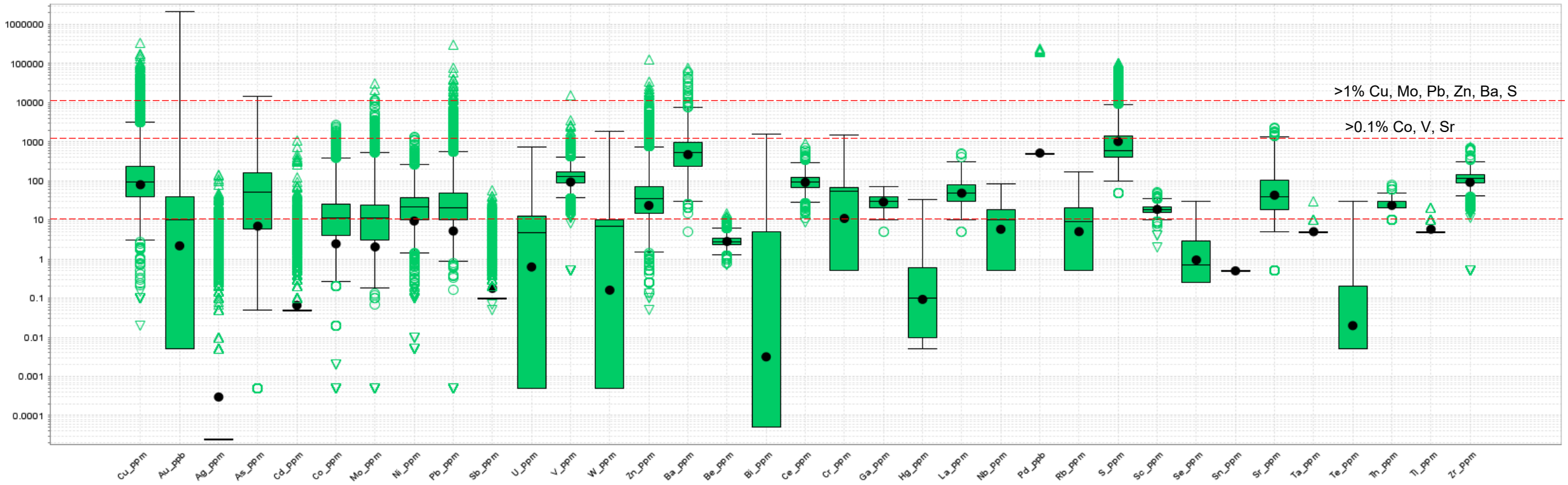

SAMPLE_SOURCE_CODE

| Value | Count | Cumulative | Count % |
|---|---|---|---|
| CT | 53510 | 53510 | 85.0 |
| DC | 1805 | 55315 | 2.9 |
| HCORE | 7503 | 62818 | 12.0 |
| SO | 24 | 62842 | 0.038 |

# Portia region

# Legacy data: geochemistry

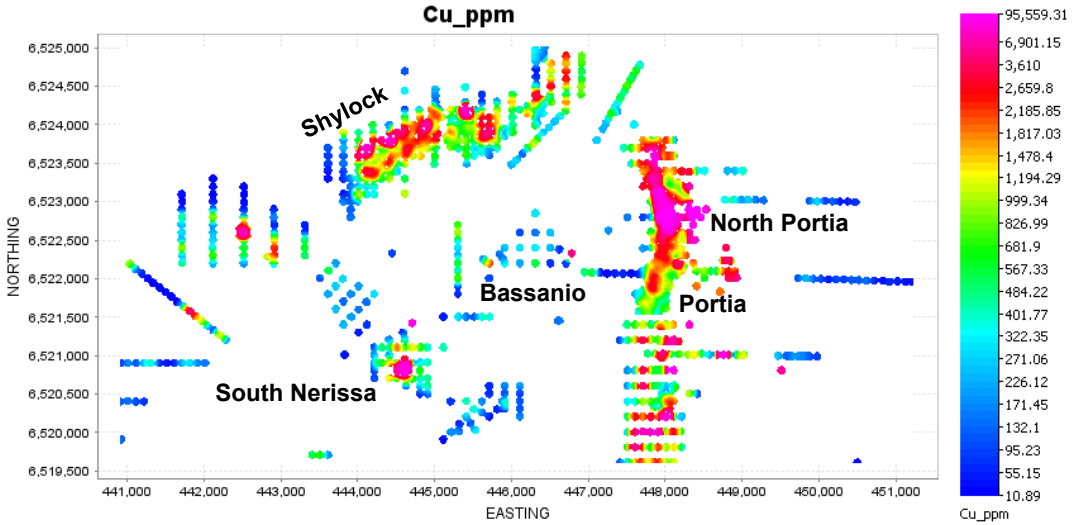
- 35 elements from more than 500 samples. Cu intersection: maximum 1 m @ 33.8 % Cu – BEN0395 from 91 m (not in core library).
- Correlation coefficient: Cu vs Co = 0.11, Cu vs Bi = 0.33, Cu vs Ag = 0.16, Cu vs Pb = 0.0049 and Cu vs Zn = 0.0015.
  More information in associated data: *Legacy data-Portia.csv; Correlation-Portia.xlsx*
- The critical minerals Bi, Co, Mo, Sb, V and W show significant values (>100 times crustal abundance) in the Portia region.
- La and Ce show outliers up to 500 and 900 ppm respectively. The maximum value of Au is 2109.6 ppm
  (Eyre Formation; Drillhole PTDD207, 83–83.7 m; Fire assay, AES method).

