



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

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Acknowledgement of Country

As guests here on Whadjuk 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.





Copper in South Australia



SOUTH AUSTRALIA Major Exploration Models



SOUTH

energymining.sa.gov.au

Strong demand for Cu and Co

Renewed interest in sed-hosted Cu in SA

- CODA Minerals Elisabeth Creek
 JORC 2012 Resource Emmie Bluff total 43.3 Mt @ 1.84% CuEq
 JORC 2012 Resources MG14 total 1.83 Mt @ 1.24% CuEq>0.5% cut off
 JORC 2012 Resources Windabout total 17.67 Mt @ 0.77% CuEq>0.5% cut off
- Taruga Worrumba Anticline
 - 7m @ 1.8% Cu from 85m (ASX announcement 3 May 2021)
 - 22m @ 1,050 ppm TREO from 27m (ASX announcement 12th July 2022)
- EnviroCopper progressing ISR project at Kapunda
- other companies exploring in SedCu space in SA include: IGO, First Quantum, Renascor, FMG, OZ Minerals, Gold Road
- ADI Round 1-3 funding for several SedCu projects



Secondary Cu in qtz and calcite veins cutting Tapley Hill Fm, Kapunda

Sediment-hosted copper in South Australia





Deposit	Ore (Mt)	Cu (%)	Cu (kt)	Co (%)	Past production (Cu - kt)				
Emmie Bluff	43-71	0.3-1.5	325	0.016-0.064	-				
Windabout	17.65	0.77		0.05	-				
MG14	1.83	1.24		0.033	-				
Gully	0.9	0.9	8.1	0.01	-				
Sweet Nell	0.35	1.2	4.2		Neg				
Cattlegrid	15	0.67	100	0.01	>156				
Main Open Cut	3.3	0.51	17		16				
Kapunda	3.7	1.2	47		14				
Mountain of Light	1.2	0.82	10		0.6				
Blinman	?0.21	>3.5-15			9.9				
Burra	2.7	3.3			90				

→ just how prospective is SA for sediment-hosted Cu deposits?

Central African Copperbelt (CACB) vs SA



from: Van Langendonck et al., 2013



Bockmann et al., 2022



Comparison CACB - SA

Continental margins - lithosphere thickness model (Hoddard et al., 2020)

→ both have enriched sub-continental lithospheric mantle (SCLM)



Hoggard et al., 2020



Comparison CACB - SA

Basement highs play important role

Basement-proximal Zambian Copperbelt





Stuart Shelf



Tonkin and Wallace, 2021

Sed-Cu mineralisation in SA

Ore textures

replacement (laminae, clasts), cements, veins



Emmie Bluff – clast and matrix cpy, replacement textures

Cattlegrid/Mt Gunson - permafrost breccia

Mineral systems components for SedCu in SA

- ✓ Geological setting
- ✓ Chronostratigraphy
- ✓ Prolonged depositional history
- ✓ Evaporites
- ✓ Host rocks
- ✓ Source rocks
- ✓ Structural traps
- ✓ Basement endowment
- ✓ Demonstrated Cu enrichment



Review of Neoproterozoic SedCu in SA

- 920 records for Neoproterozoic SedCu deposits/prospect/occurrences
- **619** after database clean-up removal of igneous-related, insignificant occurrences and non-descriptive entries

Deposit Number: 3 Details Location	Beas Deposit Details 068 Deposit Name: Mount Gunson Geology Commodities References Historical Deposit	7
Deposit Synonyms Mineral District Deposit Summary Deposit Description	Brennans, Emi 6192, Main Open Cut, MI 3717, MI 3718, MI 3719, MI 3720; MI 3721; MI 5598; Musolino, Plateau Brennans, Emi 6192, Main Open Cut, MI 3717, MI 3718, MI 3719, MI 3720; MI 3721; MI 5598; Musolino, Plateau Mount Gunson Copper Cut, MI 3717, MI 3718, MI 3719, MI 3720; MI 3721; MI 5598; Musolino, Plateau Cut-Aq-Co-2n-Pb mineralisation at Marinoan disconformity at base of Whyalla Sandstone, Most production from 1984-90 for 830, 0001 @ (16% Cut) MOUNT GUNSON, copper orde mineralisation was disconformity at base of Whyalla Sandstone, Most production from 1984-90 for 830, 0001 @ (16% Cut) MOUNT GUNSON, copper orde mineralisation was disconformity at base of Whyalla Sandstone, Most production from 1984-90 for 830, 0001 @ (16% Cut) MOUNT GUNSON, copper orde mineralisation, termed a core sup Andrura Formation, a fluviatile red bad sequence, representing a basement high during the known as the PV Woomers Shale. Lower in the Marinoan disconformity of the supports to the support of the	
covery Year amodities Minerals gue Minerals	2 1875 2 1875 Copper, Sandstone, Silver Atacamite, Azurite, Bornite, Chalcoptet, Chalcoptrite, Chrysocolla, Covellite, Cuprite, Digenite, Djurfeite, Malachin, Burdov, B Geethite, Manganese Oxide	

