Cooperative Research Centre for
Landscape Environments
and Mineral Exploration

Inland acid sulfate soils – a new geochemical sampling medium: a regional orientation study from the Mount Lofty Ranges, South Australia

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CRCLEME

Acknowledgements

- **CRC LEME, CSIRO Mineral Exploration, CSIRO Glass Earth**
- **Pima Mining NL**
- **Charles Butt**
- **Andy Burtt & Justin Gum (PIRSA)**
- **Stuart McClure (SEM, microprobe)**
- **Richard Merry (CSIRO L&W, Adelaide)**

Outline of talk

- **What are inland acid sulfate soils?**
- **Where do they occur?**
- **How do they form?**
- **Regional case study – Kanmantoo, South Australia**
- **Local example – Wheal Ellen**
- **Implications for mineral exploration**

What are Acid Sulfate Soil materials?

Soils and sediments that contain **iron sulfides**, which when drained or disturbed, form **sulfuric acid**

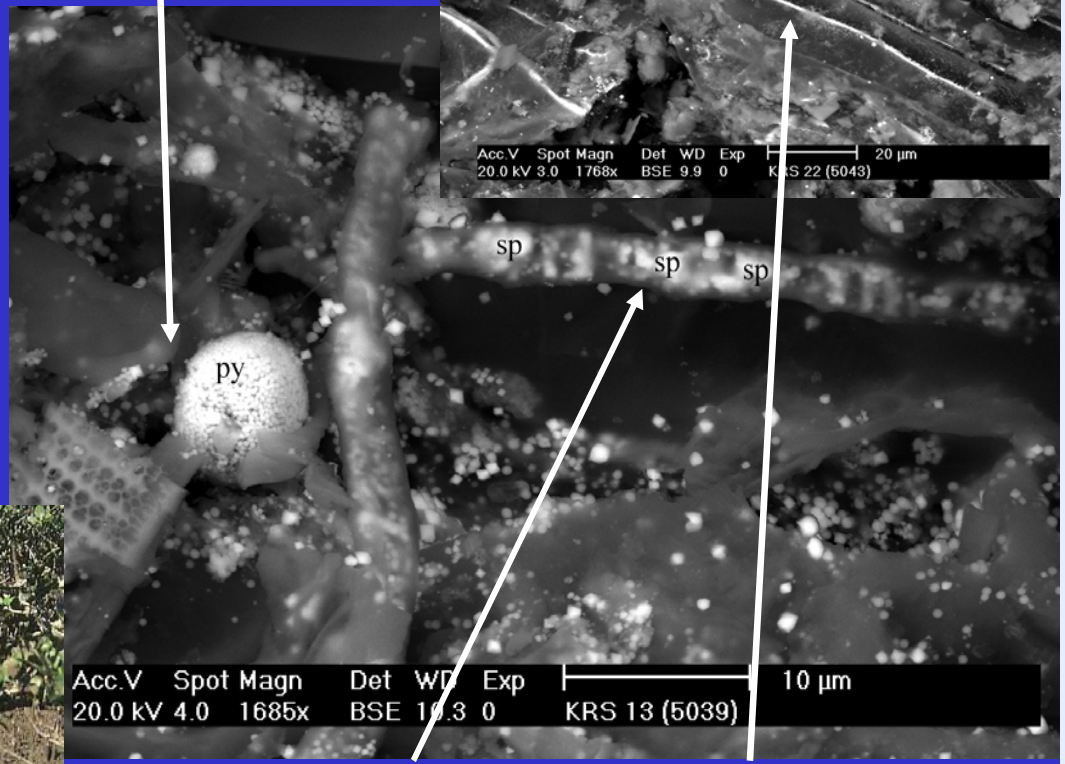
- Main form of iron sulfide
  - Pyrite (FeS_2)
- Also iron mono-sulfides (FeS)

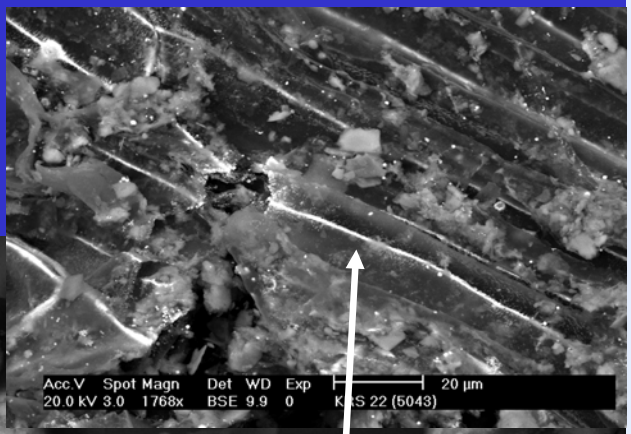
each mole of pyrite $\Leftarrow$ 2 moles sulfuric acid or 4 moles acid

Pyrite (FeS_2)

- in sulfidic material

Pyrite (py) crystals in framboids





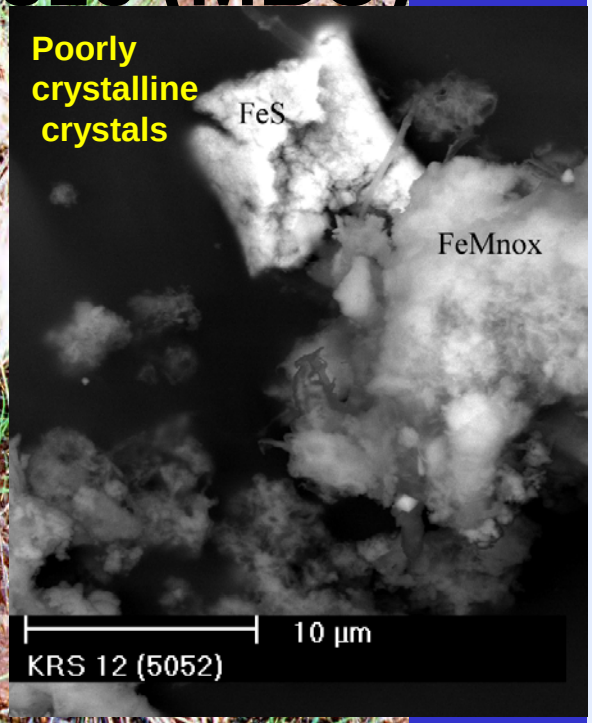
Sphalerite (ZnS)(sp) and Pb sulfide crystals (bright streaks) in plant rootlets

Iron monosulfides (FeS)

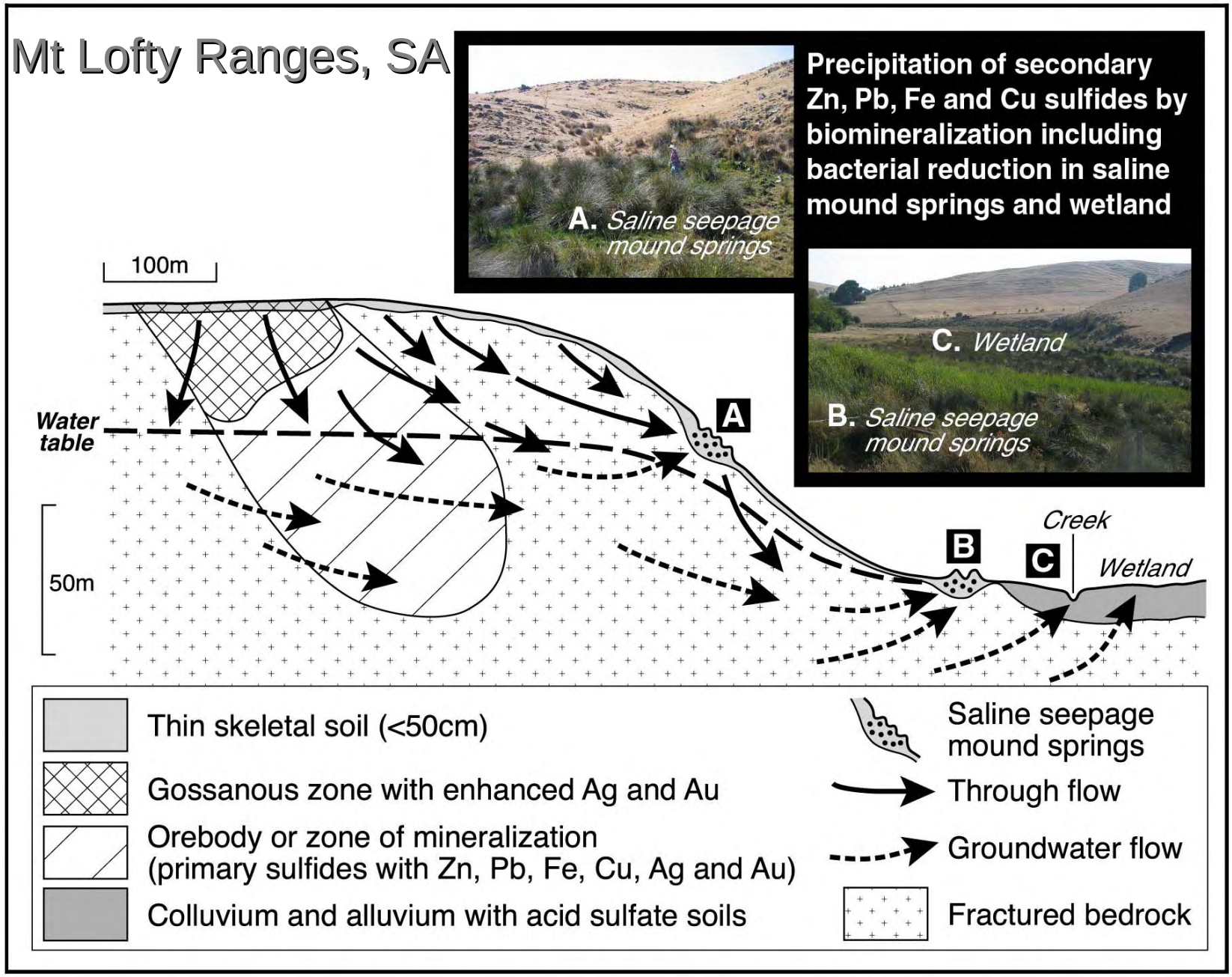
Monosulfidic Black Ooze (MBO)