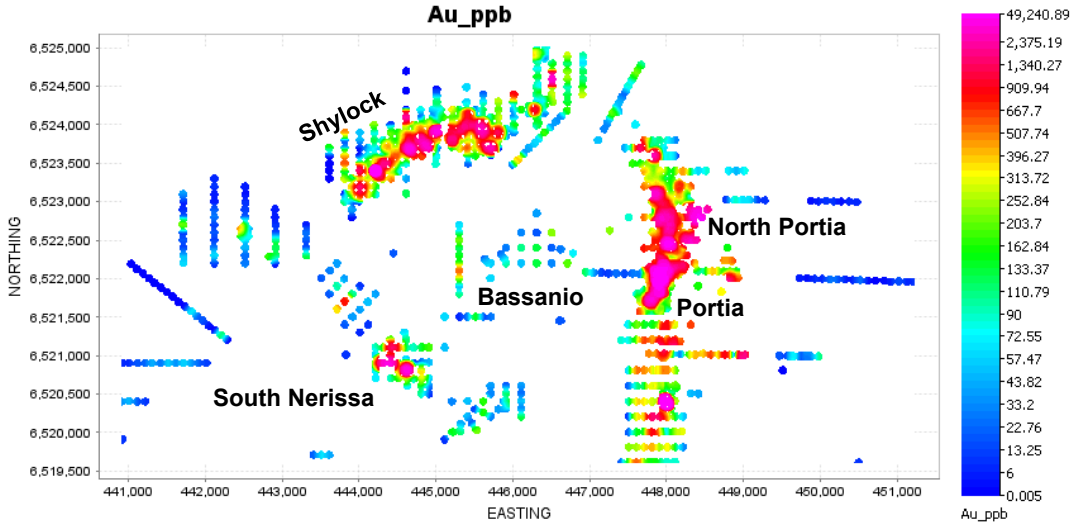


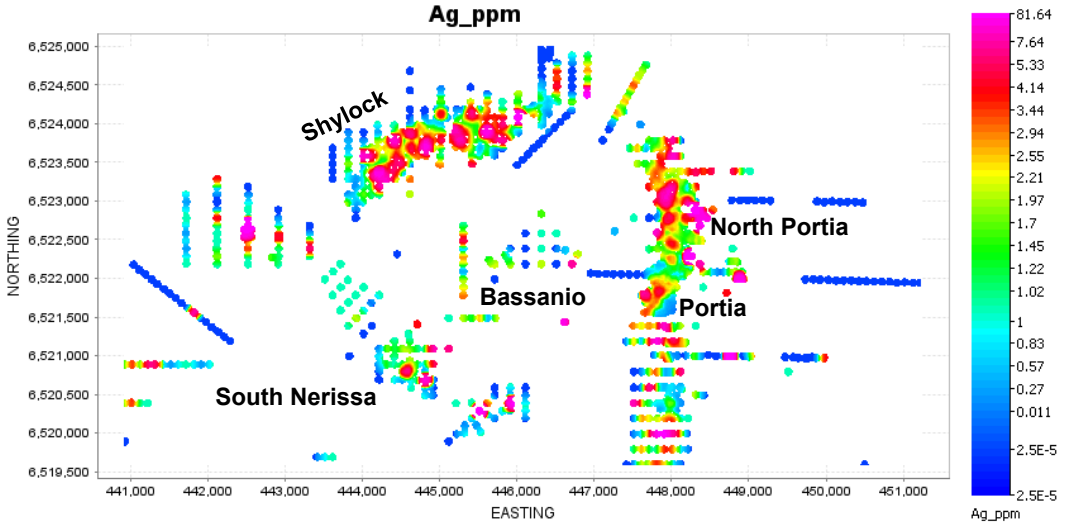

*Box plots of Portia region legacy geochemical data.*

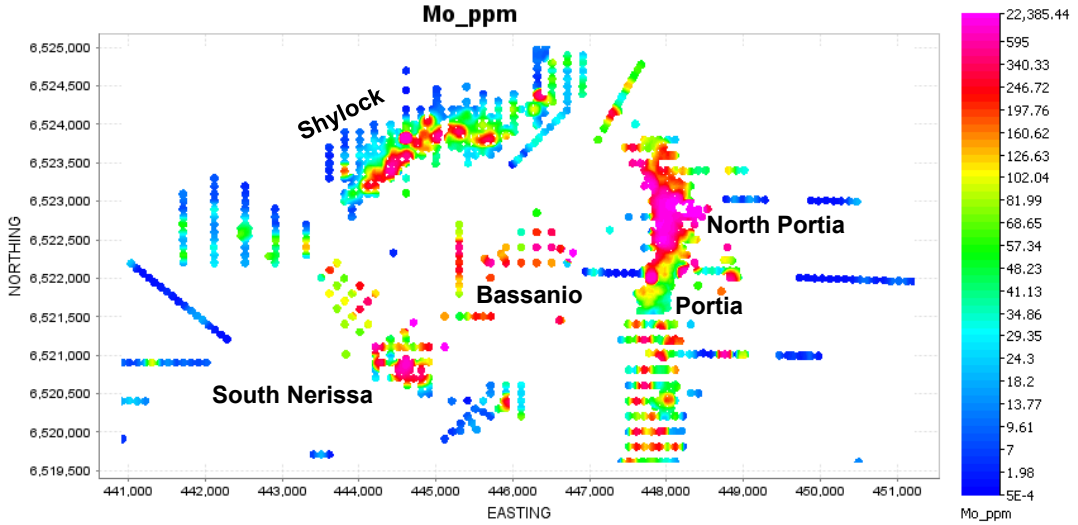
# Portia region. Legacy data: main commodities

- Highest Au concentrations occur at Portia, while highest Cu-Mo-Ag concentrations are at North Portia.
- There is general spatial coincidence between Cu, Au, Ag and Mo. Exceptions include high Mo values within the central Benagerie Dome (Bassanio and South Nerissa) and a distinct zone (to the northwest) of Cu-Ag mineralisation at Shylock which is not evident in Au and Mo values.



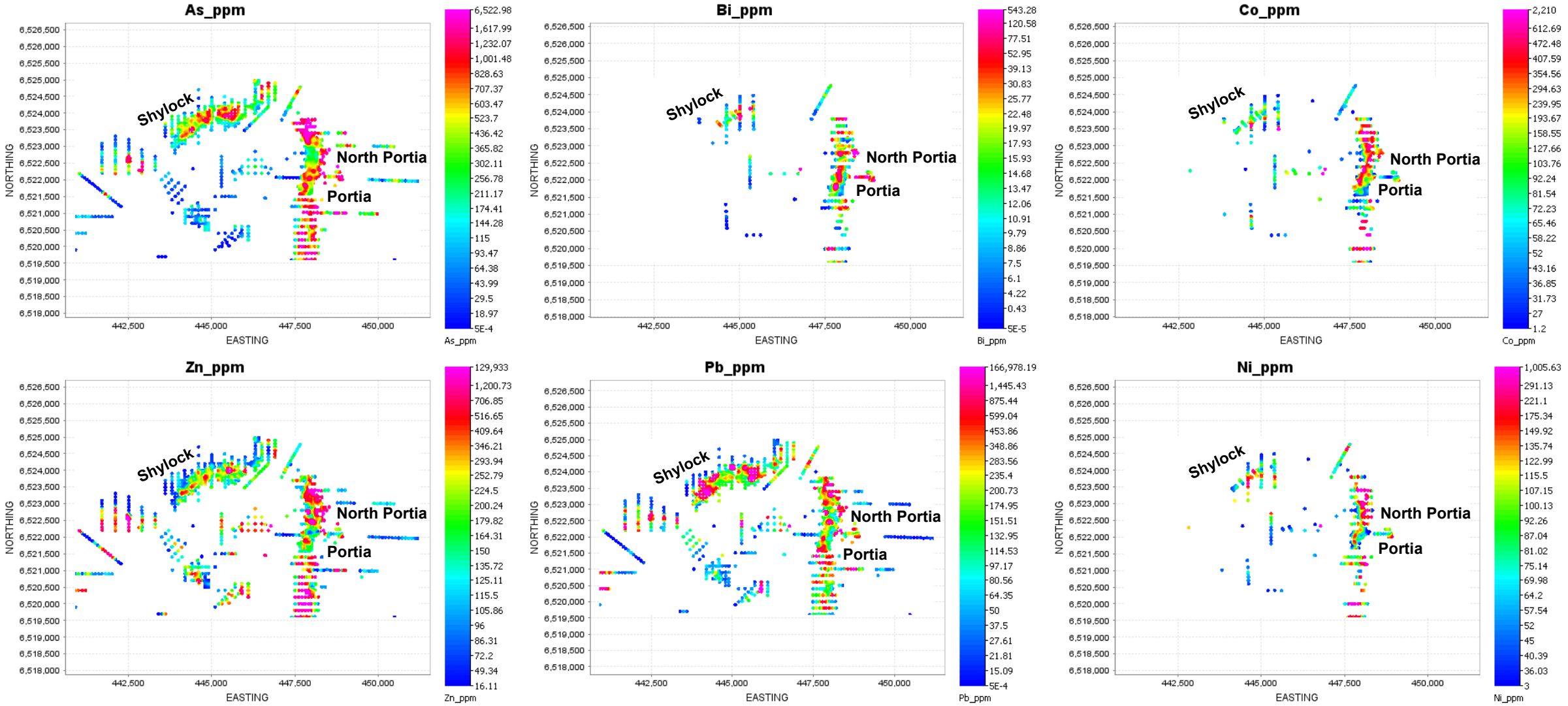



# Portia region

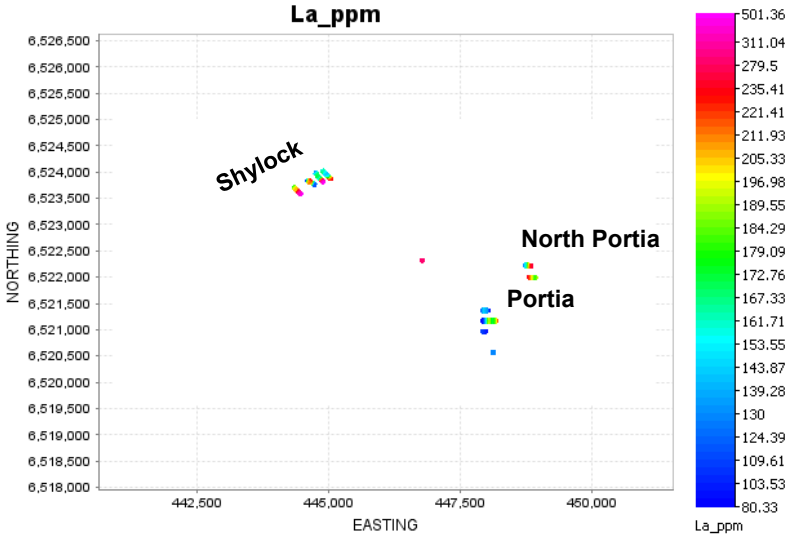
# Legacy data: critical minerals and associated elements

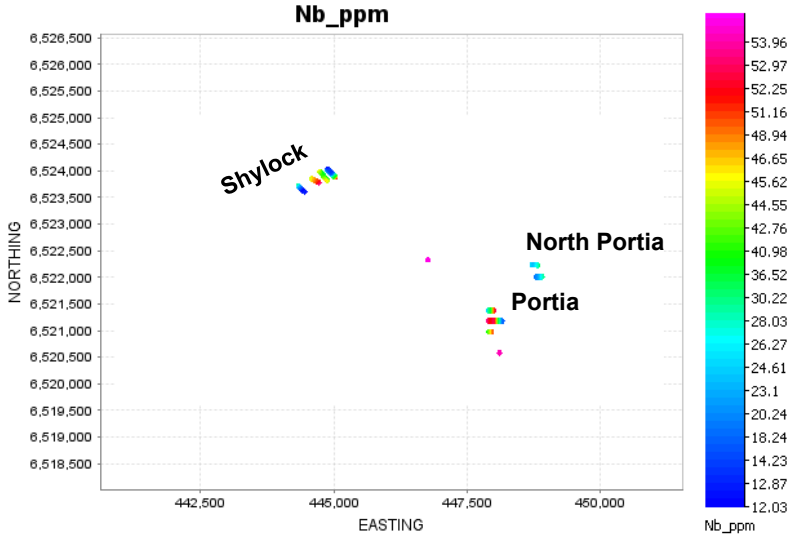
- Occurrences in the Portia region are associated with high values for most trace elements. Highest Co values are associated with North Portia.

