

The race to Net-Zero by utilizing Australia's salt basins for holistic energy technologies

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The University of Adelaide & The University of Oslo



Halite

Acknowledgement of Country

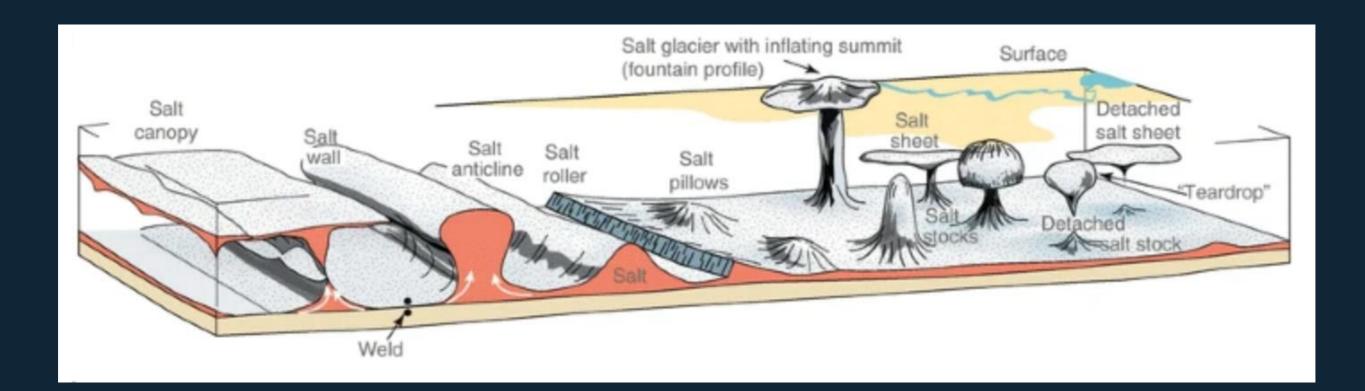
I want to acknowledge the Aboriginal and Torres Strait Islander peoples of Australia. I acknowledge the traditional custodians of the lands on which I live, where the university is located, where I conduct my field research, and places I visit. I pay my respects to the ancestors and Elders past and present. I am committed to honoring Australian Aboriginal and Torres Strait Islander peoples' unique cultural and spiritual relationships to the land, water, sea, and sky and their rich contribution to society.



Wilpena Pound Ikara-Flinders Ranges National Park South Australia

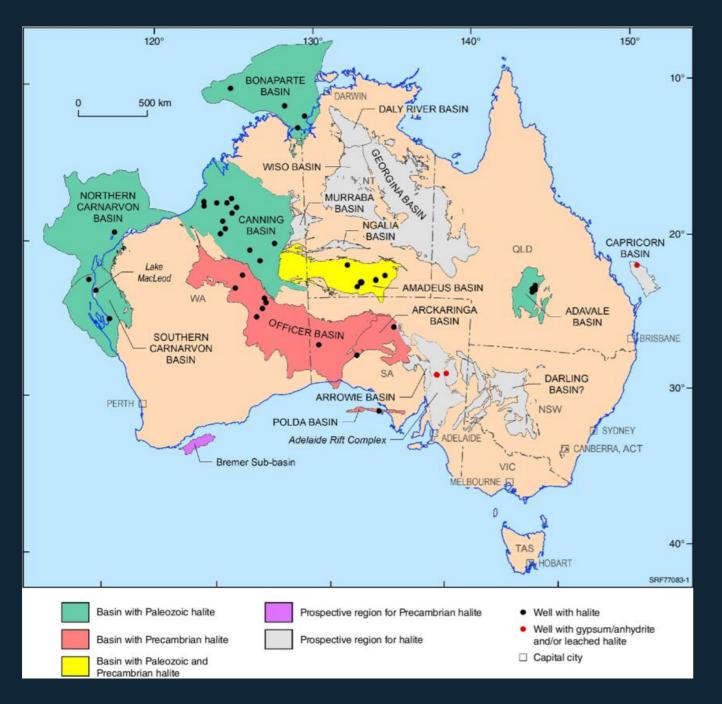
Introduction to Salt Basins

- Globally recognized
- Significant for petroleum systems and gas storage (caverns) outside of Australia
- Exciting potential for energy transition applications within Australia
- Many research gaps allow for development of new topics