- Reacts rapidly when disturbed
- De-oxygenates water supplies

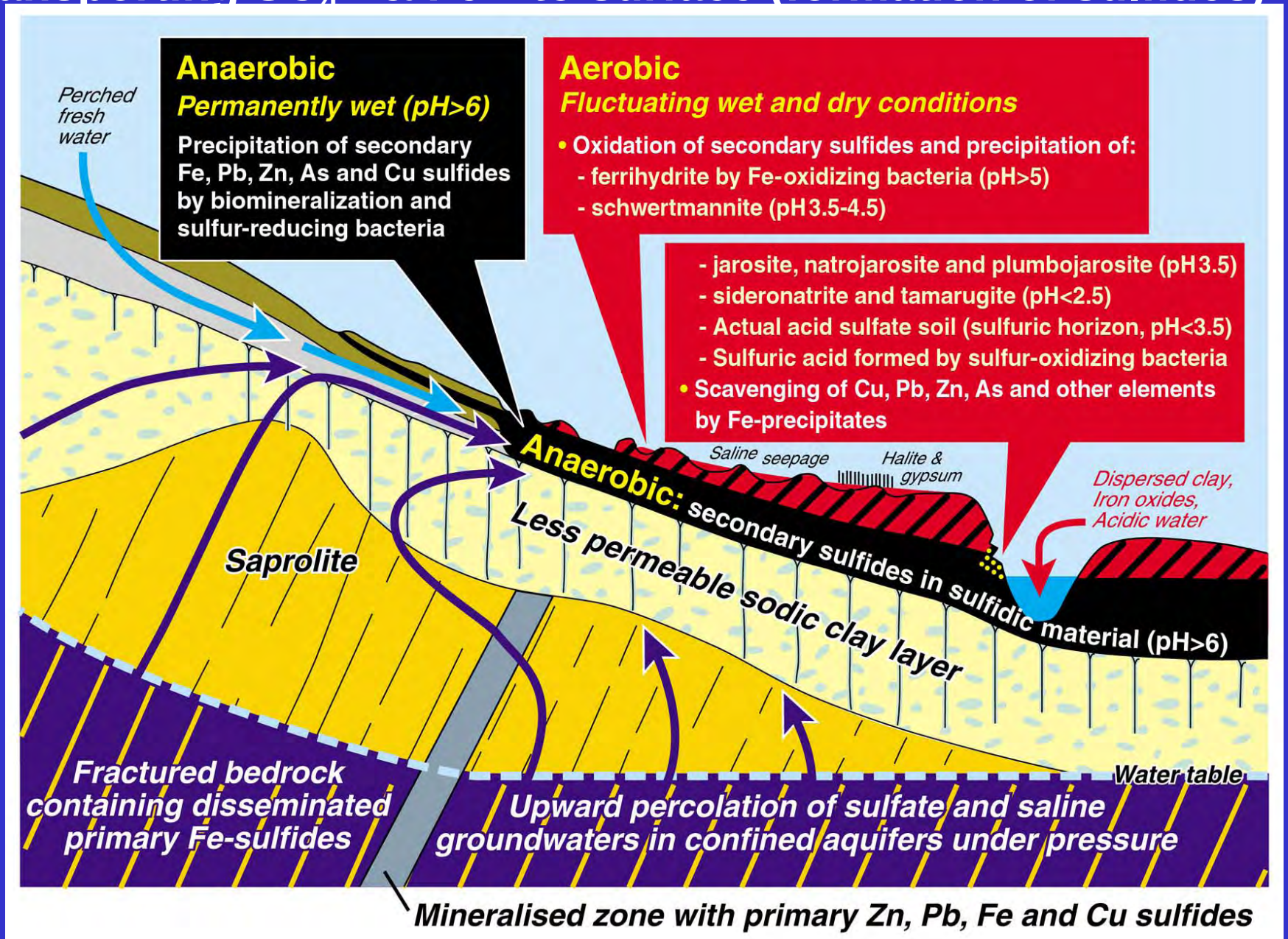
Iron oxyhydroxysulfates, from oxidation of FeS scavenge elements (As, Cd etc)



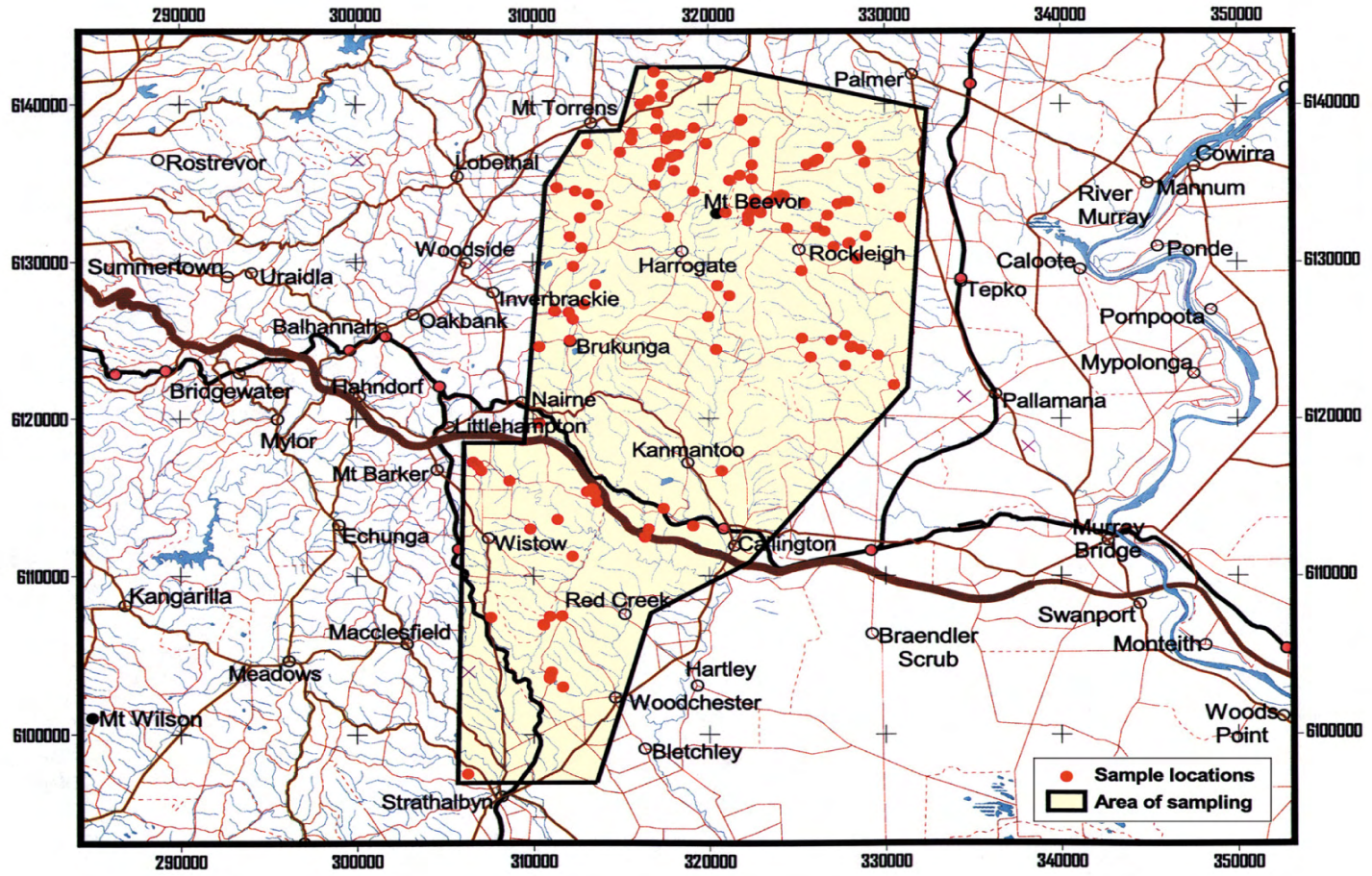
Where do inland Acid Sulfate Soils occur?

