Applying basin analysis to unravel the sedimentary-hosted mineral potential of the Stuart Shelf, South Australia

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with contributions by M. Kunzmann³, G. Gouthas¹, G. Gordon¹, A. Caruso¹, A. Collins⁴, M. Blades⁴, D. Subarkah⁴, J. Lloyd⁴ & W. Preiss¹&⁴

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Background

- Australia has a lot of basins of various ages that host base metal mineralisation

→ **proven mineral provinces with mature and active frontier exploration**

- wide range of basin styles, clastic and carbonates, black shales and redbeds
- many are relatively undeformed, outcrop or shallow under cover
- many are very deformed and intruded, mineralised, deeply eroded and buried under regolith/cover

→ **using approaches commonly used by petroleum industry has the potential to provide new insights for exploration mineral targets within those basins**
Sediment-hosted stratabound Cu deposits

- Characterised by disseminations, cements and veinlet-hosted copper minerals that are peneconformable with their sedimentary or metasedimentary host rocks.
- Deposits are typically thin (<50 m) but laterally extensive (several kilometres) with copper grades of about 1–3%.
- Orebodies are commonly hosted in sandstone, siltstone, shale and dolomite mainly in intracratonic sedimentary basins.
- Ore genesis involves circulation of sedimentary basin-derived brines that dissolves and transport copper, which precipitate ore minerals at redox boundaries within either primary or secondary reduced strata.

But... there can be lots of variations to the model in terms of traps, timing and mechanism.
Copper occurrences in SA → ~40% SedCu

Mineral systems components

- Geological setting ✓
- Chronostratigraphy ✓
- Prolonged depositional history ✓
- Evaporites ✓
- Host rocks ✓
- Source rocks ✓
- Structural traps ✓
- Basement endowment ✓
- Demonstrated Cu enrichment ✓
Why the Stuart Shelf?

- renewed and increased exploration interest
- known sediment-hosted Cu (Co-Pb-Zn) deposits
- overlies world-class Olympic Cu-Au Province
- similarities to Central African Copper Belt

Mineralisation:

- Neoproterozoic Tapley Hill Fm (mainly at base)
- permafrost breccia at contact between Mesoproterozoic redbeds of Pandurra Fm and Neoproterozoic aeolian sandstones of Whyalla Sandstone
- palaeo-basement highs (e.g. Pernatty High)
Stratigraphy of the Stuart Shelf

Umberatana Group

- mudstones, siltstones, sandstones and carbonates
- includes Sturtian and Marinoan glacials
- Tapley Hill Formation – reductant

Stratigraphic correlation chart of the southern Stuart Shelf (from: Tonkin, 2019)
GSSA/CSIRO
Sedimentary Cu project

- Re-log key drillholes with a focus on detailed characterisation of **facies, lithology, sedimentary structure, depositional environment** and **redox**

- **Stratigraphic correlation** of the Stuart Shelf to understand **basin structure** and **evolution** to identify areas most likely to host sedimentary copper mineralisation

- **Basin architecture** (unit extents, thicknesses, depth to key horizons, faults) to be mapped using geophysics (magnetics, gravity, seismic and EM where available) and through selected drillhole logging by using a **litho- and sequence stratigraphic approach**

- **Downhole data collection**: pXRF, gamma, C/O and Pb isotopes, pyrite chemistry to be collected from selected drillholes
New data collection included

- 25 out of 25 drillholes logged & HyLogged™
- 10570 m of core
- 9245 gamma data, 4711 pXRF data (including standards)
- 120 samples for carbon isotope, 8 samples for Rb-Sr dating
- 20 thin sections for diagenesis study
- 3450 detailed core photographs
- 3D surfaces Top Pandurra Fm, Beda Basalt & Tapley Hill Fm, Base Whyalla Sst
- 18 lithofacies, 5 facies association

<table>
<thead>
<tr>
<th>FA 1: offshore (basin floor)</th>
<th>FA 2: offshore transition (slope)</th>
<th>FA 3: shallow subtidal to shoreface (platform)</th>
<th>FA 4: intertidal to supratidal (sandflat, sabkha)</th>
<th>FA 5: continental (glacial, fluvioglacial)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LF→5</td>
<td>LF→4</td>
<td>LF→5</td>
<td>LF→1</td>
<td>LF→3</td>
</tr>
</tbody>
</table>