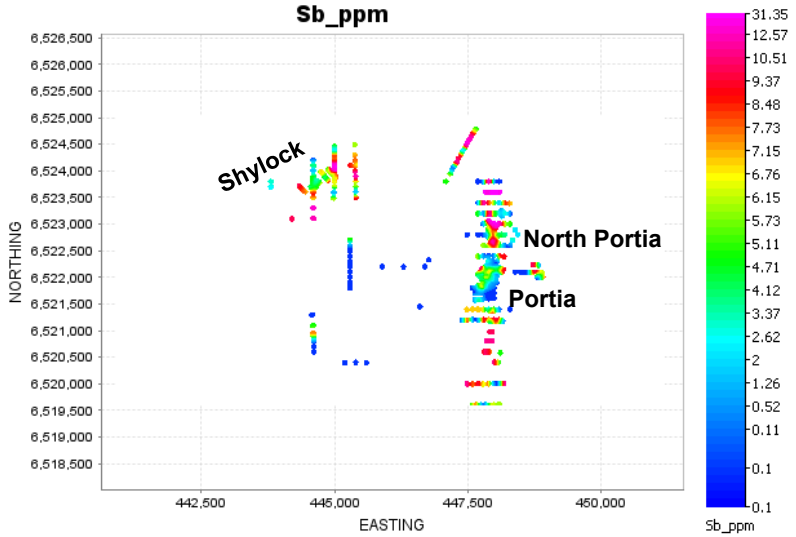


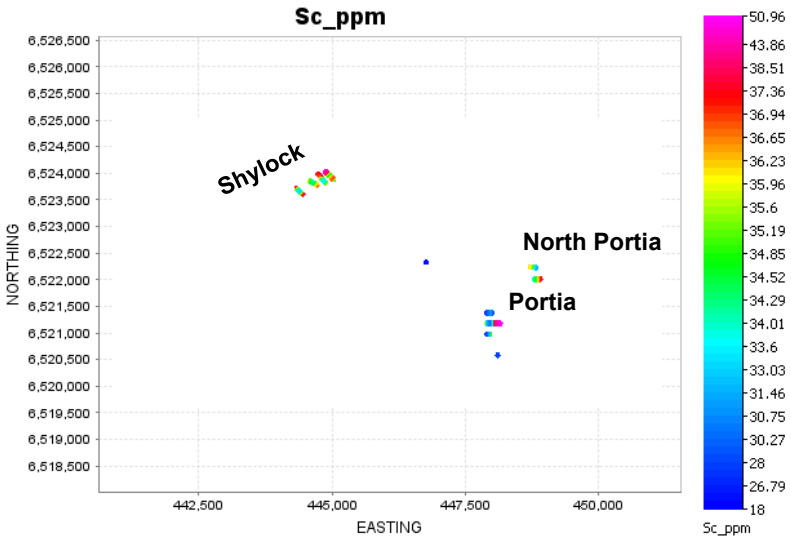
# Portia region. Legacy data: critical minerals

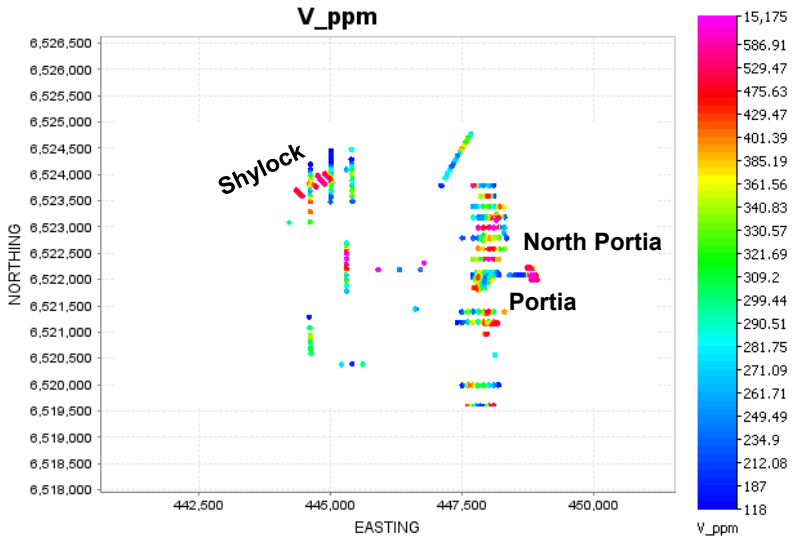
- Shylock contains high values of La, Sb, and V.
- North Portia contains high Sb, V and W values.

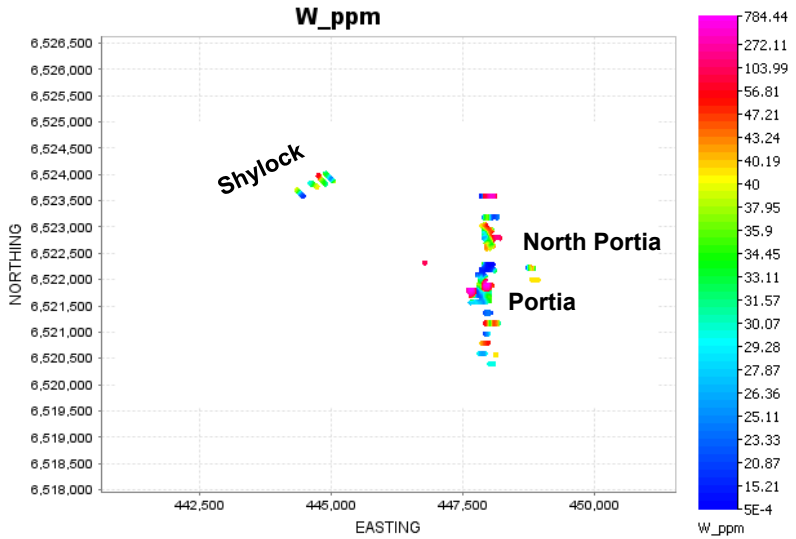


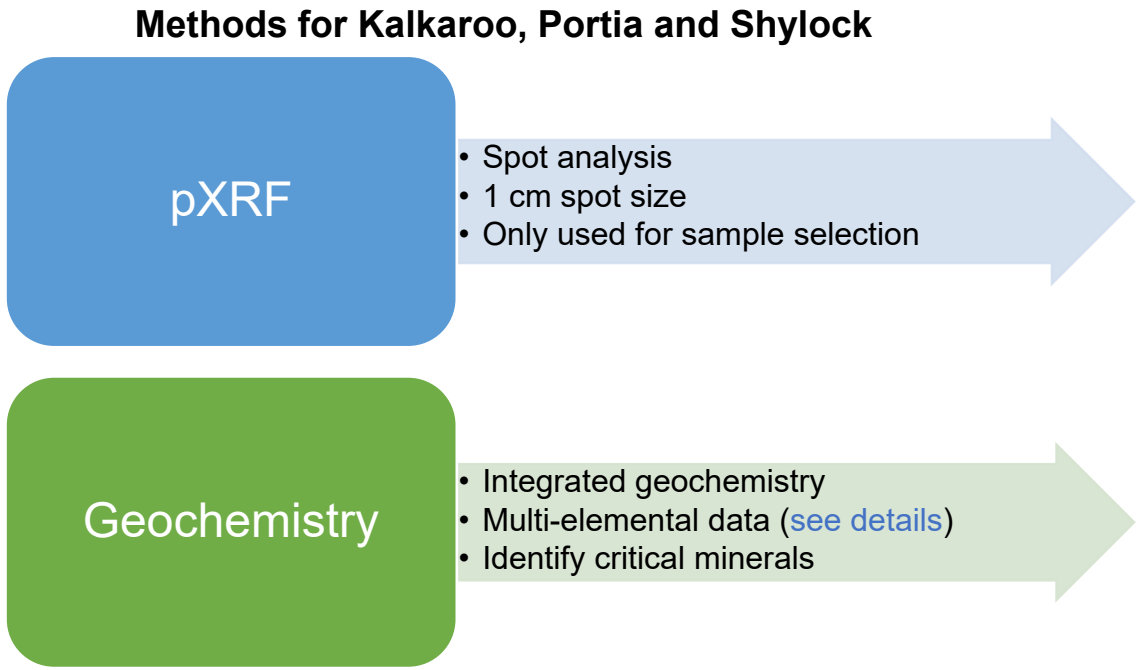



# Resampling strategy

- Geochemical data has been complemented with additional metadata to achieve an integrated geochemistry data set (containing coordinates of the drillholes, sample location, lithologies, stratigraphy, observations, and the new geochemistry data).
- 29 targeted samples were collected and re-assayed for a full suite of major and trace element geochemistry to characterise the critical mineral potential of Kalkaroo, Portia and Shylock. Sample preparation was done by ALS Geochemistry (Adelaide) and analysis by Bureau Veritas Laboratory (Perth).