	Class	Description
stratabound	stratabound	Sediment-hosted stratabound copper sulphide mineralisation primarily controlled by lithological features (e.g. REDOX stratigraphic trap) or porosity that is unrelated to tectonic processes (e.g. permafrost breccia horizon).
	stratabound (low confidence)	Sediment-hosted stratabound copper mineralisation controlled by lithological features (e.g. REDOX stratigraphic trap) or porosity that is unrelated to tectonic processes (e.g. permafrost breccia horizon), but mineralisation is either insignificant, formed by secondary processes, or lacks information for a confident classification.
	structurally-controlled	Evidence for primary copper mineralisation that is directly related to a tectonic structure (e.g. hosted within shear/fault zone, breccia or within structures related to folding). Many deposits in this class are also hosted within structures related to diapirism.
structural	vein-hosted	Copper mineralisation hosted within quartz/carbonate veins, with no identified structural influence. Generally very little context is able to be provided for mineralisation in this class.
	surface	Copper mineralisation dominated by secondary copper minerals with no evidence of primary processes. Surface influenced mineralisation may be structurally controlled, but not vein hosted, as mineralisation in quartz veins requires higher temperatures than what can occur at the surface.

Neoproterozoic SedCu deposits in SA



Neoproterozoic SedCu deposits in SA

Emerging patterns

- dominantly hosted in Tapley Hill Fm and permafrost breccia developed at contact Mesoproterozic Pandurra Fm and Neoproterozoic Whyalla Sandstone
- around Pernatty High
- along western margin of Beda Volcanics
- within extend of underlying
 Cariewerloo Basin (Pandurra Fm)



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:

Cattlegrid Pit Mount Gunson

- 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)



Stuart Shelf data availability - seismic





Seismic line 03GA-OD1



03GA-0D1

Stuart Shelf data availability – drillholes





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[™] \rightarrow 10570 m of core relogged

- → 9245 gamma data, 4711 pXRF data (including standards)
- \rightarrow 120 samples for carbon isotope, 8 samples for Rb-Sr dating
- \rightarrow 20 thin sections for diagenesis study
- \rightarrow 3450 detailed core photographs
- → 3D surfaces Top Pandurra Fm, Beda Basalt & Tapley Hill Fm, Base Whyalla Sst
- \rightarrow 18 lithofacies, 7 facies association







Stuart Shelf stratigraphy – a historical challenge



Umberatana Group

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





Busfield & LeHeron, 2014

Drillhole review and data collection - example





Facies analysis

18 lithofacies \rightarrow 7 facies associations (FA)

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





Facies analysis

18 lithofacies \rightarrow 7 facies associations (FA)