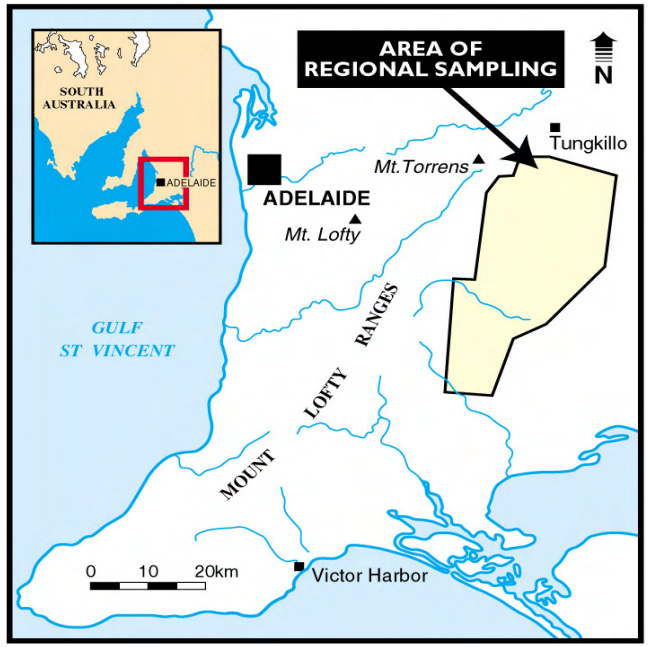


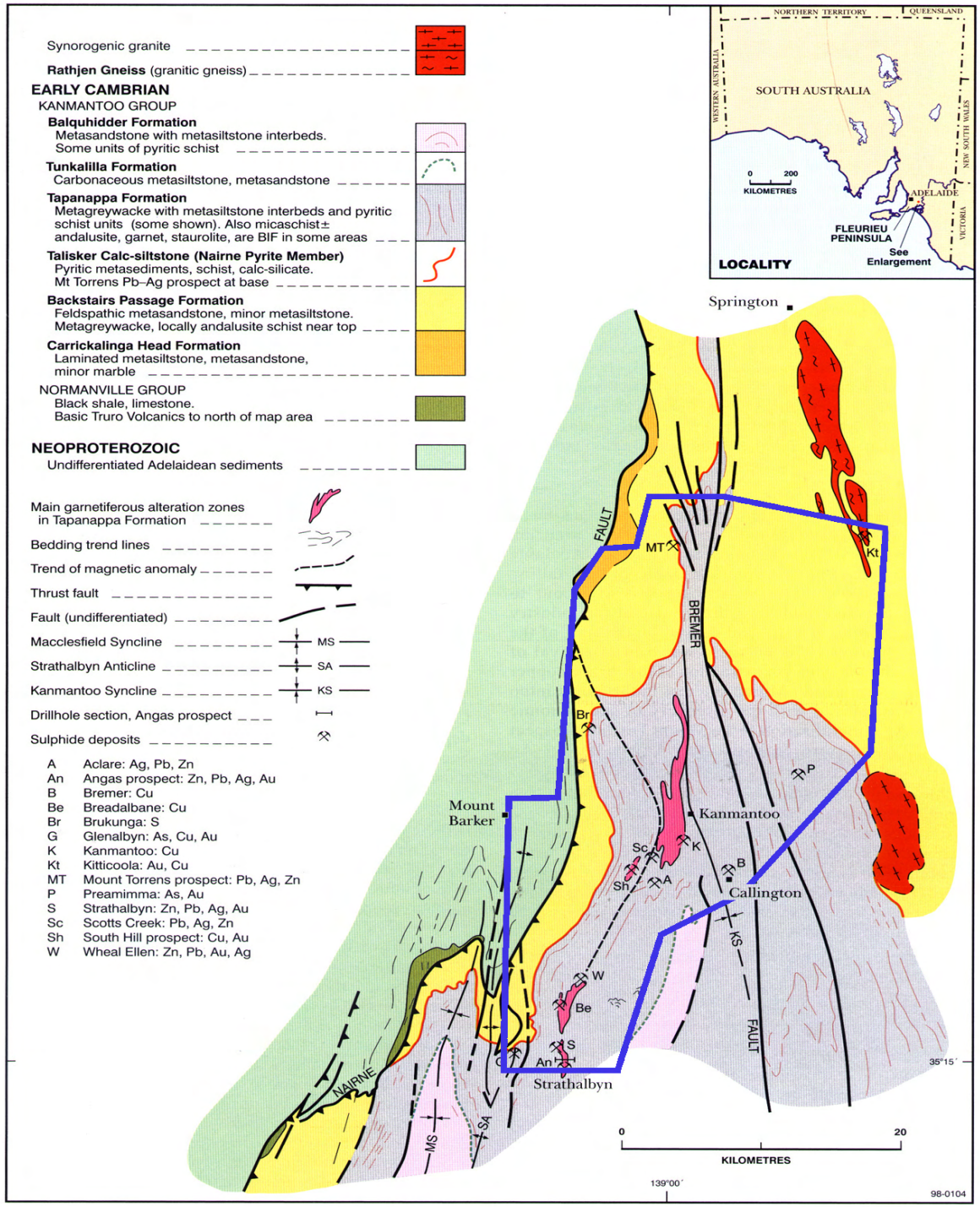
Geologically controlled groundwater discharge zones Transporting SO_4^{2-} & Fe^{2+} to surface (formation of sulfides)



Location of survey

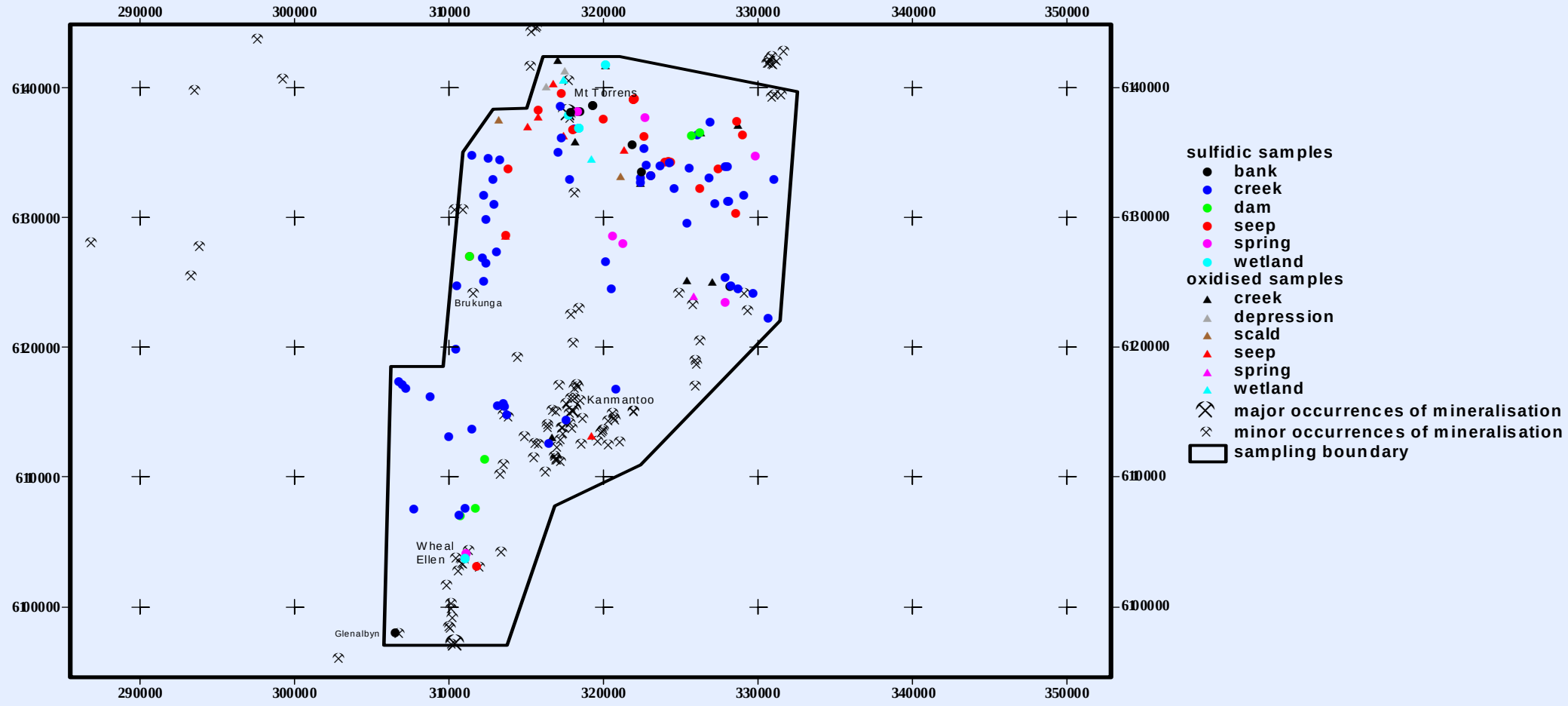





Synorogenic granite
Rathjen Gneiss (granitic gneiss)
EARLY CAMBRIAN
KANMANTOO GROUP
Balquhidder Formation
Metasandstone with metasiltstone interbeds.
Some units of pyritic schist
Tunkalilla Formation
Carbonaceous metasiltstone, metasandstone
Tapanappa Formation
Metagreywacke with metasiltstone interbeds and pyritic schist units (some shown). Also micaschist± andalusite, garnet, staurolite, are BIF in some areas
Talisker Calc-siltstone (Nairne Pyrite Member)
Pyritic metasediments, schist, calc-silicate.
Mt Torrens Pb–Ag prospect at base
Backstairs Passage Formation
Feldspathic metasandstone, minor metasiltstone.
Metagreywacke, locally andalusite schist near top
Carrickalinga Head Formation
Laminated metasiltstone, metasandstone, minor marble
NORMANVILLE GROUP
Black shale, limestone.
Basic Truro Volcanics to north of map area
NEOPROTEROZOIC
Undifferentiated Adelaidean sediments
Main garnetiferous alteration zones in Tapanappa Formation
Bedding trend lines
Trend of magnetic anomaly
Thrust fault
Fault (undifferentiated)
Macclesfield Syncline
Strathalbyn Anticline
Kanmantoo Syncline
Drillhole section, Angas prospect
Sulphide deposits
A Aclare: Ag, Pb, Zn
An Angas prospect: Zn, Pb, Ag, Au
B Bremer: Cu
Be Breadalbane: Cu
Br Brukunga: S
G Glenalbyn: As, Cu, Au
K Kanmantoo: Cu
Kt Kitticoola: Au, Cu
MT Mount Torrens prospect: Pb, Ag, Zn
P Preamimma: As, Au
S Strathalbyn: Zn, Pb, Ag, Au
Sc Scotts Creek: Pb, Ag, Zn
Sh South Hill prospect: Cu, Au
W Wheal Ellen: Zn, Pb, Au, Ag
NORTHERN TERRITORY
QUEENSLAND
WESTERN AUSTRALIA
SOUTH AUSTRALIA
NEW SOUTH WALES
VICTORIA
0 200
KILOMETRES
ADELAIDE
FLEURIEU PENINSULA
See Enlargement
LOCALITY
Springton
FAULT
MT
Kt
BREMER
Br
P
Mount Barker
Kanmantoo
Sc
K
Sh
A
B
Callington
KS
W
Be
S
An
Strathalbyn
NAIRNE
MS
SA
FAULT
35°15′
0 20
KILOMETRES
139°00′
98-0104