More information in associated data:
- *Integrated Kalkaroo and Portia.xlsx*



# New geochemistry
## Sample summary

- The new geochemistry for Kalkaroo, Portia and Shylock deposits are restricted largely to the mineralised-altered zones to assess the potential for critical minerals in association with their primary commodity (although limited by available drillholes in the Core Library at Tonsley). For all the deposits the samples were taken from known regions of high copper and gold.
- Laboratory batch: EX3605 (GSSA database number).
- A total of 6 drillholes were sampled at Kalkaroo and the Portia region.
- Kalkaroo: samples were dominated by clays and albitised metasiltstones. 18 samples were collected from 6 m intervals within 3 drillholes. Samples were collected across the cover (Namba and Eyre formations) to basement (Willyama Supergroup) transition. The 3 drillholes were selected to assess REE prospectivity within drillholes available in the core library.
- Portia region: samples were dominated by clays and metasiltstones. 11 samples were collected from up to 18 m intervals within drillholes (Note: large intervals were required due to limited available material in storage). Samples were collected across the cover (Namba and Eyre formations) to basement (Willyama Supergroup) transition. Drillhole BE7 is the closest publicly available drill core to the Portia deposit and was selected to investigate REE potential. Two drillholes from Shylock were selected to investigate the association of mineralisation with Co, Bi and REEs.

| Drillhole Name | Dh number | Deposit name |
|---|---|---|
| KKRC128 | 227974 | West Kalkaroo |
| KKRC124 | 227973 | West Kalkaroo |
| KKRC139 | 227975 | West Kalkaroo |
| BE 7 | 145809 | Portia |
| SHAC035 | 294663 | Shylock |
| SHAC025 | 294653 | Shylock |

*Sampled drillholes in this study.*

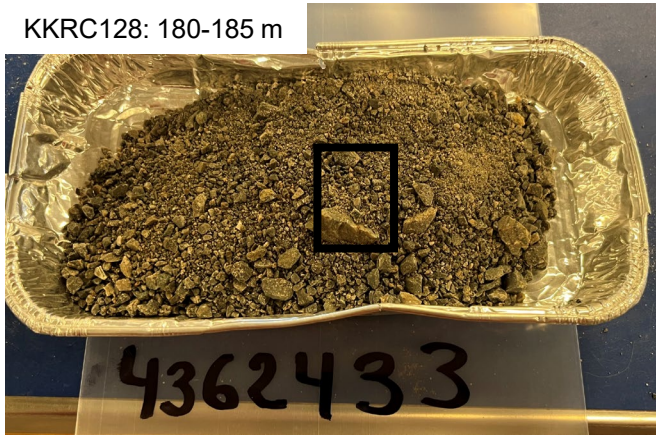
# Kalkaroo

## Mineralisation and alteration

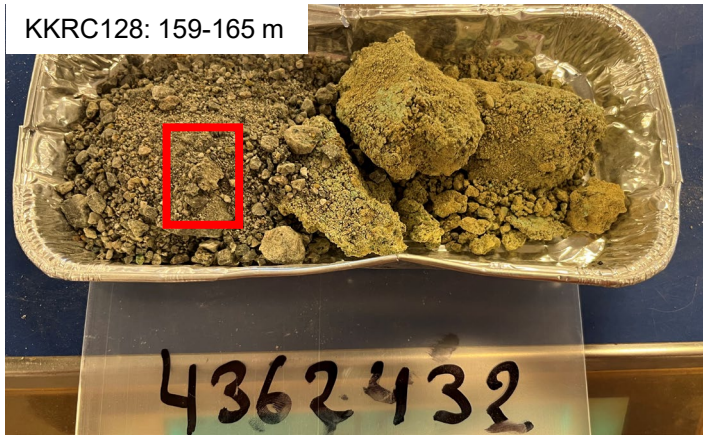
**Mineralisation:** Primary mineralisation: chalcopyrite, pyrite, minor molybdenite and gold, which occur as both replacement and vein styles. Chalcocite and malachite associated with supergene mineralisation. Biotite and chalcopyrite veins.

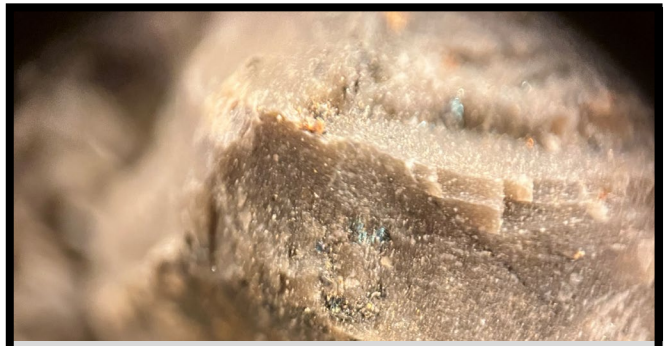
**Alteration:** Albitisation, silicification, biotite-albitisation, quartz-magnetite-biotite assemblages.

KKRC128: 180-185 m




KKRC128: 159-165 m



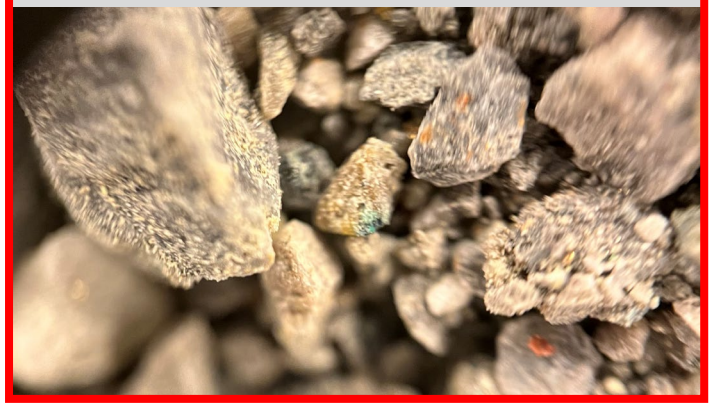



Silicified Willyama Supergroup with disseminated sulphides

Sulphides in albitised rock fragments

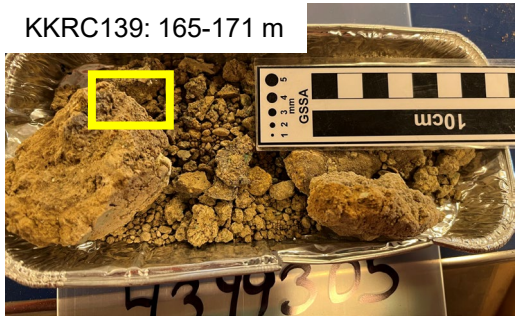
Chalcopyrite in albitised rock fragments

Albitised rock fragments



# Kalkaroo. Mineralisation and alteration

KKRC139: 165-171 m




Malachite staining

Malachite and chalcocite

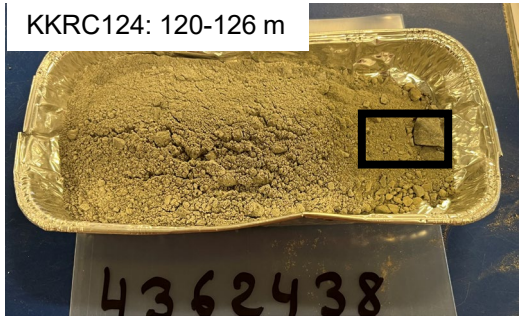
Biotite relicts

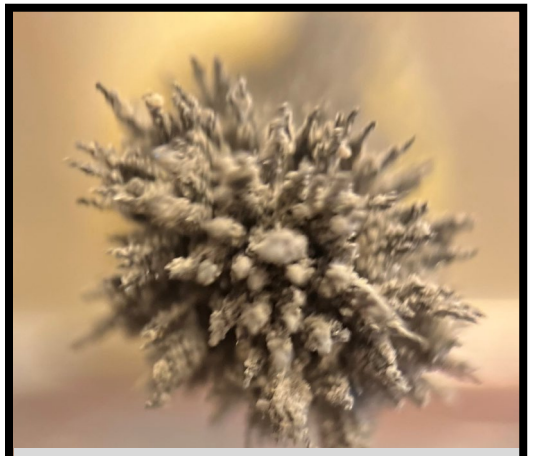
KKRC139: 108-114 m


Hematite and limonite with fragments of schist

Schist fragment

KKRC124: 120-126 m



Magnetite

Very fine material of albite and quartz

KKRC124: 144-147 m


Chalcopyrite and biotite veinlets

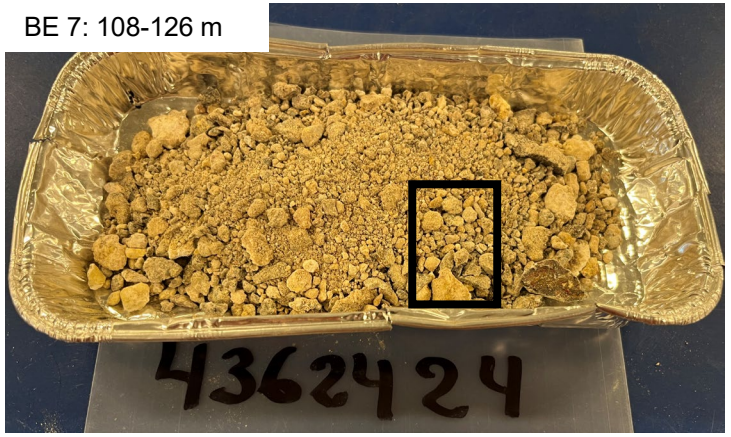
Disseminated biotite in silicified-albite fragment.