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Australian Salt Basins





Bradshaw et al., 2023

Salt Caverns

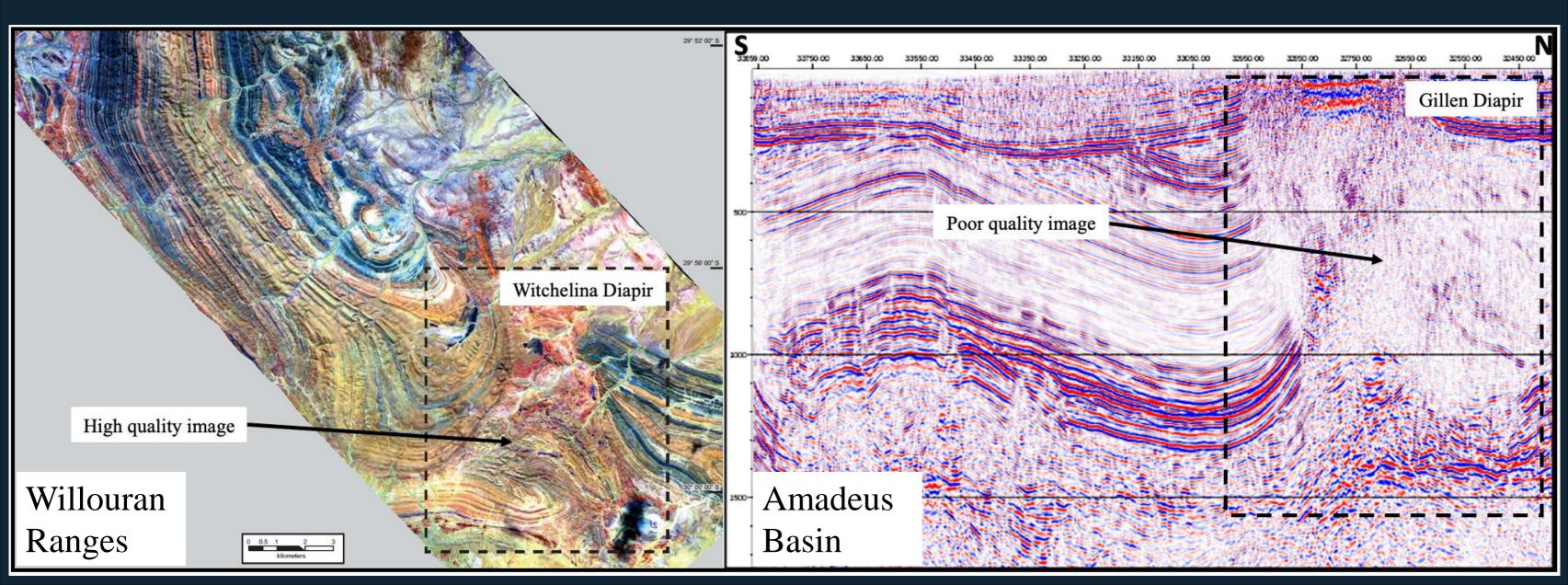
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Geothermal Energy

Critical Minerals

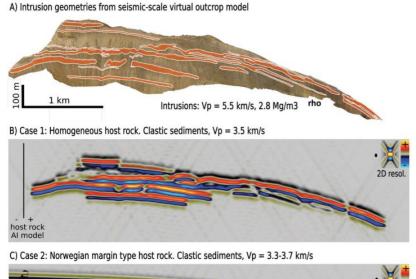
Natural Hydrogen

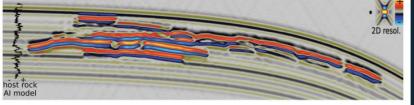
Outcrop Analogues – Inputs for Seismic Interpretation, Geophysical re-processing



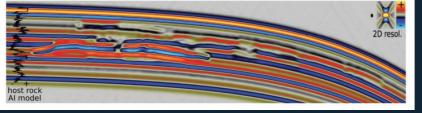
Outcrop Analogues – Inputs for Modelling

Synthetic Seismic



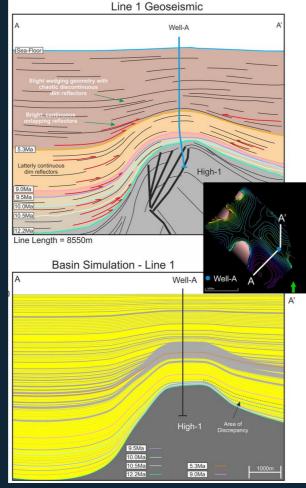


D) Case 3: Neuquén Basin type host rock. Mixed clastics, carbonates, evaporites, Vp = 3.5-5.9 km/s