Images of data collection and core analysis.
How does this look in one representative drillhole?
Facies analysis

18 lithofacies (LF) $\rightarrow$ 5 facies associations (FA)

distinguished based on compositional and textural properties, and the occurrence of distinct sedimentary structures

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<tbody>
<tr>
<td>5 LF</td>
<td>4 LF</td>
<td>5 LF</td>
<td>1 LF</td>
<td>3 LF</td>
</tr>
</tbody>
</table>

SKYW-79 1A  SLT 102  HODD 3  MSDP02  SLT 106  SLT 103  PP 15  SAE 22
Facies analysis

18 lithofacies (LF) $\rightarrow$ 5 facies associations (FA)

in parts these are aligned closely with existing stratigraphic units

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<td>3 LF</td>
</tr>
<tr>
<td>Tapley Hill Fm (basal)</td>
<td>Tapley Hill Fm</td>
<td>Tapley Hill Fm Brighton Limestone Nuccaleena Fm Cox Sandstone Mb</td>
<td>Angepena Fm</td>
<td>Whyalla Sandstone Appila Tillite Wilmington Fm</td>
</tr>
</tbody>
</table>
Stratigraphy and facies of the Stuart Shelf based on basin-wide drillhole analysis

| Stratigraphy | Stuart Shelf | MDP102 | MG510 | HMD 1 | HOD31 | BUTE | EDAY7 | SR65 | PP55 | GY13 | Vanguard 1 | BUTE | BR23 | SAE 11 | SAE 22 | SLT106 | SLT101 | SLT102 | SLT103 | SLT107 | BLAH-CHIEF 1 | VICG5 | DIO1 | SR101 | MRD 1 | SH7 | BPDP | GC1 | SR132 |
|--------------|--------------|--------|-------|-------|-------|------|-------|------|------|------|------------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-----------|-------|------|-------|------|------|------|------|-------|
| SIMMENS QUARTZITE | Corrabbula Sandstone Member | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| TREGOLANA SHALE Member | Corrabbula Sandstone | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| WHYALLA Sandstone | Whyalla Sandstone | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | |
| WILLMINGTON Formation | Willmington Formation | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| ANGEPENA Formation | Angepena Formation | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | |
| COX Sandstone Member | Cox Sandstone Member | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | |
| BRIGHTON Limestone | Brighton Limestone | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | |
| TAPLEY HILL Formation | Tapley Hill Formation | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | | | | |
| ‘basal grit’ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| APPILIA Tillite | Appilia Tillite | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| UNDIFFERENTIATED | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GOLDFIELD GROUP | Back point Fm. | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GAWLER RANGE Volcanics/ Hillaba Suite | Gawler Range Volcanics/ Hillaba Suite | X | X | X | X | X | X | X | X | X | X | X | | | | | | | | | | | | | | |
| Gawler Craton (undiff.) | Gawler Craton (undiff.) | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | |

**Legend:**
- X: Present
- : Not applicable
Tapley Hill Formation

3D surface top Tapley Hill Formation based on >1500 drillholes, displayed on Depth To Basement (SARIG)

by: G. Gouthas et al., 2022
Tapley Hill Formation

FA 3 - shallow subtidal to shoreface

FA 2 - offshore transition

FA 1 - offshore

- in most drillholes the base of the Tapley Hill Fm is characterised by a variety of offshore lithofacies
- black mudstones only occur in the lowermost part of the THF and coincide with the highest gamma values within the THF
  \[ \text{maximum flooding surface (MFS)} \]
- indicative of rapid deepening and flooding across the entire Stuart Shelf after the Sturtian glaciation
- followed by a basin-wide regression
<table>
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<th>LF2</th>
<th>LF3</th>
<th>LF4</th>
<th>LF5</th>
</tr>
</thead>
<tbody>
<tr>
<td>black mudrock</td>
<td>laminated siltstone</td>
<td>intercalated dark and light dolomitic siltstone</td>
<td>grainflow deposit</td>
<td>sandstone - siliciclastic</td>
</tr>
</tbody>
</table>