# Portia region
## Mineralisation and alteration

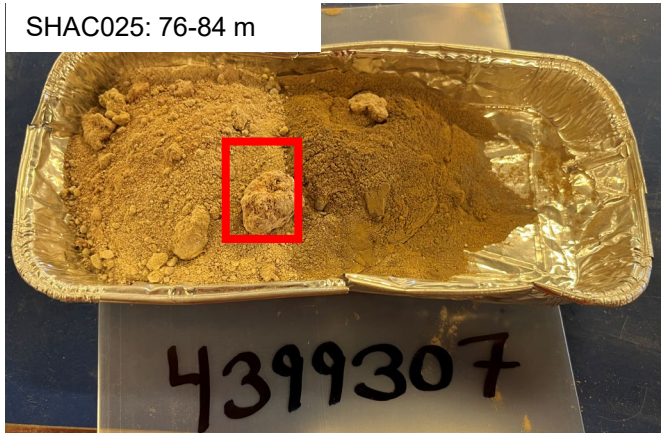
**Mineralisation:** Gold mineralisation hosted in clay is not visible. No copper mineralisation was identified.

**Alteration:** Silicified fragments with vuggy textures. Albitised fragments with some hematite staining +/-magnetite.

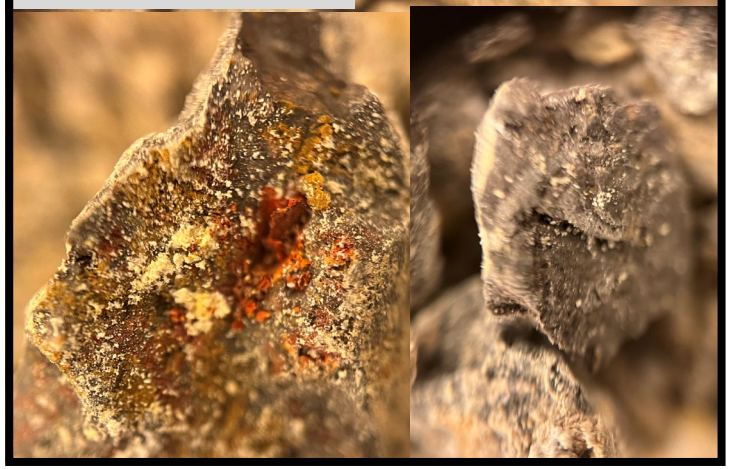
BE 7: 108-126 m




SHAC025: 76-84 m



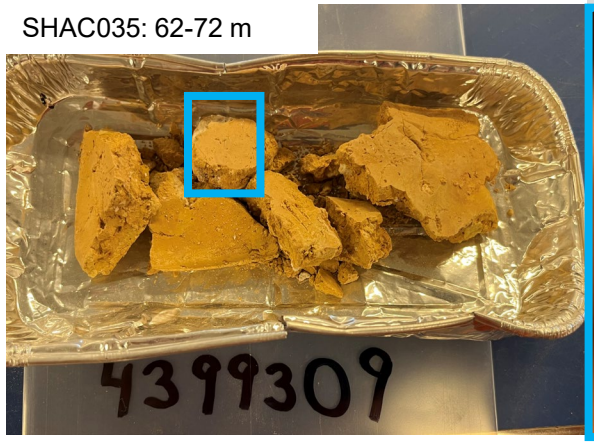

Albitised fragments



Silicification (vuggy texture)