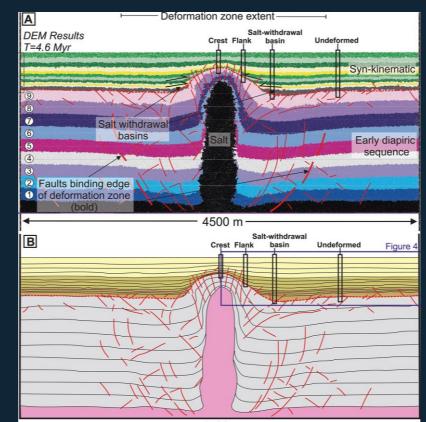
Planke et al., 2018

Forward Stratigraphic Modelling



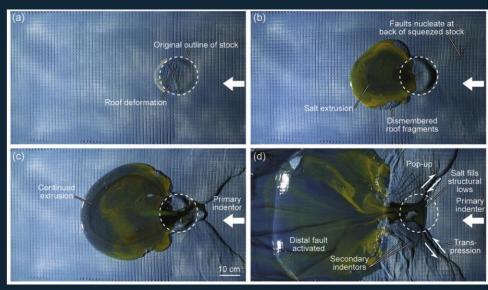
Christie et al., 2020

Numerical Modelling

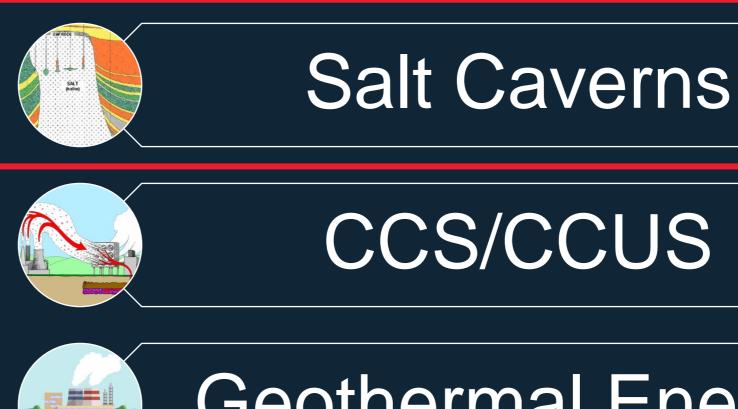


Cumberpatch et al., 2021

Physical Modelling



Dooley et al., 2018



Energy Storage

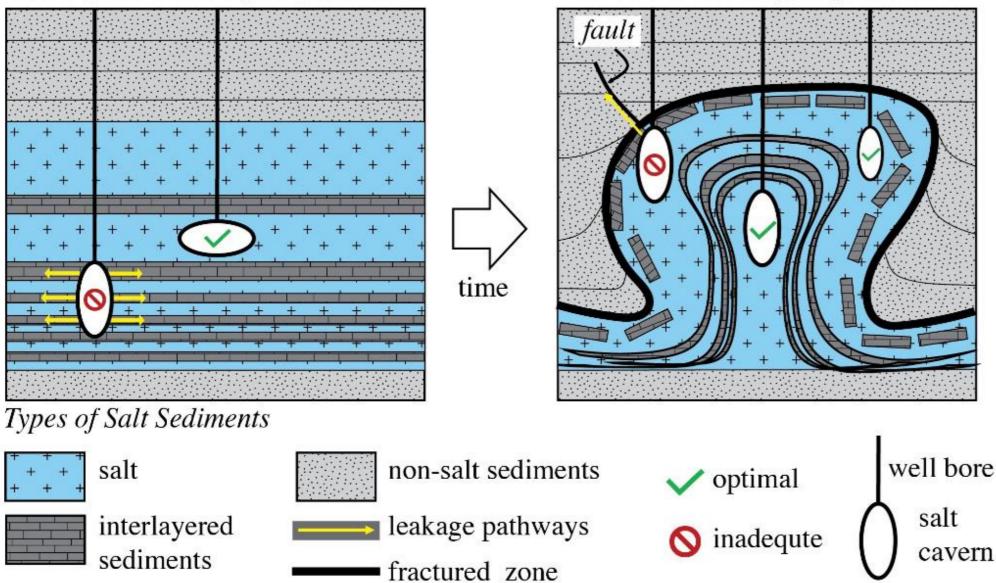




Geothermal Energy

Energy Storage

RP1: Undeformed Salt Sediments



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Kernen et al., 2024

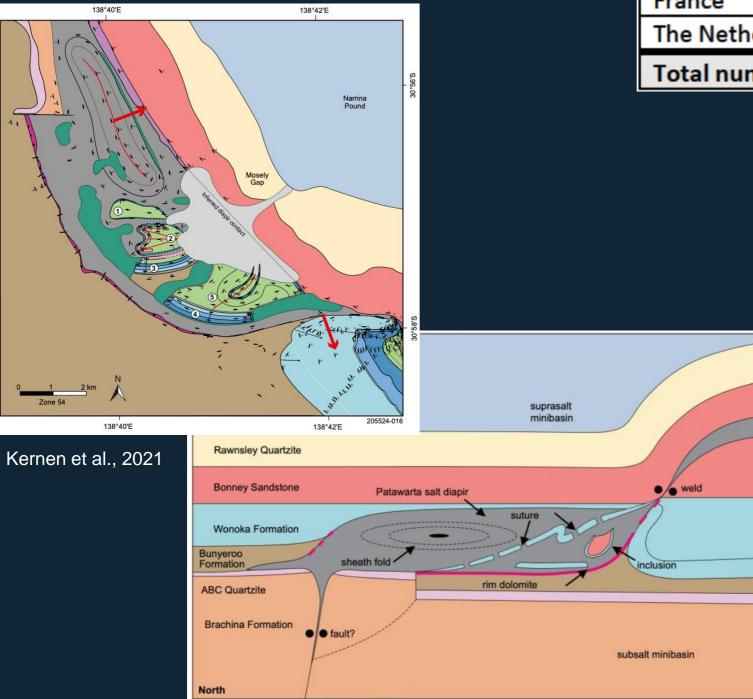
RP 2: Deformed Salt Sediments

Undeformed salt sediments or layered evaporite sequences in sedimentary basins are found in abundance across Australia (approximately 15 basins)

Deformed salt sediments or diapiric bodies are also common across Australia

Need outcrop studies because there has not been an investment in high quality 3D geophysical datasets across Australia's salt basins

Energy Storage



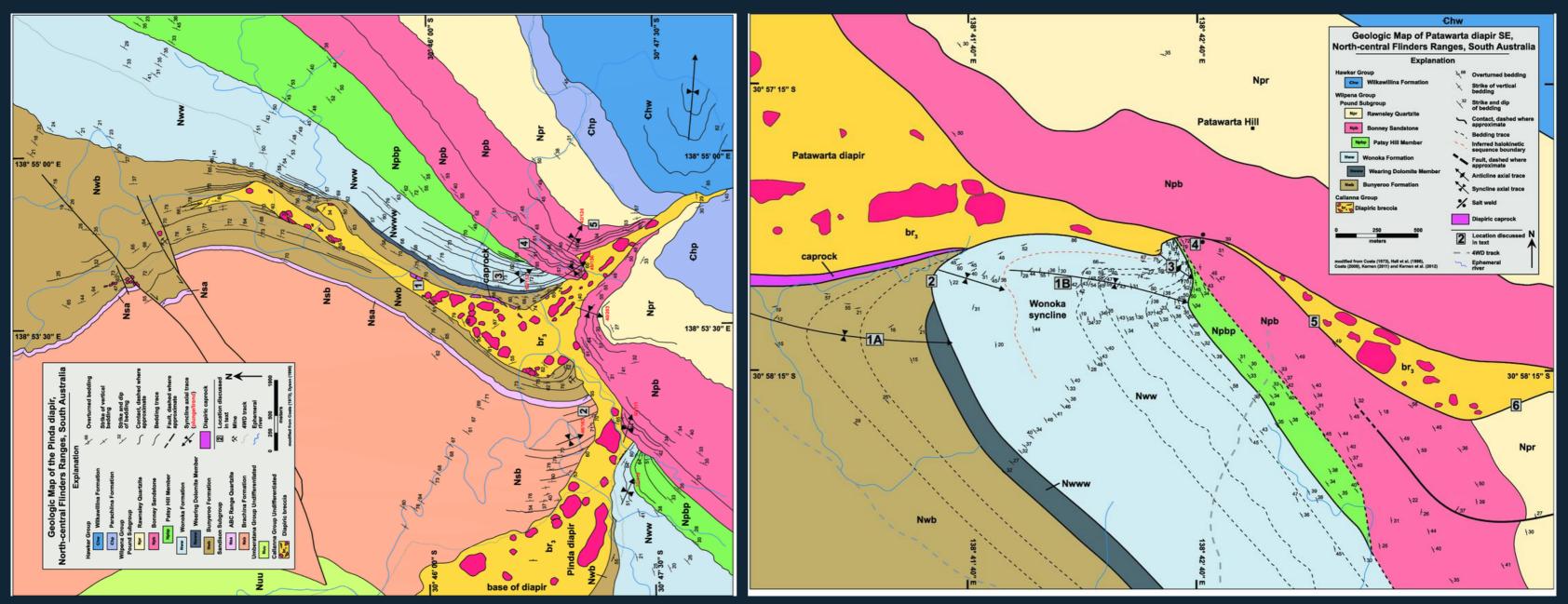
				Storage	product	Nun	nber of caverns	
Number of caverns per country				Natural gas		770		
(top 5 + the Netherlands)				LPG		628		
United States of America		78	781 Cru		de oil		202	
Germany		33	7	Unknown		53		
Canada		20	7					
United Kingdom		16	3	Diesel		6		
France		70		Helium		6		
The Netherlands (11 th)		g	9 Hydroger		n	6		
Total number of caverns		16	78	Nitrogen		4		
Total number of caverns		10	/0	CAES		3		
	Country		Caver	ns in bedded	Caverns in don	nal salt	Unknown	
	,			salts				
	Armenia Canada China Denmark France			-	19		-	
				207	-		-	
				23	-		-	
			- - 134 5 - 2 2		7 189 - 13 - 7		-	
							70 14	
Germany Iraq Mexico Morocco The Netherlands							14	
							-	
							-	
							-	
	Poland		2		18		-	
	Portugal	ugal		-	-		6 in salt walls	
• weld Russia Turkey United Kingdom			3		-		7	
				-	-		6	
				145	-		18	
	United States of America			468 313			-	
inclusion	Total (% of total number of caverns)		991 (~59%)		566 (~34%)		121 (~7%)	
salt minibasin	Incidents normalise total number of cav per salt type (in %)			~2%	~9%		~16%	
South								