Sampling environments

155 samples -
48 seeps/springs and wetlands
71 creeks



Occurrence of pyritic ASS

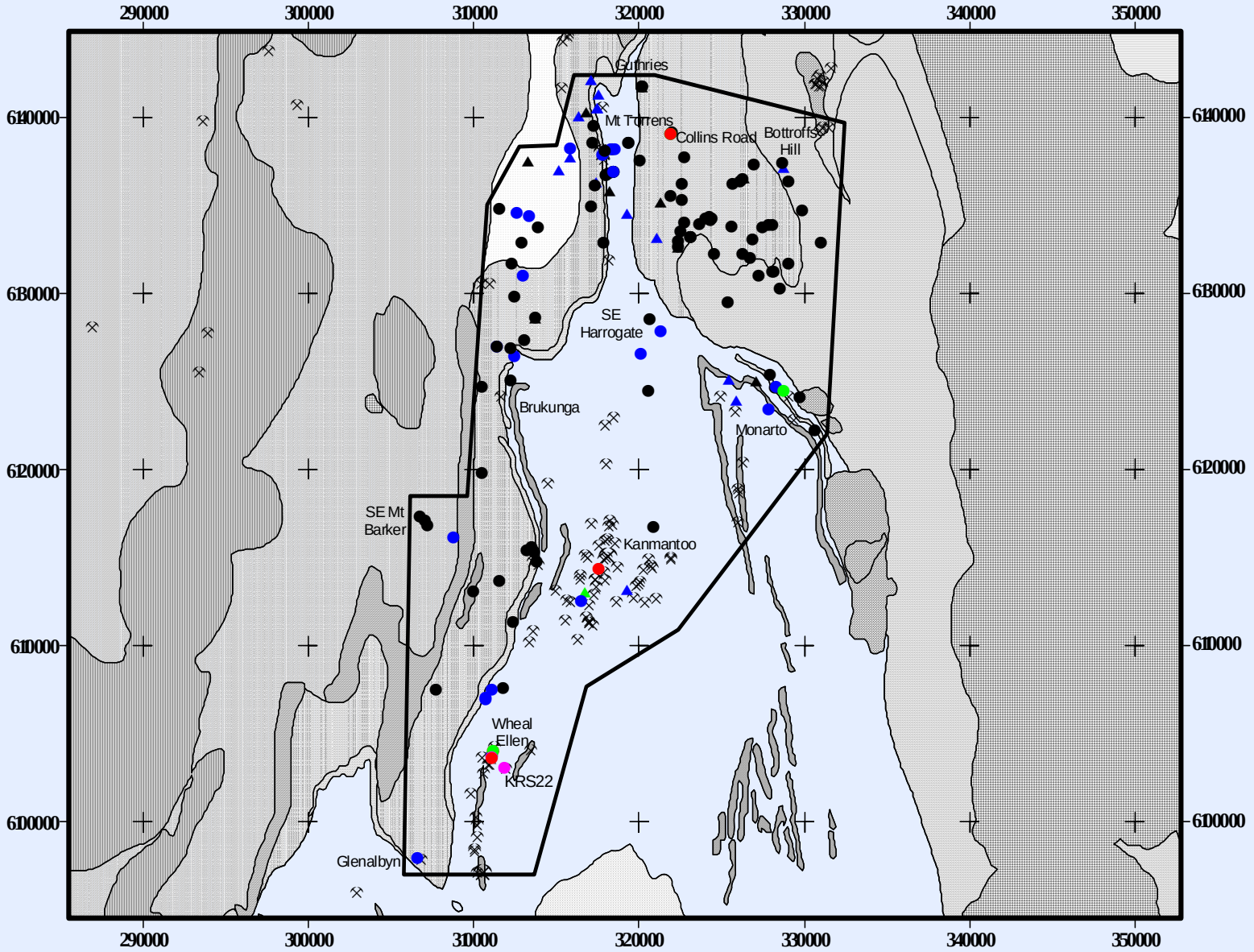
spring

seep

ferrihydrite weeps and algae

sulfidic layer in stream sediment

Au

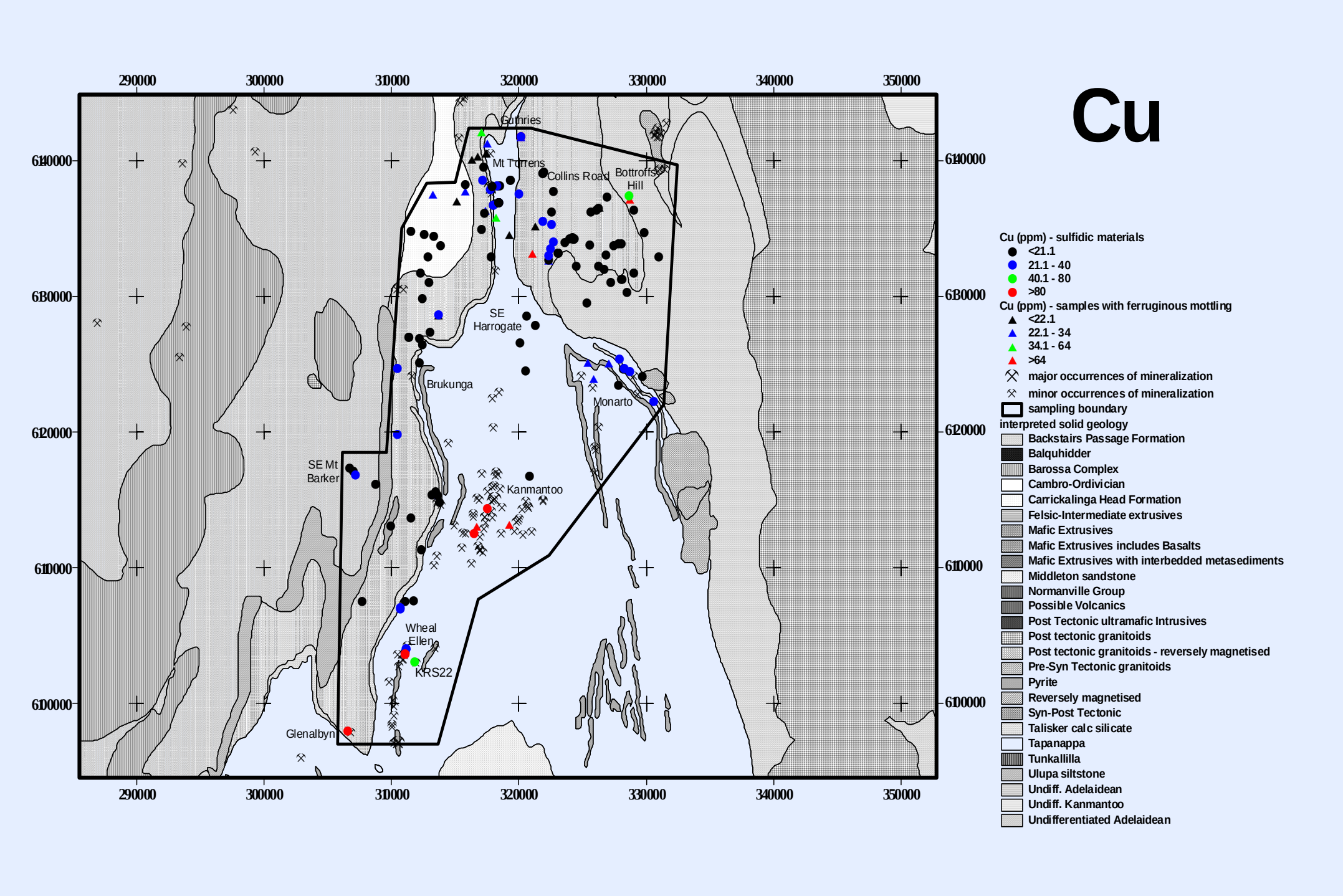


Au (ppb) - sulfidic materials
- below detection limit (1)
- 1 - 3
- 3.1 - 5
- 5.1 - 24.5
- >24.5

Au (ppb) - samples with ferruginous mottling
- below detection limit (1)
- 1 - 3
- >3

- major occurrences of mineralization
- minor occurrences of mineralization
- sampling boundary

interpreted solid geology
- Backstairs Passage Formation
- Balquhidder
- Barossa Complex
- Cambro-Ordivician
- Carrickalinga Head Formation
- Felsic-Intermediate extrusives
- Mafic Extrusives
- Mafic Extrusives includes Basalts
- Mafic Extrusives with interbedded metasediments
- Middleton sandstone
- Normanville Group
- Possible Volcanics
- Post Tectonic ultramafic Intrusives
- Post tectonic granitoids
- Post tectonic granitoids - reversely magnetised
- Pre-Syn Tectonic granitoids
- Pyrite
- Reversely magnetised
- Syn-Post Tectonic
- Talisker calc silicate
- Tapanappa
- Tunkallilla
- Ulupa siltstone
- Undiff. Adelaidean
- Undiff. Kanmantoo
- Undifferentiated Adelaidean