Hyaline quartz

SHAC035: 62-72 m

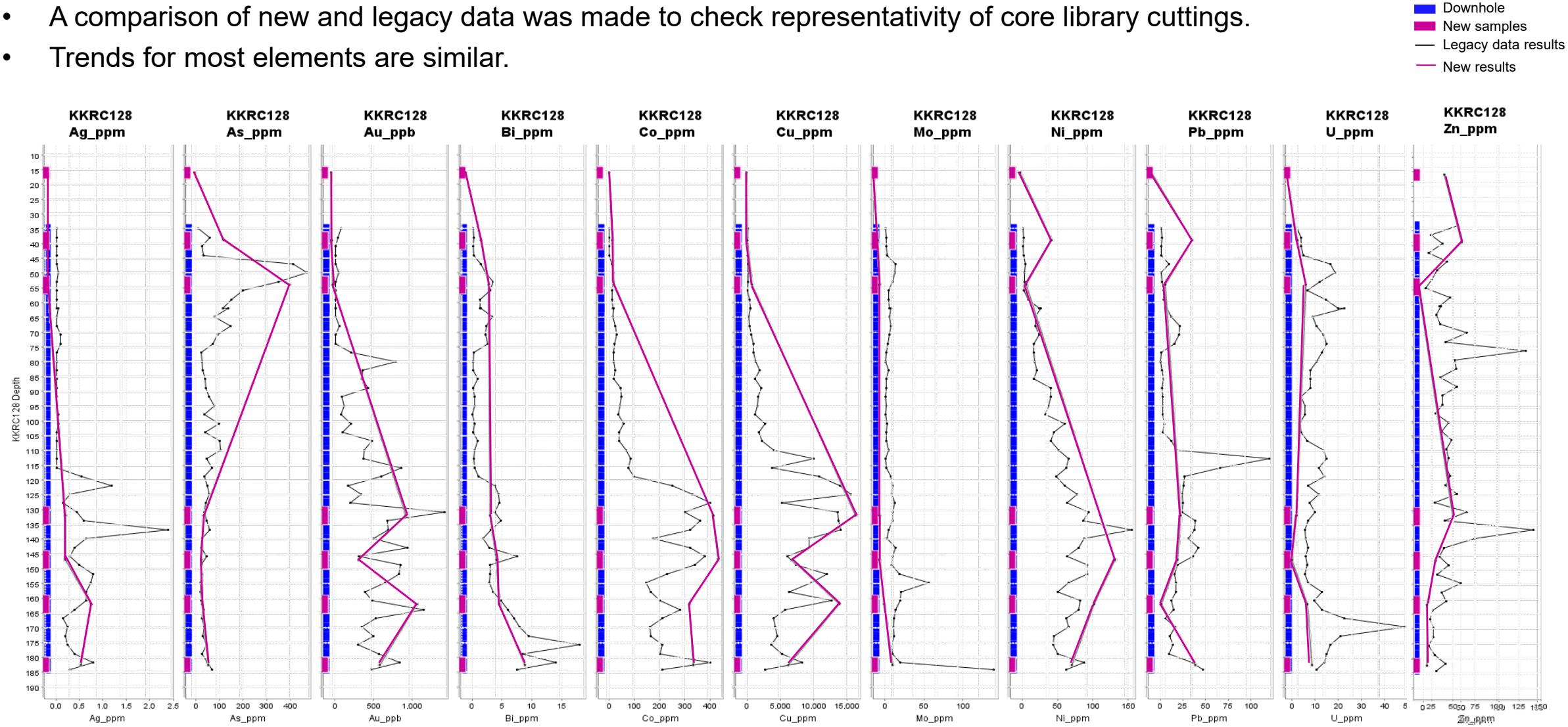



Very altered schist relicts in a hematite matrix

# Trace elements: Kalkaroo

## Legacy data and new geochemistry – drillholes KKRC128

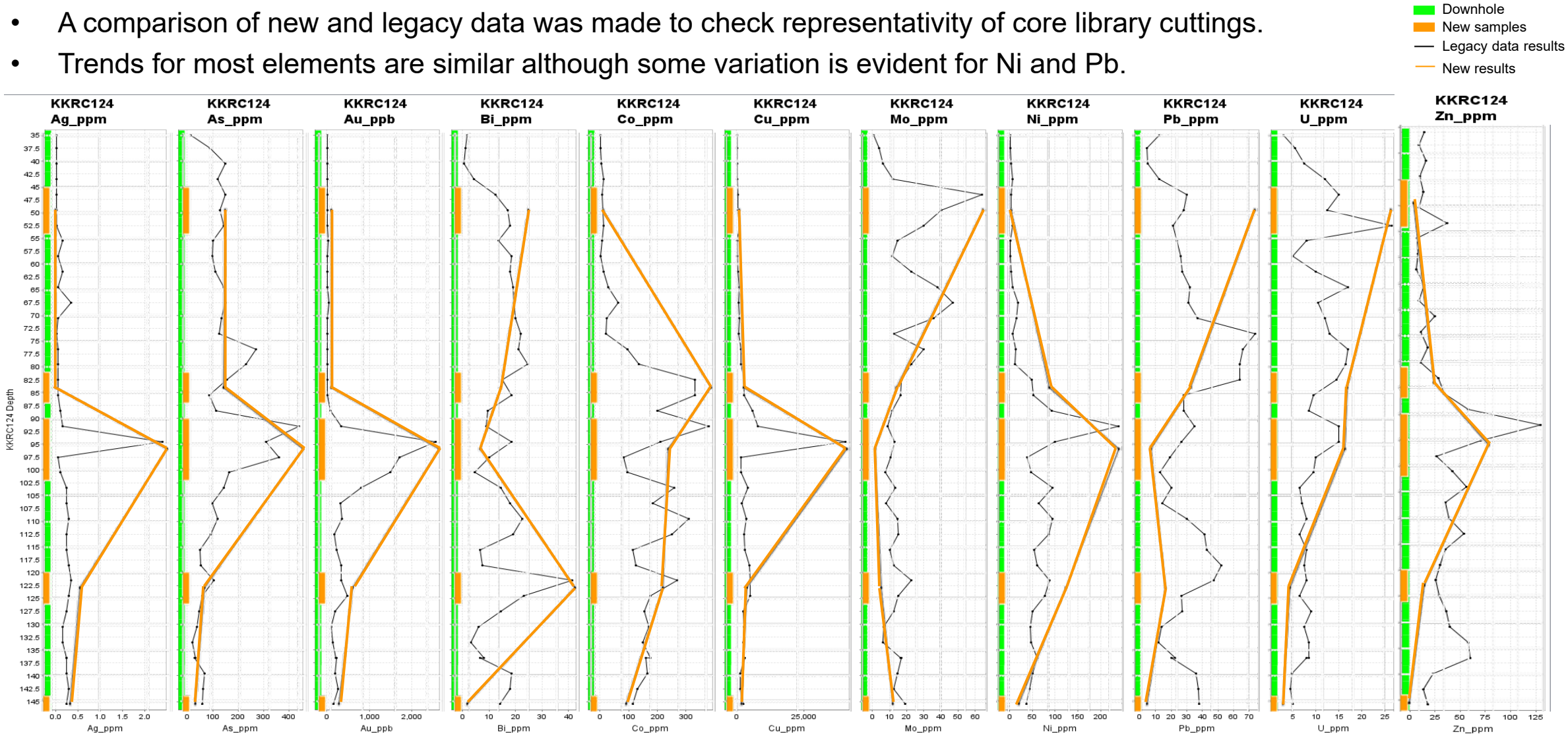
- A comparison of new and legacy data was made to check representativity of core library cuttings.
- Trends for most elements are similar.



# Trace elements: Kalkaroo

## Legacy data and new geochemistry – drillholes KKRC124

- A comparison of new and legacy data was made to check representativity of core library cuttings.
- Trends for most elements are similar although some variation is evident for Ni and Pb.



# Trace element summary

The new geochemical data returned similar base metal values to the legacy data.

**Kalkaroo**: significantly elevated values (>10x crustal abundance) for Cu, Au, As, Bi, Co, Mo and Te.

| Element | Crustal abundance (ppm) | Median (ppm) | Mean (ppm) | Maximum (ppm) |
|---|---|---|---|---|
| Cu | 28 | 3120 | 6612 | 4.54 % (sample 4362436) |
| Au | 0.0013 | 0.325 | 0.407 | 1.68 (sample 4362436) |
| As | 2.5 | 61.9 | 103 | 416 (sample 4362436) |
| Bi | 0.16 | 6 | 8.16 | 28 (sample 4362438) |
| Co | 17.3 | 223 | 206.08 | 525 (sample 4399305) |
| Mo | 1.1 | 10.70 | 14.27 | 57 (sample 4362434) |
| Te | 0.01 | 2 | 4.72 | 30.8 (sample 4362434) |

More information in associated data:
- *Integrated Kalkaroo and Portia.xlsx*
- *Correlation-all data.xlsx*

# Trace element summary

The new geochemical data returned similar base metal values to the legacy data.

**Portia region**: significantly elevated values (>10x crustal abundance) for Cu, Au, As, B, Bi, Mo, Te and W.

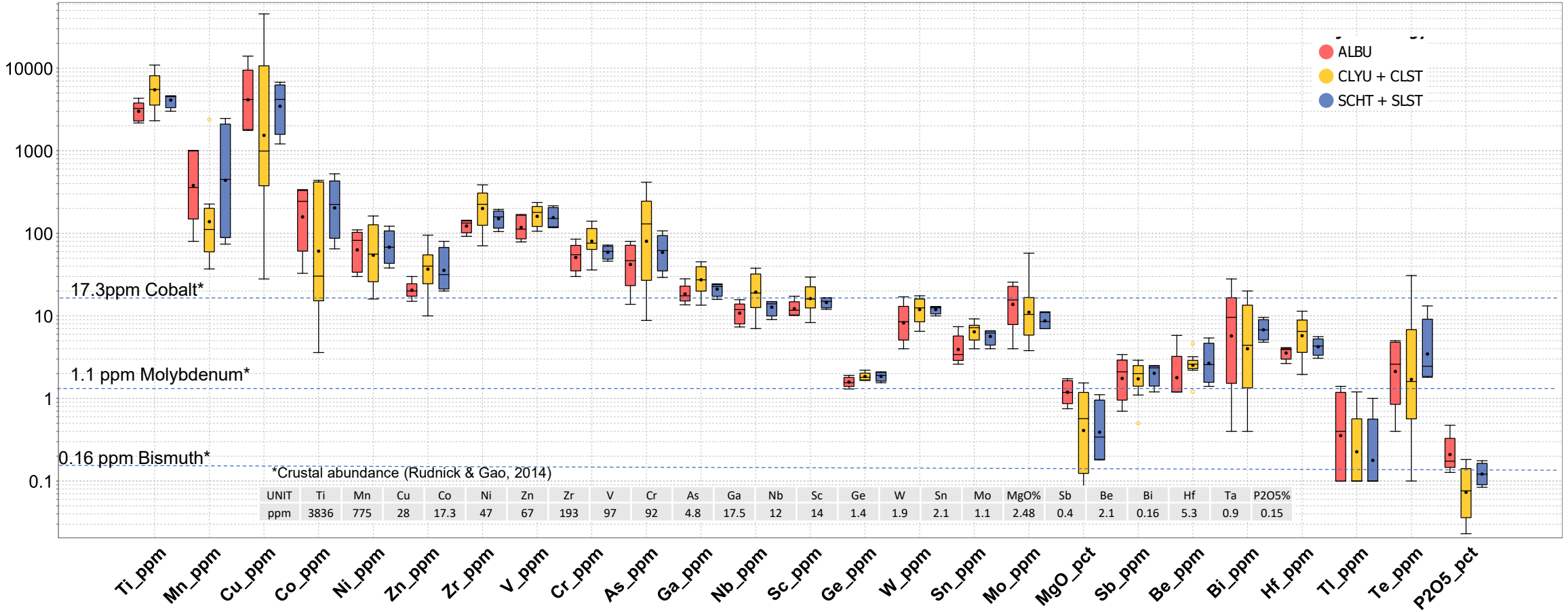
| Element | Crustal abundance (ppm) | Median (ppm) | Mean (ppm) | Maximum (ppm) |
|---|---|---|---|---|
| Cu | 28 | 232 | 294 | 826 (sample 4362425) |
| Au | 0.0013 | 0.040 | 0.0657 | 0.294 (sample 4399307) |
| As | 2.5 | 76 | 129 | 474 (sample 4399309) |
| B | 11 | 180 | 198 | 420 (Sample 4399306) |
| Bi | 0.16 | 2.6 | 3.5 | 7.8 (sample 4399311) |
| Mo | 1.1 | 23.2 | 23.9 | 49.8 (sample 4399311) |
| Te | 0.01 | 0.4 | 0.57 | 1.4 (sample 4399311) |
| W | 1.9 | 20 | 24.1 | 48 (sample 4399307) |

More information in associated data:
- *Integrated Kalkaroo and Portia.xlsx*
- *Correlation-all data.xlsx*

# Critical Mineral potential – Kalkaroo

- Based on the newly acquired geochemistry, Kalkaroo has potential for the critical metals Co, Bi, Mo and Te in addition to the main commodities of Cu and Au.

| 18 samples | Ti_ppm | Mn_ppm | Cu_ppm | Co_ppm | Ni_ppm | Zn_ppm | Zr_ppm | V_ppm | Cr_ppm | As_ppm | Ga_ppm | Nb_ppm | Sc_ppm | Ge_ppm | W_ppm | Sn_ppm | Mo_ppm | MgO_pct | Sb_ppm | Be_ppm | Bi_ppm | Hf_ppm | Tl_ppm | Te_ppm | P2O5_pct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Minimum | 2170.00 | 37.00 | 28.00 | 3.60 | 16.00 | 10.00 | 70.50 | 78.60 | 30.00 | 8.80 | 13.50 | 7.02 | 8.30 | 1.30 | 4.00 | 2.60 | 3.80 | 0.06 | 0.50 | 1.20 | 0.40 | 1.95 | 0.10 | 0.10 | 0.02 |
| Maximum | 10900.00 | 2460.00 | 45400.00 | 525.00 | 162.00 | 95.00 | 386.00 | 236.00 | 140.00 | 416.00 | 45.20 | 37.80 | 29.50 | 2.20 | 17.50 | 9.20 | 57.40 | 1.73 | 3.40 | 5.80 | 28.00 | 11.40 | 1.40 | 30.80 | 0.47 |
| Mean | 4827.22 | 555.72 | 6612.78 | 206.08 | 72.33 | 36.67 | 181.69 | 153.06 | 71.39 | 103.07 | 24.69 | 17.01 | 15.40 | 1.78 | 11.50 | 5.76 | 14.27 | 0.79 | 1.98 | 2.62 | 8.16 | 5.23 | 0.42 | 4.72 | 0.14 |
| Median | 4480.00 | 166.00 | 3120.00 | 223.50 | 68.00 | 30.00 | 152.50 | 148.00 | 66.00 | 61.90 | 23.55 | 14.75 | 15.15 | 1.75 | 12.25 | 6.20 | 10.70 | 0.69 | 2.05 | 2.50 | 6.00 | 4.24 | 0.10 | 2.00 | 0.13 |