FA1: offshore (below wave storm base)
Examples from basal part of Tapley Hill Fm

SLT 102
HODD 3
Vanguard 1
**FA2: offshore transition** (between storm-wave base and fair weather-wave base)

<table>
<thead>
<tr>
<th>LF6</th>
<th>LF7</th>
<th>LF8</th>
<th>LF9</th>
</tr>
</thead>
<tbody>
<tr>
<td>edgewise conglomerate</td>
<td>slumps</td>
<td>rip up beds</td>
<td>debrite</td>
</tr>
</tbody>
</table>

HODD 3

HODD 3

SAE 22

BLANCHE 1
**FA2: offshore transition** (between storm-wave base and fair weather-wave base)

- present in most drillholes with Tapley Hill Fm
- important marker horizon

→ **basal surface of forced regression!**
FA3: shallow subtidal to shoreface

<table>
<thead>
<tr>
<th>LF12</th>
<th>LF13</th>
</tr>
</thead>
<tbody>
<tr>
<td>laminated silty dolostone</td>
<td>sandstone - siliciclastic</td>
</tr>
</tbody>
</table>

Images showing core samples with labels SLT 102 and SLT 103.
Brighton Limestone

**FA 3 - shallow subtidal to shoreface**

<table>
<thead>
<tr>
<th>LF10</th>
<th>LF14</th>
</tr>
</thead>
<tbody>
<tr>
<td>stromatolite</td>
<td>microbiolaminite</td>
</tr>
</tbody>
</table>

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**Map and Core Images:**

- **Brighton Lst**
- **Stuart Shelf**
- **THZ**
- **Olympic Dam High**
- **HWD 1**
- **SAE 22**
- **Pernatty High**
- **GY13**
- **HODD3**
- **all SLT cores**
- **SLT 102**
- **SLT 106**
- **HODD 3**
- **SCYW-79 '1A**
- **Olympic Dam**
- **HODD7**
- **BUTE DDH7**
- **SLT cores**

**Core Images:**

- **SLT 106**
- **SLT 102**
- **HODD 3**
Updated stratigraphy of the Stuart Shelf

Busfield & LeHeron, 2014
Correlating across the Stuart Shelf

Sequence Stratigraphic System Tracts and Surfaces

Pernatty High

Facies and Facies Associations

Correlating across the Stuart Shelf

Pernatty High
Correlating across the Stuart Shelf

Flattened to MFS

Sequence Stratigraphic System Tracts and Surfaces

- LST
- SB
- FSST
- TS
- HST
- MFS
- TST
- BSFR

Facies and Facies Associations
- Black matrix
- breccia
- sandstone
- siltstone

- yellow
- stromatolite
- deltaite

- green
- mudstone
- siltstone
da
dale

- blue
- lenticular
- tidal flat

- red
- diamictite
- mudstone

Pernatty High

Stuart Shelf

- Corroboree Sandstone Member
- Topalina Shale Member
- Corroboree Formation
- Willunga Formation
- Calliope Formation
- EEL Sensitives Member
- Brighton Limestone
- Tapley Hill Formation
- Apple Title

Pernatty High

100 km
What’s next....

Geophysics
updated basin depth to Pandurra Fm by gravity inversion

AEM advanced processing

Gairdner Dyke swarm mapping

Basin Analysis
1D burial history logs

sandstone diagenesis

3D basin model including facies maps

Mineralogy & Geochemistry
hyperspectral mineralogy by lithofacies

carbon isotopes

pXRF geochemistry
… new data to take home

Interactive with links to GSSA’s mineral deposit database MinDep!


https://dsd-gdp.s3.amazonaws.com/2043140/GDP00121.zip
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We would like to acknowledge this land that we are presenting from today is the traditional lands of the Larriki people and that we respect their spiritual relationship with their country. We also acknowledge the Larriki people as the custodians of the Darwin region and that their cultural and heritage beliefs are still as important to the people living here.

The Department for Energy and Mining acknowledges Aboriginal people as the First Nations Peoples of South Australia. We recognise and respect the cultural connections as the traditional owners and occupants of the land and waters of South Australia, and that they continue to make a unique and irreplaceable contribution to the state.