Cu
290000
300000
310000
320000
330000
340000
350000
6140000
6130000
6120000
6110000
6100000
Guthries
Mt Torrens
Collins Road
Bottroffs Hill
SE Harrogate
Brukunga
Monarto
SE Mt Barker
Kanmantoo
Wheal Ellen
KRS22
Glenalbyn
Cu (ppm) - sulfidic materials
<21.1
21.1 - 40
40.1 - 80
>80
Cu (ppm) - samples with ferruginous mottling
<22.1
22.1 - 34
34.1 - 64
>64
major occurrences of mineralization
minor occurrences of mineralization
sampling boundary
interpreted solid geology
Backstairs Passage Formation
Balquhidder
Barossa Complex
Cambro-Ordivician
Carrickalinga Head Formation
Felsic-Intermediate extrusives
Mafic Extrusives
Mafic Extrusives includes Basalts
Mafic Extrusives with interbedded metasediments
Middleton sandstone
Normanville Group
Possible Volcanics
Post Tectonic ultramafic Intrusives
Post tectonic granitoids
Post tectonic granitoids - reversely magnetised
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Pyrite
Reversely magnetised
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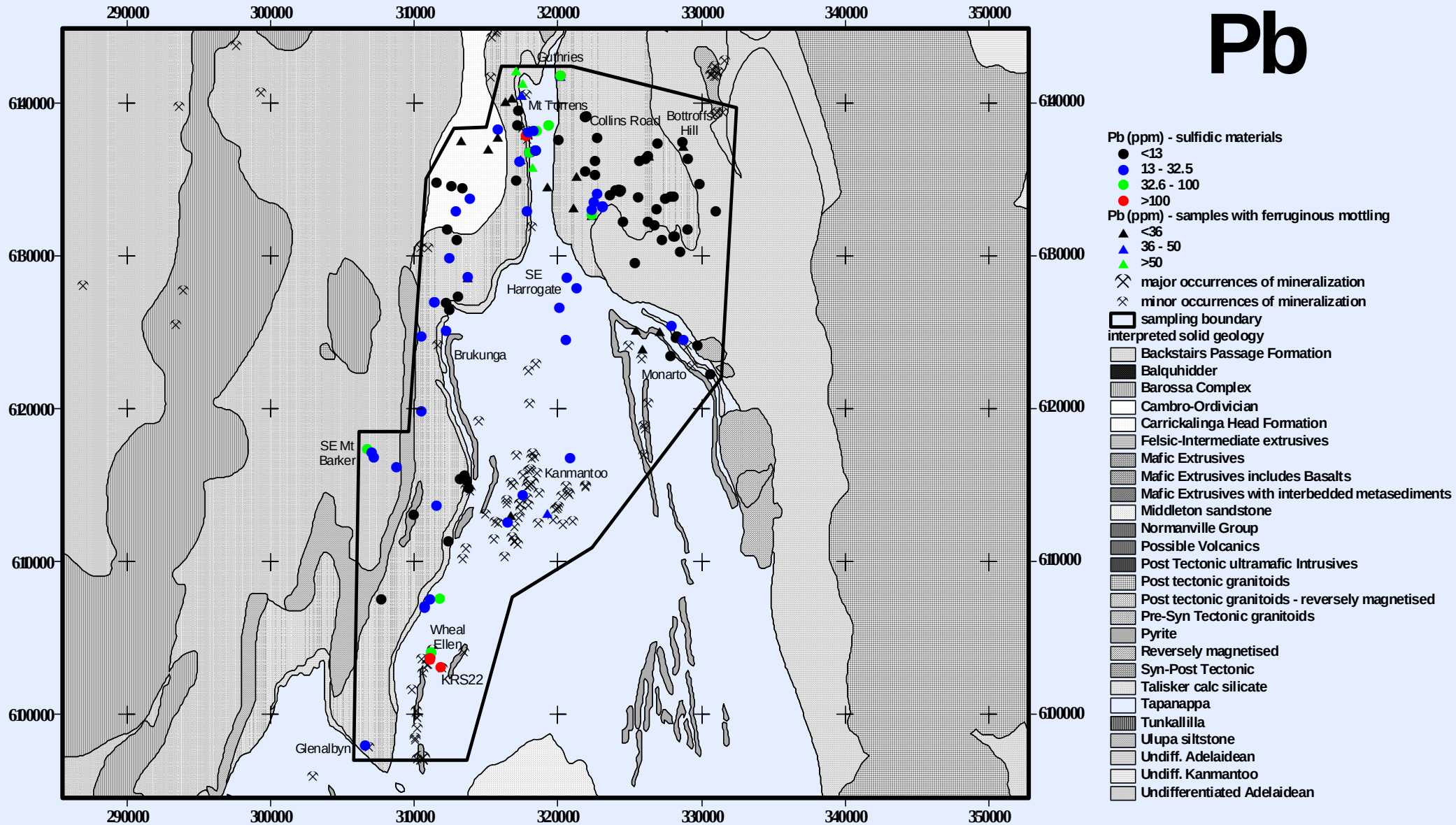
Talisker calc silicate
Tapanappa
Tunkallilla
Ulupa siltstone
Undiff. Adelaidean
Undiff. Kanmantoo
Undifferentiated Adelaidean


Pb
290000
300000
310000
320000
330000
340000
350000
6140000
6130000
6120000
6110000
6100000
Guthries
Mt Torrens
Collins Road
Bottroffs Hill
SE Harrogate
Brukunga
Monarto
SE Mt Barker
Kanmantoo
Wheal Ellen
KRS22
Glenalbyn
Pb (ppm) - sulfidic materials
<13
13 - 32.5
32.6 - 100
>100
Pb (ppm) - samples with ferruginous mottling
<36
36 - 50
>50
major occurrences of mineralization
minor occurrences of mineralization
sampling boundary
interpreted solid geology
Backstairs Passage Formation
Balquhidder
Barossa Complex
Cambro-Ordivician
Carrickalinga Head Formation
Felsic-Intermediate extrusives
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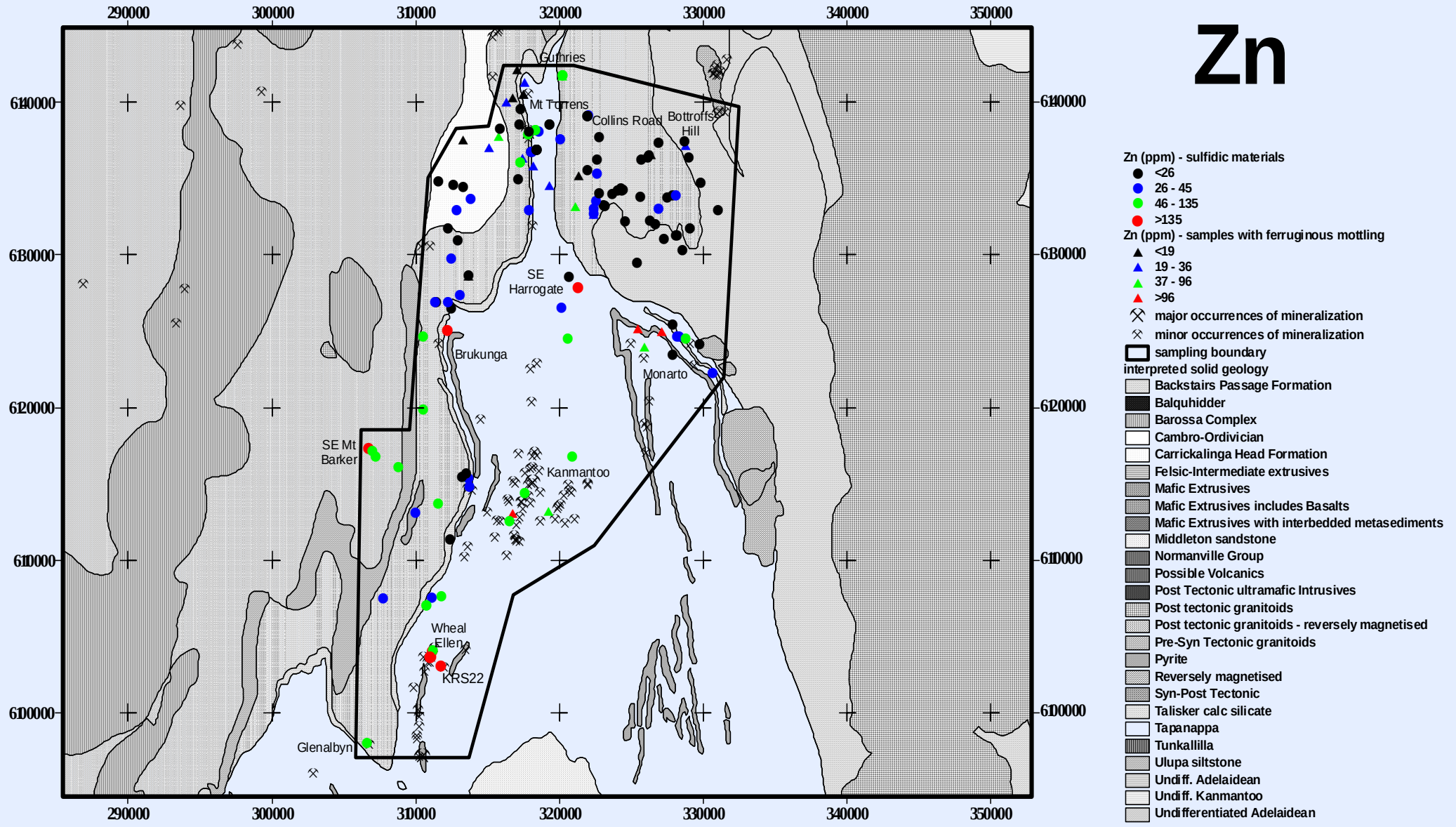
Zn
290000
300000
310000
320000
330000
340000
350000
6140000
6130000
6120000
6110000
6100000
Guthries
Mt Torrens
Collins Road
Bottroffs Hill
SE Harrogate
Brukunga
Monarto
SE Mt Barker
Kanmantoo
Wheal Ellen
KRS22
Glenalbyn
Zn (ppm) - sulfidic materials
<26
26 - 45
46 - 135
>135
Zn (ppm) - samples with ferruginous mottling
<19
19 - 36
37 - 96
>96
major occurrences of mineralization
minor occurrences of mineralization
sampling boundary
interpreted solid geology
Backstairs Passage Formation
Balquhidder
Barossa Complex
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Felsic-Intermediate extrusives
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Pyrite
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Talisker calc silicate
Tapanappa
Tunkallilla
Ulupa siltstone
Undiff. Adelaidean
Undiff. Kanmantoo
Undifferentiated Adelaidean