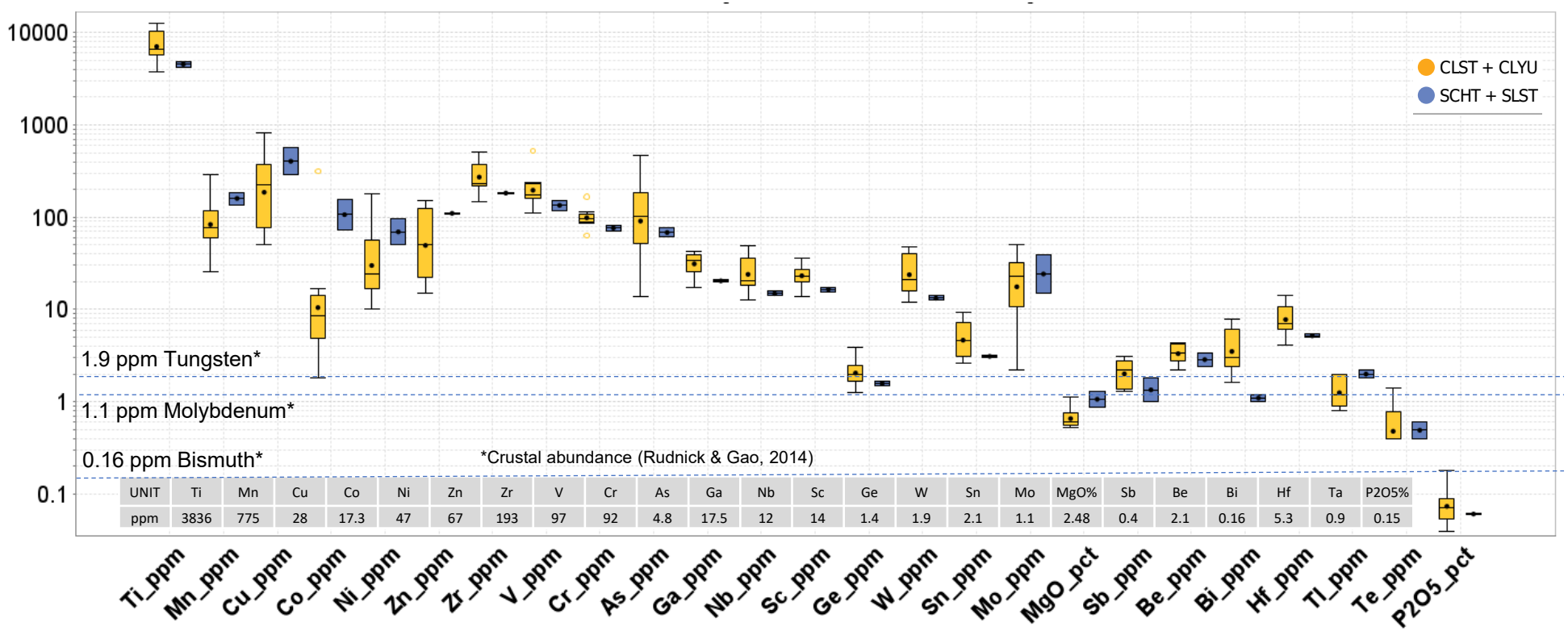



*Box and Whisker plot showing trace element concentrations determined by whole-rock geochemistry. The central box represents 50% of the data from quartile 1(Q1) to quartile 3 (Q3); outlier circles and triangles indicate the data that is further than 1.5 (Q3-Q1) from the box. The whiskers include the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

# Critical Mineral potential – Portia region

- Based on the newly acquired geochemistry, the Portia region has potential for the critical metals Mo, W and Bi in addition to the main commodities of Cu and Au.

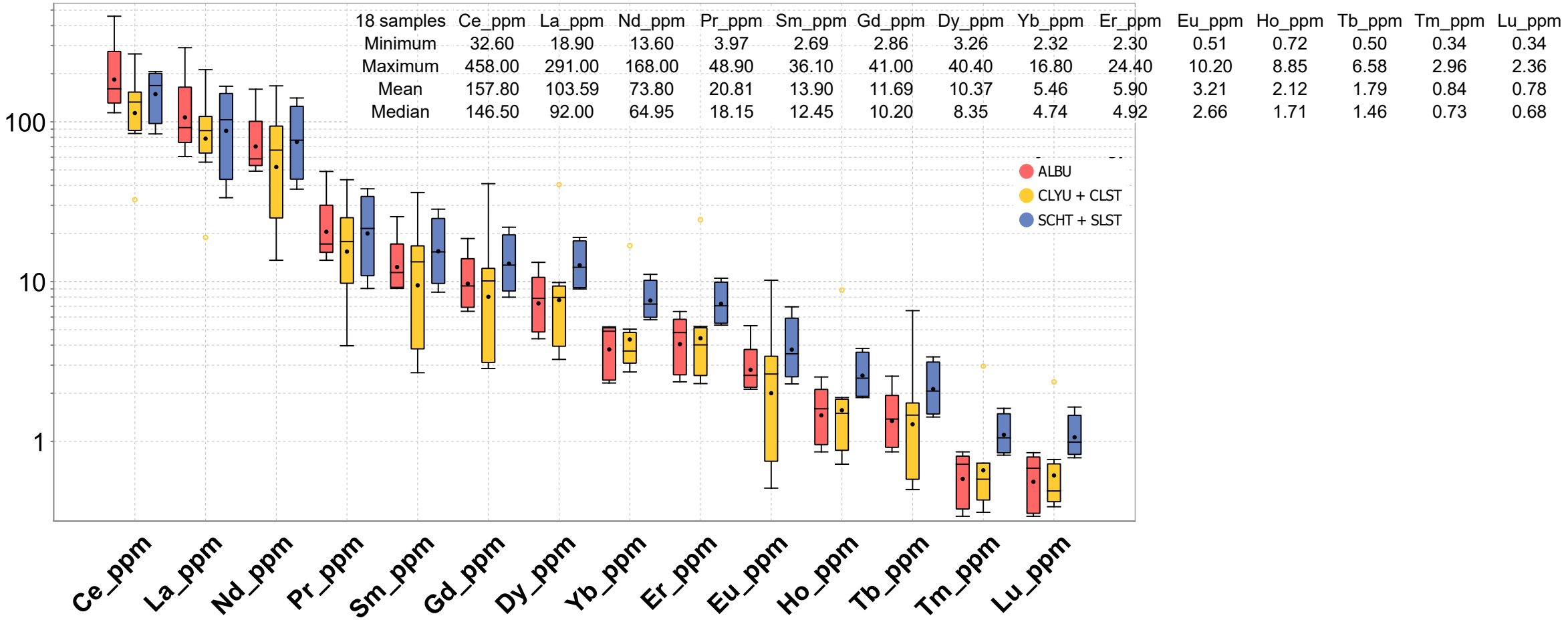
| 11 samples | Ti_ppm | Mn_ppm | Cu_ppm | Co_ppm | Ni_ppm | Zn_ppm | Zr_ppm | V_ppm | Cr_ppm | As_ppm | Ga_ppm | Nb_ppm | Sc_ppm | Ge_ppm | W_ppm | Sn_ppm | Mo_ppm | MgO_pct | Sb_ppm | Be_ppm | Bi_ppm | Hf_ppm | Tl_ppm | Te_ppm | P2O5_pct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Minimum | 3760.00 | 26.00 | 50.00 | 1.80 | 10.00 | 15.00 | 148.00 | 112.00 | 63.00 | 13.60 | 17.10 | 12.50 | 13.60 | 1.25 | 12.00 | 2.60 | 2.20 | 0.52 | 1.00 | 2.20 | 1.00 | 4.16 | 0.80 | 0.10 | 0.04 |
| Maximum | 12700.00 | 286.00 | 826.00 | 317.00 | 178.00 | 150.00 | 502.00 | 519.00 | 167.00 | 474.00 | 43.00 | 49.10 | 36.10 | 3.90 | 48.00 | 9.20 | 49.80 | 1.31 | 3.10 | 4.40 | 7.80 | 14.20 | 2.20 | 1.40 | 0.18 |
| Mean | 6968.00 | 112.36 | 294.36 | 55.54 | 50.55 | 75.91 | 270.36 | 200.91 | 97.00 | 128.96 | 30.14 | 24.37 | 22.57 | 2.05 | 24.14 | 4.71 | 23.85 | 0.75 | 1.98 | 3.31 | 3.47 | 7.71 | 1.45 | 0.57 | 0.08 |
| Median | 6075.00 | 99.00 | 232.00 | 9.40 | 28.00 | 80.00 | 233.00 | 165.00 | 96.00 | 76.00 | 28.40 | 18.70 | 22.20 | 1.90 | 20.00 | 4.00 | 23.20 | 0.61 | 1.80 | 3.40 | 2.60 | 6.68 | 1.20 | 0.40 | 0.07 |




*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 is further than 1.5 (Q3-Q1) from the box. The whiskers include the extreme outlier value. Additional element data can be found in associated data.*

# Rare earth element potential – Kalkaroo

- REE values are moderately elevated compared to crustal abundances. Ce, La, and Nd values commonly exceed 100 ppm and are typically 3 times average crustal values. LREEs reach values of >10 times crustal abundance but are typically twice average crustal values.
- Samples containing schist (Dh KKRC 139) contain slightly higher HREEs than other lithologies.