in parts these are aligned closely with existing stratigraphic units



Stuart Shelf stratigraphy based on basin-wide drillhole analysis

			Stuart Shelf	MSDP02	MG510	HWD 1	HODD3	BUTE DDH7	SR6	PP15	GY13	Van- guard 1	BUTE B 23	SAE 11	SAE 22	SLT106	SLT101	SCYW- 79 1A	SLT 102	SLT 103	SLT 107	BLAN- CHE 1	WC05 D001	SSR- 1001	MRD 1	SH7	08PD 04C	SR13/2
		UP	Simmens Quartzite													X		Χ				X		Χ	Χ		X	
		SRO	Corraberra Sandstone Member						Χ	X						X	X	Х				X		Χ	Χ		Χ	
	IOAN	WILPENA G	Tregolana Shale Member Seacliff Sandstone	X		X	x		X	X		X				X	X	X	X		X			××	X	x	X	
zoic	MARIN		Whyalla Sandstone	X	X	X	X		X	X		X		X	X	X	X	X	X	x	X			X	X			
RO2			Wilmington Formation													X												
PROTE		GROUP	Angepena Formation	X			X		Χ	X						X	x	X	X		X				Х			
		NA	Cox Sandstone Member				X			X							X			X	Х							
Z		ATA	Brighton Limestone			Χ	X	Χ	Χ	X	Χ				X	X	X	Х	X	Χ	Х							
	STURTIAN	UMBER	Tapley Hill Formation	x	x	X	x	x	X	x	X	X	x	x	x	x	x	X	X	x	X	x						
			Appila Tillite				X	X	X	x	X		X					X										
		BURRA GROUP	undifferentiated																									X
		CALLANA GROUP	Beda Basalt/ Backy Point Fm. Gairdner Dolerite	X			XXX									XX	×}x		X	X	X		XXX	x			x	
ISO. SO. DIC	20	Pandurra Formation		x	x						X		x	x						X	x	x	X		X	x		
PRO		J	Gawler Range Volcanics/ Hiltaba Suite			X	x					X		x		x	x			x	X	x			X		X	
PALEO-	PROTERO- ZOIC	202	Gawler Craton (undiff.)				x	x					x	x									x			x	x	

Updated stratigraphy of the Stuart Shelf





new sequence stratigraphy



FSST - falling stage systems tract

LST - lowstand systems tract



Correlating across the Stuart Shelf



Stratigraphic units targeted for exploration: Woolcalla Dolomite Mbr & Tindelpina Shale Mbr

Tindelpina Shale Member

black, very finely laminated carbonaceous, dolomitic or calcareous, pyritic silty shale (Coates, 1964)

Woolcalla Dolomite Member

laminated dolomite and siltstone near base of Tapley Hill Fm (Preiss, 1972)

at Mount Gunson and western shore of Pernatty Lagoon massive and laminated dolomite with frequent ooids, stromatolites, oncolites and cross-beds (stromatolite reef) close resemblance to Brighton Limestone (Preiss, 1987)

> all offshore lithofacies are present throughout lower part of Tapley Hill Fm

> they can be variably carbonaceous, dolomitic or calcareous and pyritic



Busfield & LeHeron, 2014



Tapley Hill Formation (THF)

FA 2 - offshore transition

FA 1 - offshore

 in most drillholes base of THF characterised by variety of offshoreoffshore transitional and lower shoreface-prodelta facies

regression

MFS

rapid transgession

.....

 black mudstones only occur in lowermost part of THF and coincide with highest gamma values within THF

→ maximum flooding surface (MFS)

- indicative of rapid deepening and flooding across entire Stuart Shelf after Sturtian glaciation
- followed by a basin-wide regression

FA 1: offshore

(below wave storm base)



Examples from basal part of Tapley Hill Fm



FA 2: offshore transition

(between storm-wave base and fair weather-wave base)



FA 2: 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!





Brighton Limestone

FA 5 - shallow subtidal to subtidal

stromatolite

microbiolaminite





Tapley Hill Fm

THZ

Olympic Dam

High

Pernatty High



3D surface base Tapley Hill Formation

based on >1500 drillholes, displayed on Depth To Basement (SARIG)



OZ SEEBASE 2021

100km

Stuart

Shelf

....⊕

Tapley Hill Fm

THZ



thickness Tapley Hill Formation

based on >1500 drillholes, displayed on Depth To Basement (SARIG)



OZ SEEBASE 2021

100km

Stuart

Shelf

....⊕

Olympic Dam

High

Pernatty High

What's next....

Geophysics

updated basin depth to Pandurra Fm by gravity inversion

updated 3D surfaces



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





Opportunities

Stuart Shelf

- basement highs
- older strat units in S & N Stuart Shelf
 (→ Peak & Denison)



- Mount Gunson tailings
- ISR surface near deposits





Opportunities

Adelaide Rift Complex (ARC)

- with <1% of Dh's in ARC drilled to >100m, could some of those small occurrences at surface be pointing to something bigger at depth?
- ARC diapirs REE potential (e.g. Taruga's Mount Craig project)



Torrens Hinge Zone (THZ)

 Does THZ contain significant deposits at explorable depths?



"You could hide the main mineralised segment of the CACB in Torrens Hinge Zone"

Stuart Bull, 2020 Mwale Symposium



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