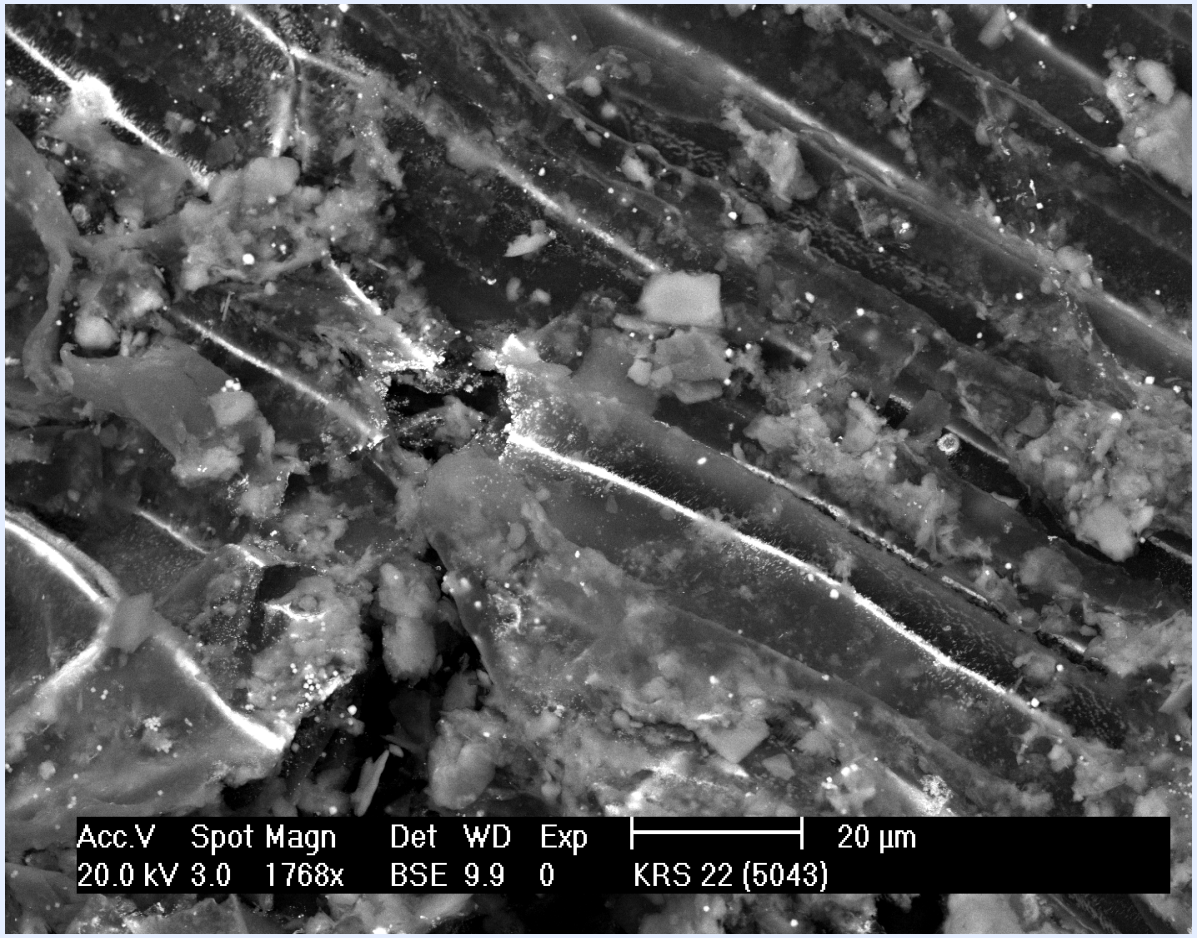
associated with known mineralization

- **Wheal Ellen**: **Ag, Au, Bi, Cd, Co, Cu, Hg, In, Ni, Pb, Sb, Se, Tl, Zn**
- **Kanmantoo area**: **As, Au, Bi, Co, Cu, Ni, Se, Tl, Zn**
- **Mt Torrens prospect**: **Ag, As, Bi, Co, Hg, Mo, Ni, Pb, Tl, Zn**
- **Monarto Cu prospect**: **As, Bi, Cd, Mo, Tl, Zn**
- **Glenalbyn**: **Cu, Sb, Tl, Zn**

not associated with known mineralization

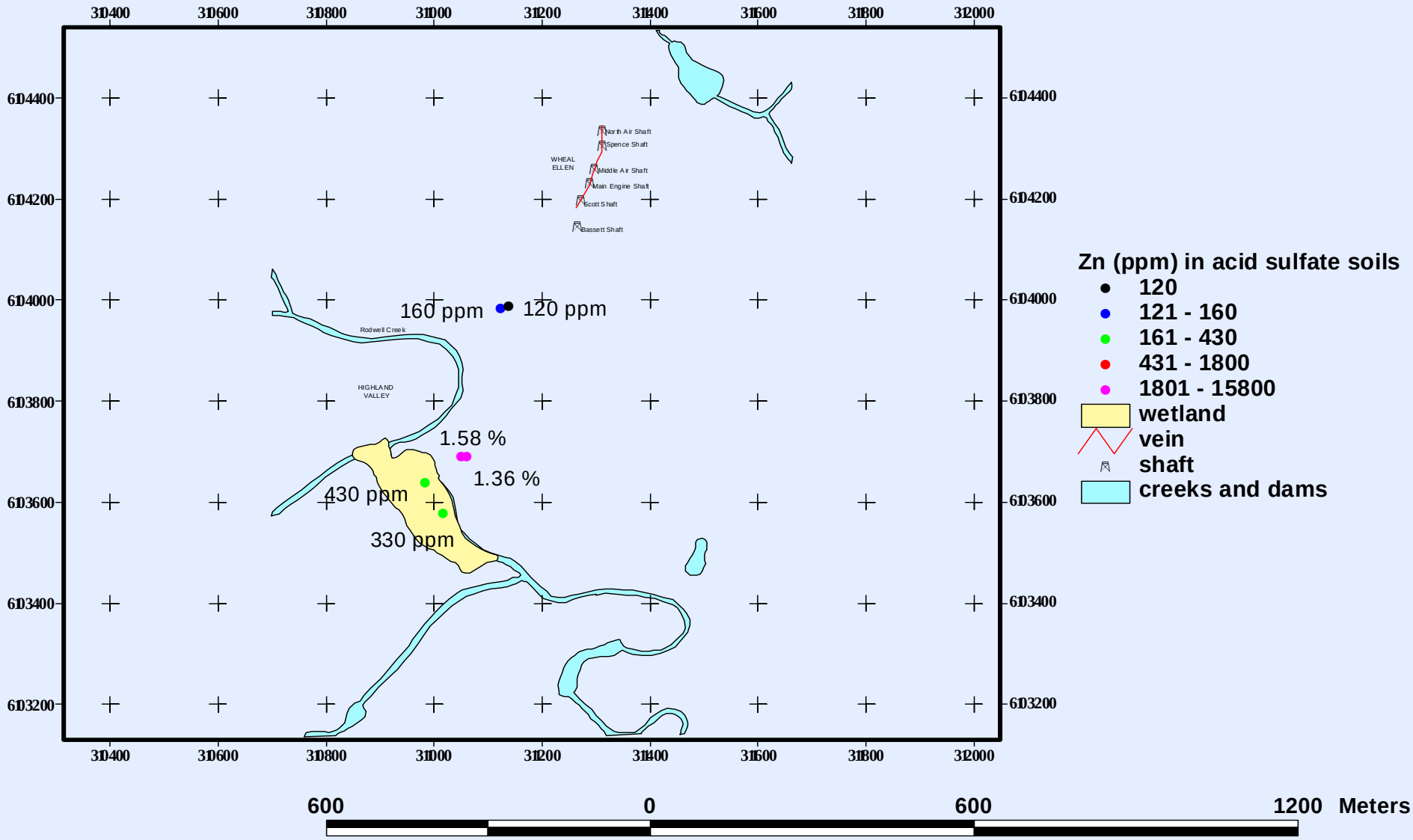
- **north of Brukunga**: **Cd, Co, Ni, Tl, Zn**
- **Guthries**: **Ag, As, Bi, Pb, Tl, Zn**
- **north of Wheal Ellen**: **Ag, As, Bi, Co, Mo, Ni, Pb, Tl, Zn**
- **south-east Harrogate 1**: **Ag, Tl, Zn**
- **south-east Harrogate 2**: **As, Mo, Zn**
- **Bottroffs Hill**: **Cu**
- **Collins Road**: **Au**
- **south-east Mount Barker**: **Pb, Zn**
- **KRS 22**: **Ag, As, Au, Bi, Cd, Pb, Sb, Zn**