			Storage p	oroduct	Number of caverns			
s per country erlands)			Natural g	as		770		
			LPG			628		
merica 781			1 Crude oil			202		
33		Unknown				53		
20)/						
16		53 Diesel				6		
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L1 th) 9			Hydrogen		6			
	· · · · · · · · · · · · · · · · · · ·		Nitrogen		4			
verns 1678		78	CAES		3			
			CAES			5		
Country		Caver	ns in bedded	Caverns in dom	nal salt	Unknown		
			salts					
Armenia		-		19		-		
Canada		207		-		-		
China		23		-		-		
Denmark		-		7		-		
France		-				70		
Germany		134		189		14		
Iraq		5		-		-		
Mexico		-		13		-		
Morocco		2		-		-		
The Netherlands		2		7		-		
Poland		2		18		-		
Portugal		-		-		6 in salt walls		
Russia		3		-		7		
Turkey		-		-		6		
United Kingdom		145		-		18		
United States of America		468		313		-		
Total (% of total number of caverns)		991 (~59%)		566 (~34%)		121 (~7%)		
Incidents normalised to total number of caverns per salt type (in %)		~2%		~9%		~16%		

Carbon Capture (Utilization) & Storage



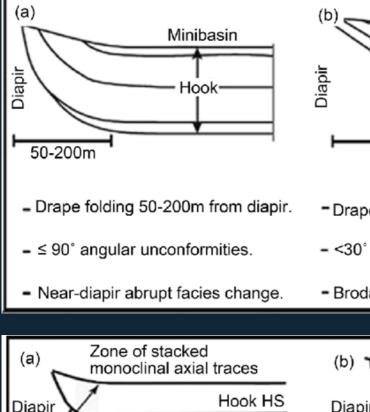
Carbon Capture (Utilization) & Storage

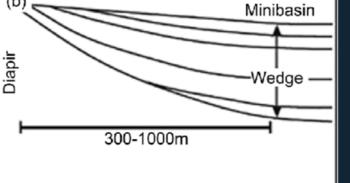


Hearon et al., 2015

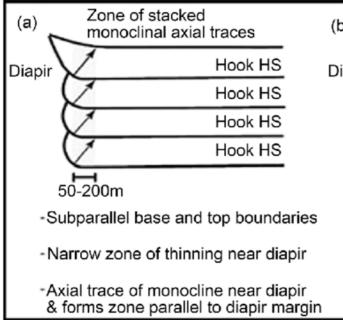
Kernen et al., 2012

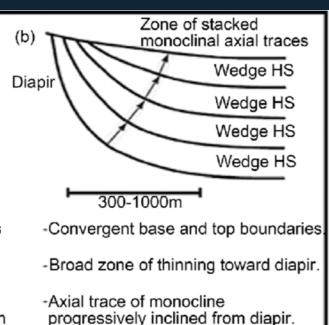
Carbon Capture (Utilization) & Storage

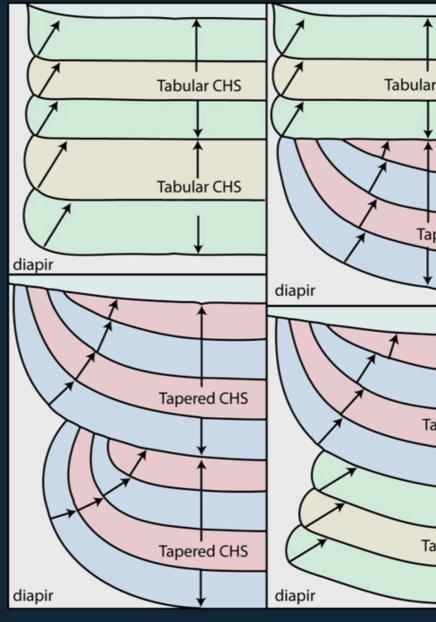




- Drape folding 300-1000m from diapir.
- <30° angular unconformities.
- Broda zone of gradational facies changes.







Giles and Rowan, 2012

Giles and Rowan, 2012



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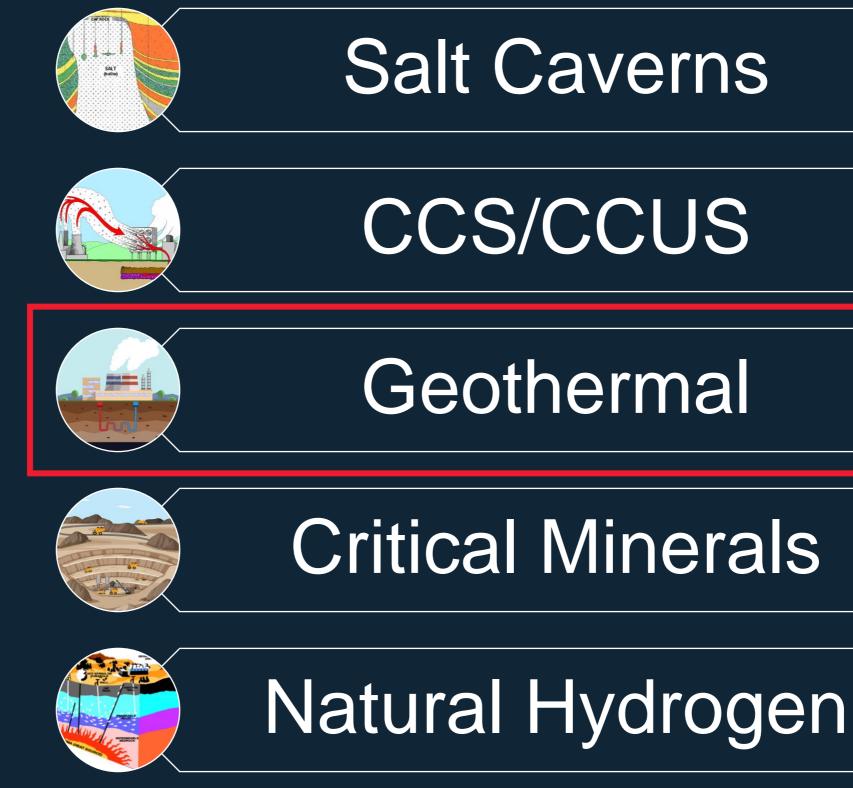
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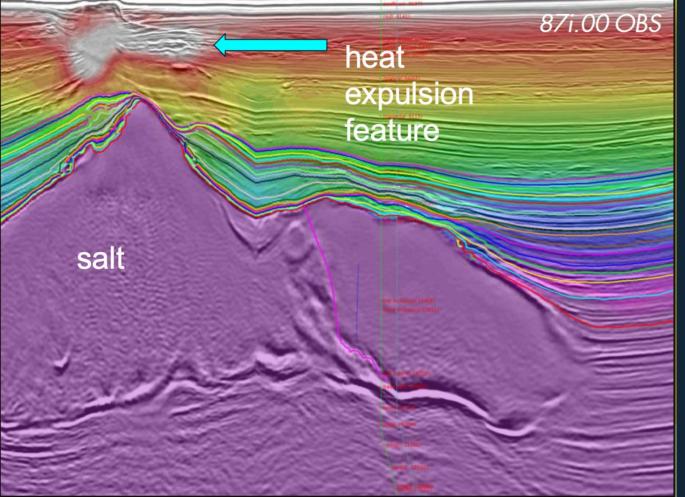
Continuation of petroleum geology studies