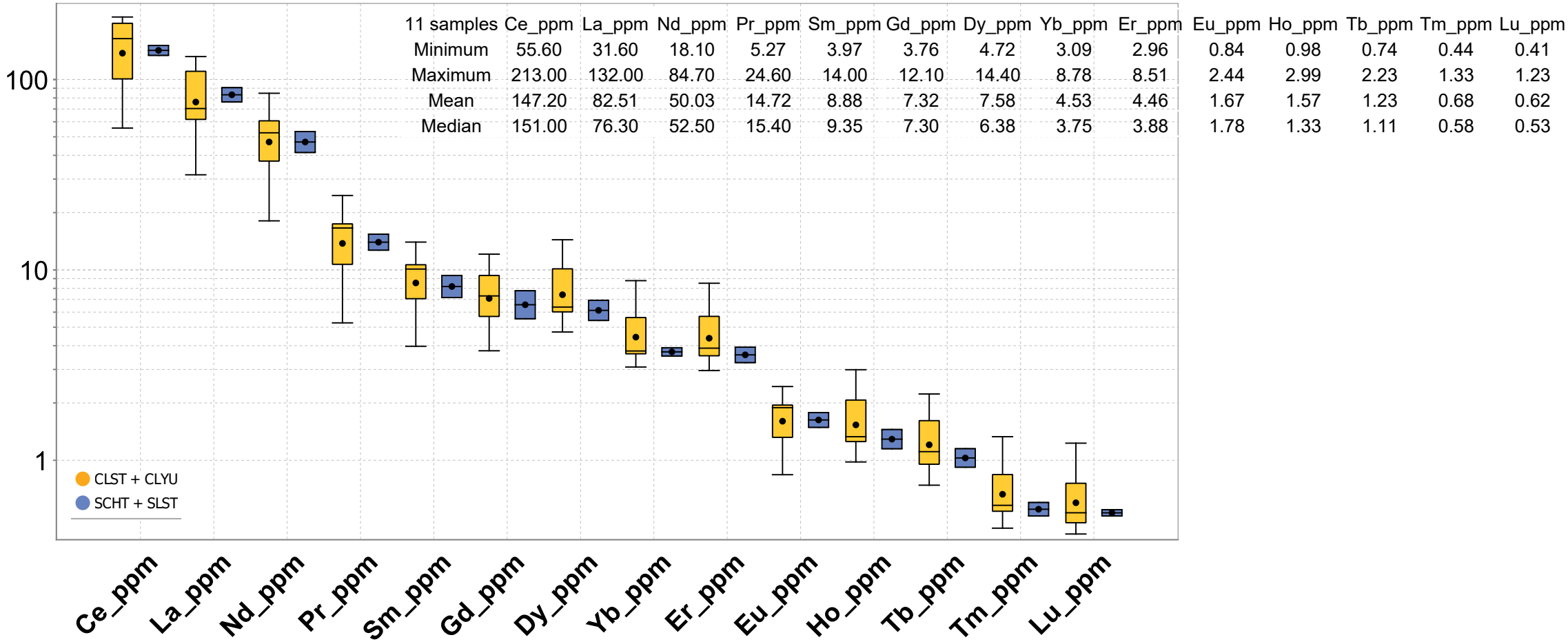



| 18 samples | Ce_ppm | La_ppm | Nd_ppm | Pr_ppm | Sm_ppm | Gd_ppm | Dy_ppm | Yb_ppm | Er_ppm | Eu_ppm | Ho_ppm | Tb_ppm | Tm_ppm | Lu_ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Minimum | 32.60 | 18.90 | 13.60 | 3.97 | 2.69 | 2.86 | 3.26 | 2.32 | 2.30 | 0.51 | 0.72 | 0.50 | 0.34 | 0.34 |
| Maximum | 458.00 | 291.00 | 168.00 | 48.90 | 36.10 | 41.00 | 40.40 | 16.80 | 24.40 | 10.20 | 8.85 | 6.58 | 2.96 | 2.36 |
| Mean | 157.80 | 103.59 | 73.80 | 20.81 | 13.90 | 11.69 | 10.37 | 5.46 | 5.90 | 3.21 | 2.12 | 1.79 | 0.84 | 0.78 |
| Median | 146.50 | 92.00 | 64.95 | 18.15 | 12.45 | 10.20 | 8.35 | 4.74 | 4.92 | 2.66 | 1.71 | 1.46 | 0.73 | 0.68 |

*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 is further than 1.5 (Q3-Q1) from the box. The whiskers include the extreme outlier value.*

# Rare earth element potential – Portia region

- REE values are moderately elevated compared to crustal abundances with LREEs commonly 3 times average crustal values and HREEs approximately twice average crustal values.




| 11 samples | Ce_ppm | La_ppm | Nd_ppm | Pr_ppm | Sm_ppm | Gd_ppm | Dy_ppm | Yb_ppm | Er_ppm | Eu_ppm | Ho_ppm | Tb_ppm | Tm_ppm | Lu_ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Minimum | 55.60 | 31.60 | 18.10 | 5.27 | 3.97 | 3.76 | 4.72 | 3.09 | 2.96 | 0.84 | 0.98 | 0.74 | 0.44 | 0.41 |
| Maximum | 213.00 | 132.00 | 84.70 | 24.60 | 14.00 | 12.10 | 14.40 | 8.78 | 8.51 | 2.44 | 2.99 | 2.23 | 1.33 | 1.23 |
| Mean | 147.20 | 82.51 | 50.03 | 14.72 | 8.88 | 7.32 | 7.58 | 4.53 | 4.46 | 1.67 | 1.57 | 1.23 | 0.68 | 0.62 |
| Median | 151.00 | 76.30 | 52.50 | 15.40 | 9.35 | 7.30 | 6.38 | 3.75 | 3.88 | 1.78 | 1.33 | 1.11 | 0.58 | 0.53 |

*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 is further than 1.5 (Q3-Q1) from the box. The whiskers include the extreme outlier value.*

# Conclusions

- The critical mineral potential at Kalkaroo is predominantly copper (Cu) and cobalt (Co), with significant values also identified for bismuth (Bi), molybdenum (Mo), tellurium (Te) and rare earth elements (REEs), as indicated by both legacy data and this study. Gold (Au) and silver (Ag), and to a lesser extent, zinc (Zn) and lead (Pb) are associated with mineralisation at Kalkaroo. Elevated concentrations of tungsten (W), nickel (Ni), and arsenic (As) are also noted. The critical minerals Ge, Hf, In, Li, Nb, Pd, Pt, Re, Ta were determined for the first time at Kalkaroo but no significantly elevated values were recorded.
- Trace element distributions at Kalkaroo are broadly associated with Cu mineralisation around the Kalkaroo Dome and West Kalkaroo however several elements show distinct zoning. The highest copper intersection recorded at Kalkaroo in this study is 4.54% Cu at 90 m in drillhole KKRC124. Significantly elevated values were also achieved for Bi (28 ppm) and Te (30.8 ppm).
- In the Portia region, the critical mineral potential is primarily Cu and Co, with significant values identified for Bi, Mo, Sb, Te, vanadium (V), and W. These elements complement primary commodities of Au and Ag, and are associated with high values for Zn and Pb. The critical minerals Ge, Hf, In, Li, Nb, Pd, Pt, Re, Ta were determined for the first time in the Portia region but no significantly elevated values were recorded. Spatial plots of geochemical data show a clear association with the Benagerie Dome, with many elements showing high values in weathered zones and cover units.

# Recommendations

- Future sampling should include the range of mineralisation styles in the Kalkaroo and Portia region.
- Mineralogical investigations are required to determine the hosts of critical minerals identified in this study.

# References

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# Acknowledgements

Georgina Gordon acquired HyLogger™ data. The staff at the South Australia Drill Core Reference Library facilitated core inspections and sampling. Amber Griffin assisted with sampling. Liliana Stoian updated SA Geodata with legacy data for Kalkaroo and Portia.

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