Fe, Pb, Zn sulfides – KRS22



- **Ag** **7.5 ppm**
- **Au** **45 ppb**
- **Cd** **14 ppm**
- **Cu** **75 ppm**
- **Pb** **2850 ppm**
- **Sb** **8 ppm**
- **Zn** **2600 ppm**

Zn - acid sulfate soils, Wheal Ellen



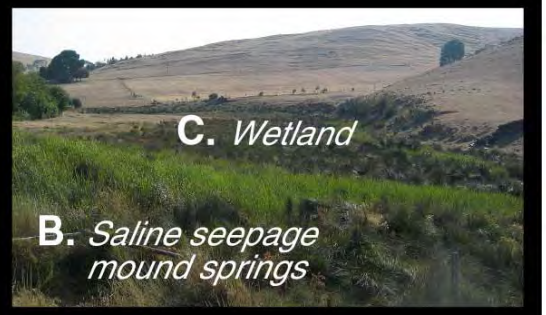
sulfidic materials – Wheal Ellen

element	400 m	1 km	1.3 km
Ag (ppm)	0.35	<0.1	2
Au (ppb)	7	7	30
Bi (ppm)	0.6	0.25	5
Cd (ppm)	0.5	0.2	1.6
Cu (ppm)	32	27	100
Pb (ppm)	70	35	900
Zn (ppm)	140	1.47%	380

Where do inland Acid Sulfate Soils occur?

Mt Lofty Ranges, SA

Precipitation of secondary Zn, Pb, Fe and Cu sulfides by biomineralization including bacterial reduction in saline mound springs and wetland



Thin skeletal soil (<50cm)

Gossanous zone with enhanced Ag and Au

Orebody or zone of mineralization (primary sulfides with Zn, Pb, Fe, Cu, Ag and Au)

Colluvium and alluvium with acid sulfate soils

Saline seepage mound springs

Through flow

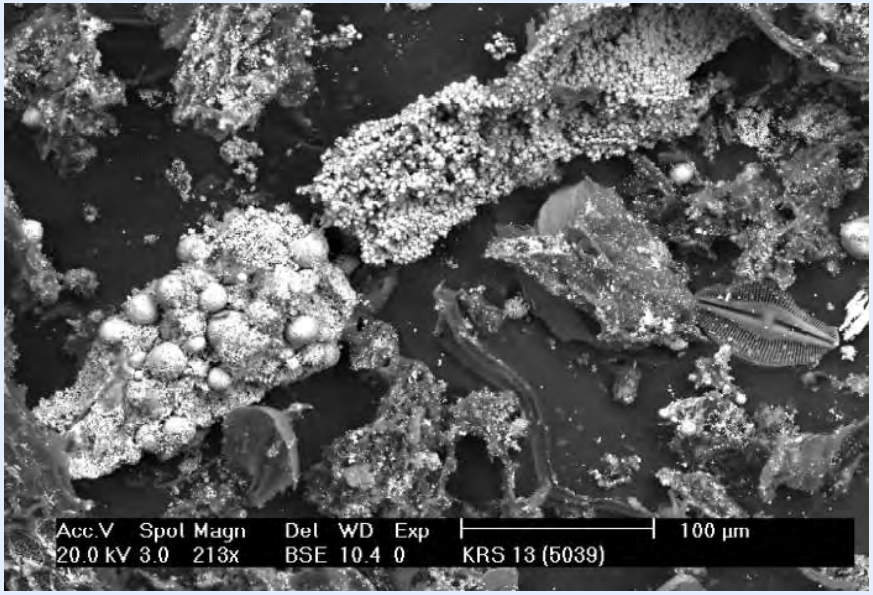
Groundwater flow

Fractured bedrock

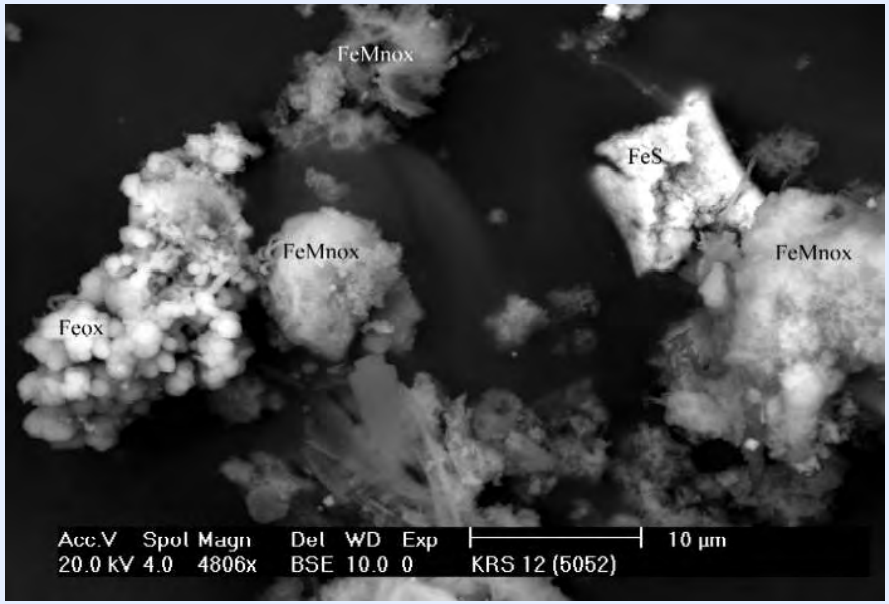
Mineralogy, inland ASS, Kanmantoo

- mainly **quartz**
- **silicates** (micas, feldspars, smectites, amphiboles, chlorite, kaolin)
- **sulfides** (pyrite, Fe monosulfides, galena, sphalerite, chalcopyrite)
- **native gold**
- **accessories** (zircon, rutile, anatase, monazite, xenotime, ilmenite)
- **sulfates** (bassanite, gypsum, jarosite, natrojarosite, plumbojarosite, barite)
- **halides** (halite, bischofite, $CdCl_2$)
- **oxides** (ferrihydrite, schwertmannite, goethite, hematite, Mn oxides with Zn, Co, I)
- **carbonates** (calcite, aragonite)