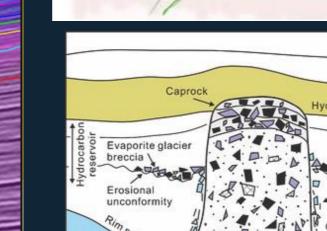
Field analogues are key to characterize lateral facies changes and structural geology adjacent to and above diapiric bodies

Geothermal Energy

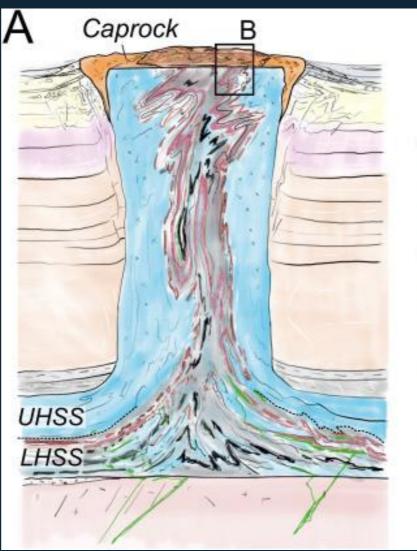


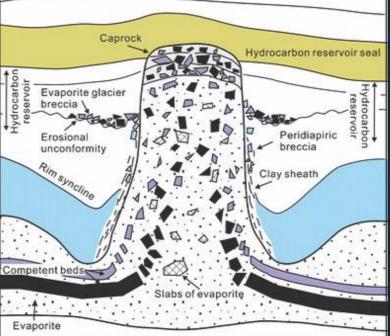
Geothermal Energy

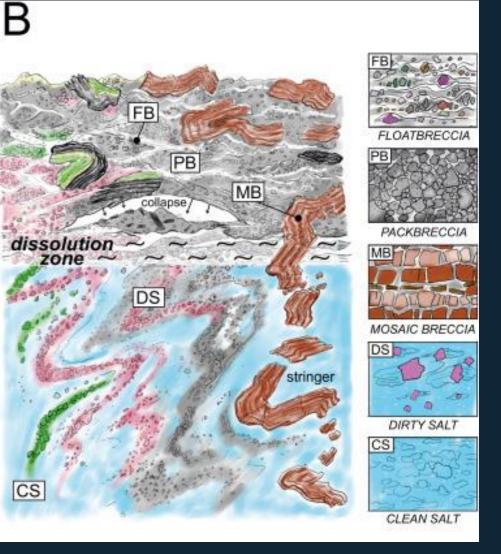




Kernen et al., 2014





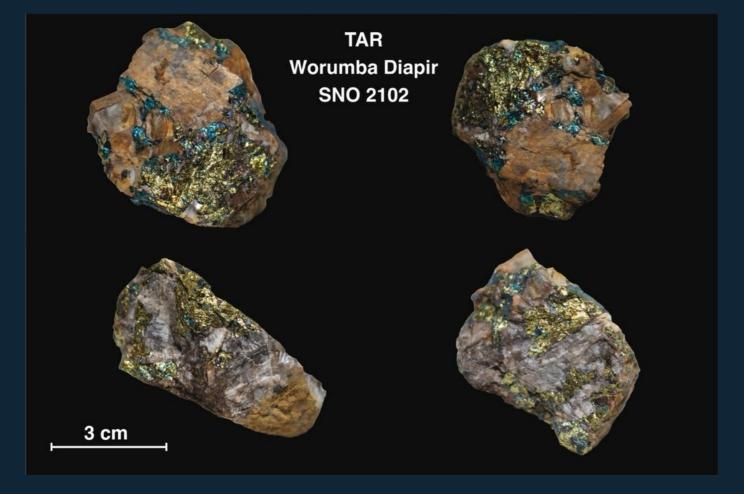


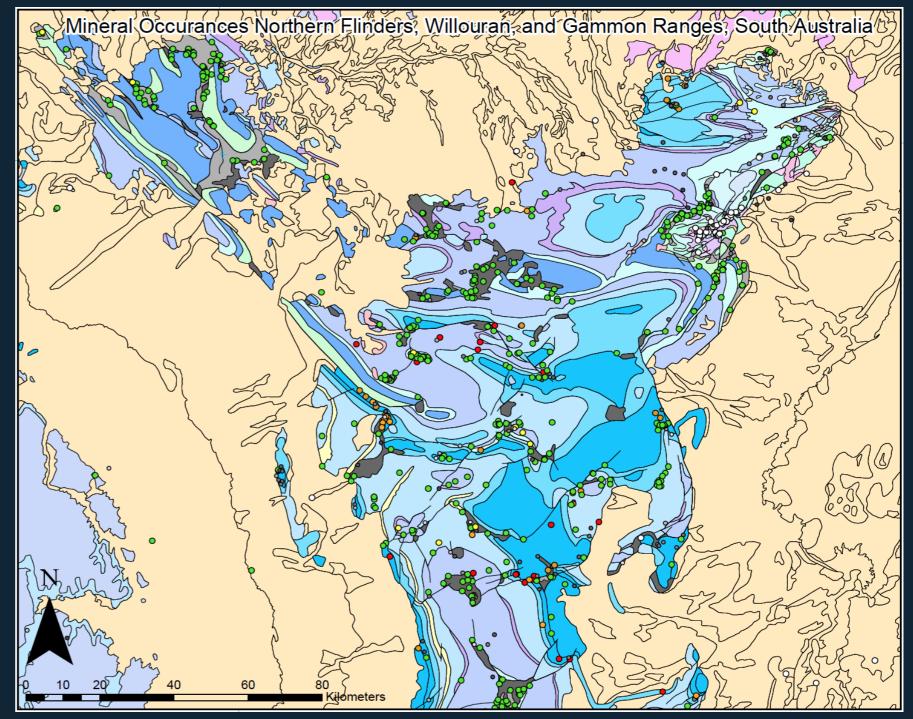
Zavada et al., 2021

Critical Mineral Exploration



Critical Minerals

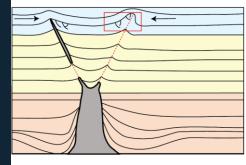




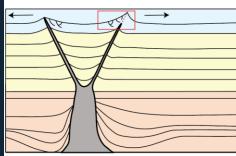
Copper (green), Gold (yellow), Lead/Zinc (orange), Manganese (red), and Uranium (white)

Critical Minerals

Tectonic Evolution of the Oraparinna Diapir forming the Bunkers Graben and Linda Prospect Dr. Rachelle Kernen



Regional compression related to the initiation of the Delamerian Orogeny closes the thin diapiric "horns" on either side of the Bunkers Graben forming a weld. The lystric faults defining the Linda Prospect area are reactiviate ed, inverted, and folded through a series of discrete reginal compres sional events that creates the structure we currently see in map view