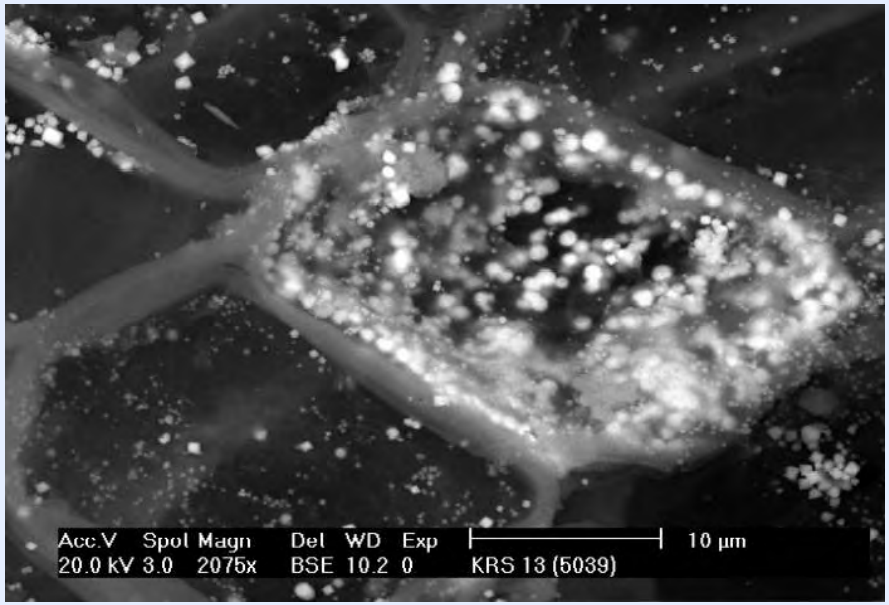
pyrite

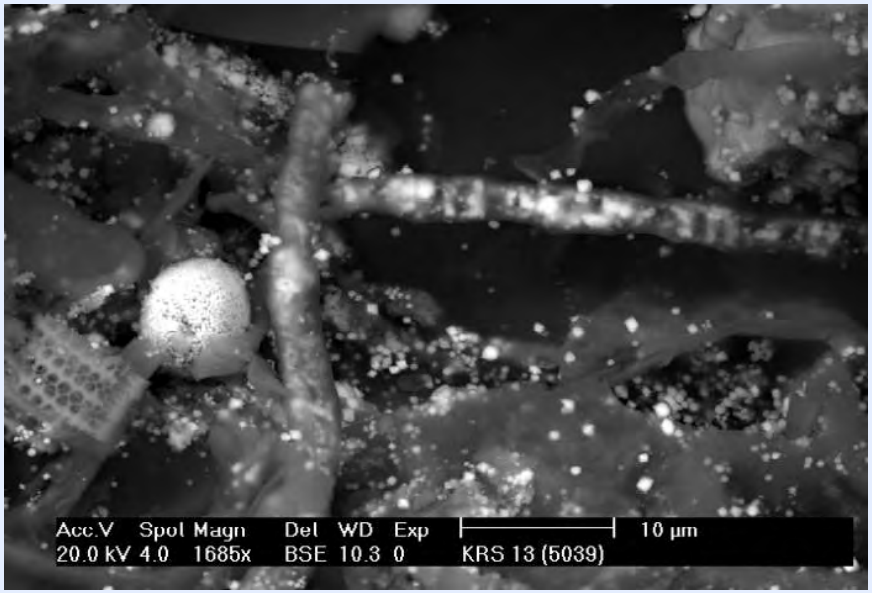


monosulfide

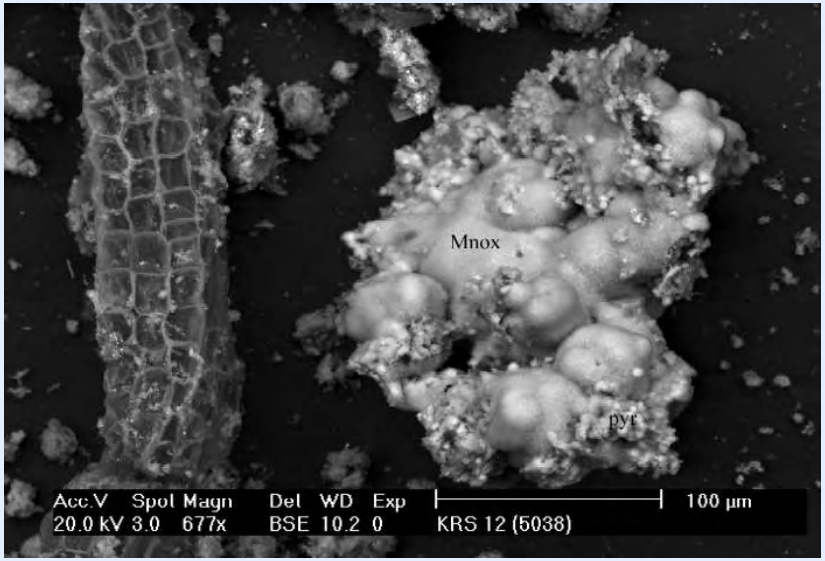


Zn sulfide

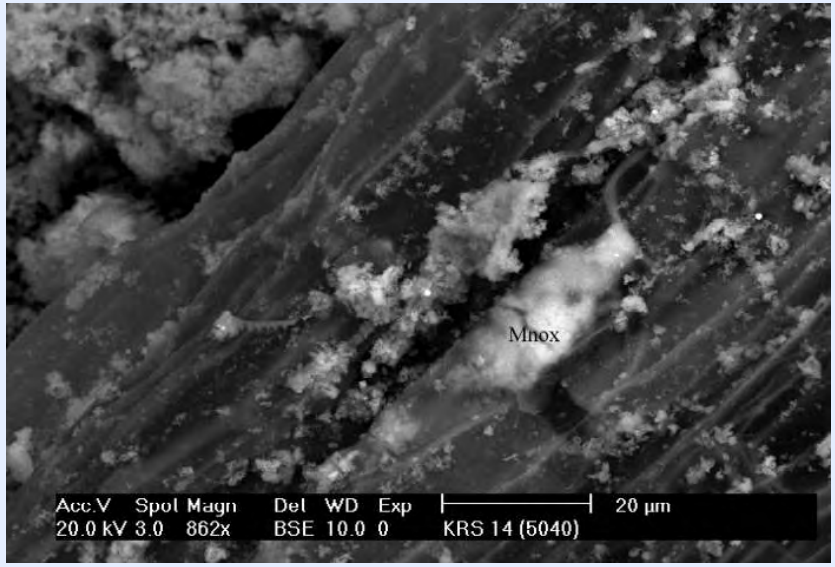




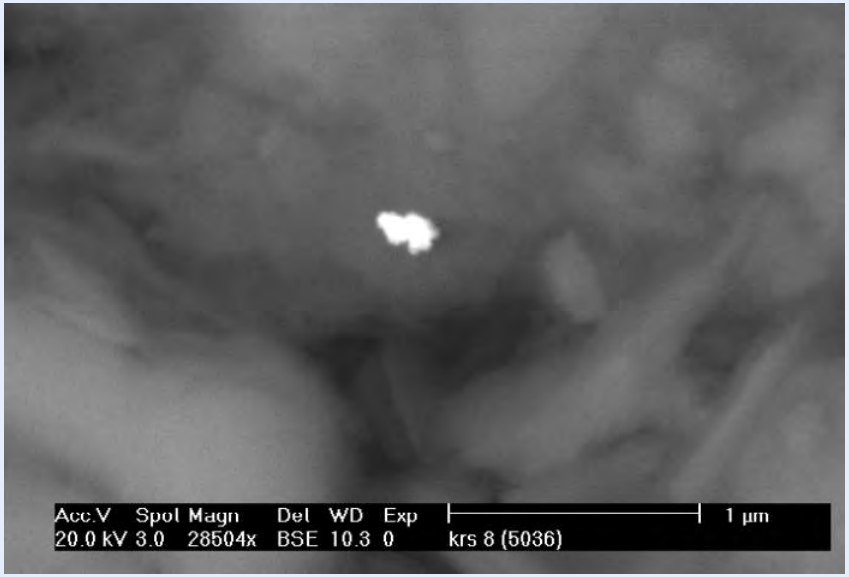
Mn oxide

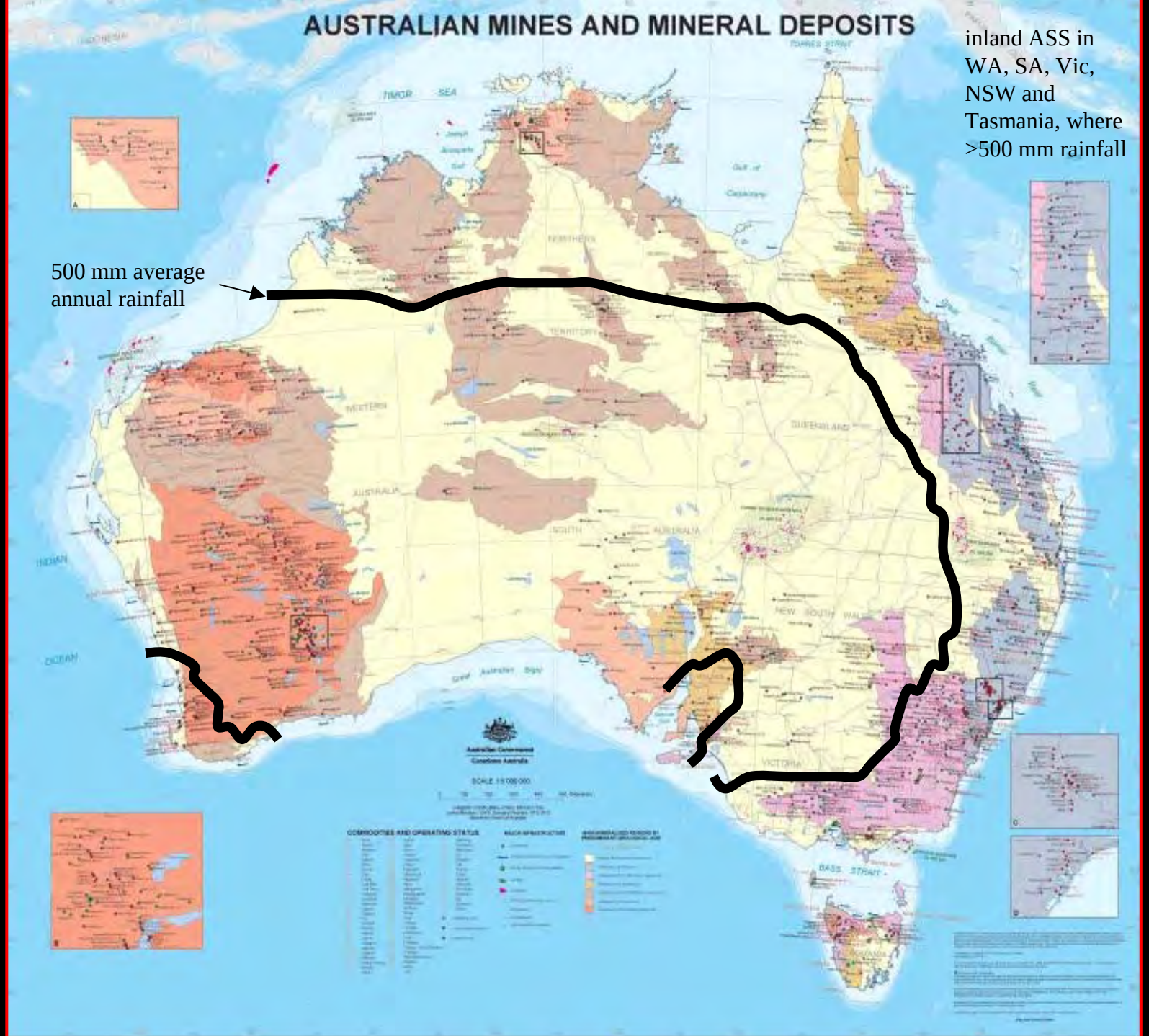


iodine-bearing Mn oxide



native gold




AUSTRALIAN MINES AND MINERAL DEPOSITS
inland ASS in WA, SA, Vic, NSW and Tasmania, where >500 mm rainfall
500 mm average annual rainfall

Implications for mineral exploration

- metals derived from bedrock via groundwaters
- large dispersion haloes
- surface signature of blind mineralization
- geochemical anomalies are reflected in the mineralogy of the materials
- acid sulfate materials easy to recognize and sample
- acid sulfate materials geographically widely distributed in southern Australia
- no special sample preparation required (except drying)