Extension continues during deposition of the Hawker Group (blue) ~541-530 million years ago. That extension allows lystric faults to form thus creating the Linda Prospect.

Due to the close proximty of the diapir and high biological component of the Archeocyathid Reef, this sets off a serious of chemical reactions to dissolve the reef and preciptate zinc forming a unique style of MVT deposit.

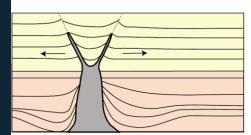
Extension continues during deposition of Wilpena Group creating

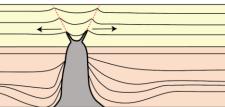
"horns" or two small diapirs on

either side of the Bunkers Graben.

Deposition of the Wilpena Group (yellow) ~588-541 million years

Major rift extension continues during deposition of Wilpena Group allowing the syn-tectonic



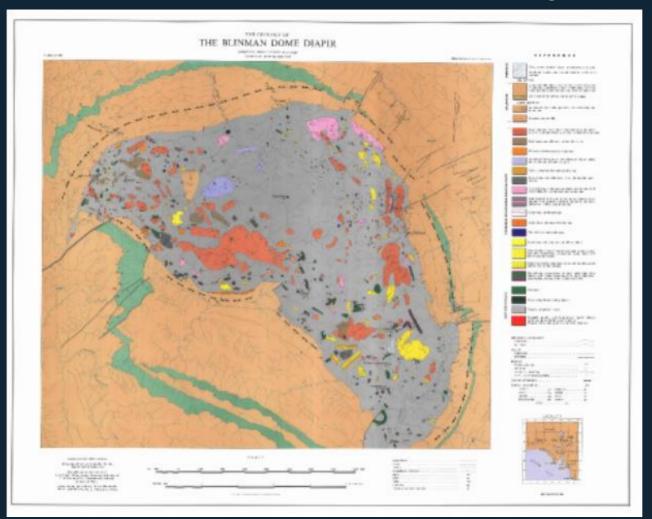


formation of Bunkers Graben. End of deposition of the Umberatana Group (tan) ~588 million years ago.

ago.

Future rift extension forms the Bunkers Graben (location indicated by red dashed line) above the Oranarinna Di

Joanne Weissgerber



Kernen unpublished



Kat Mazi-Ward



Dianne Amos

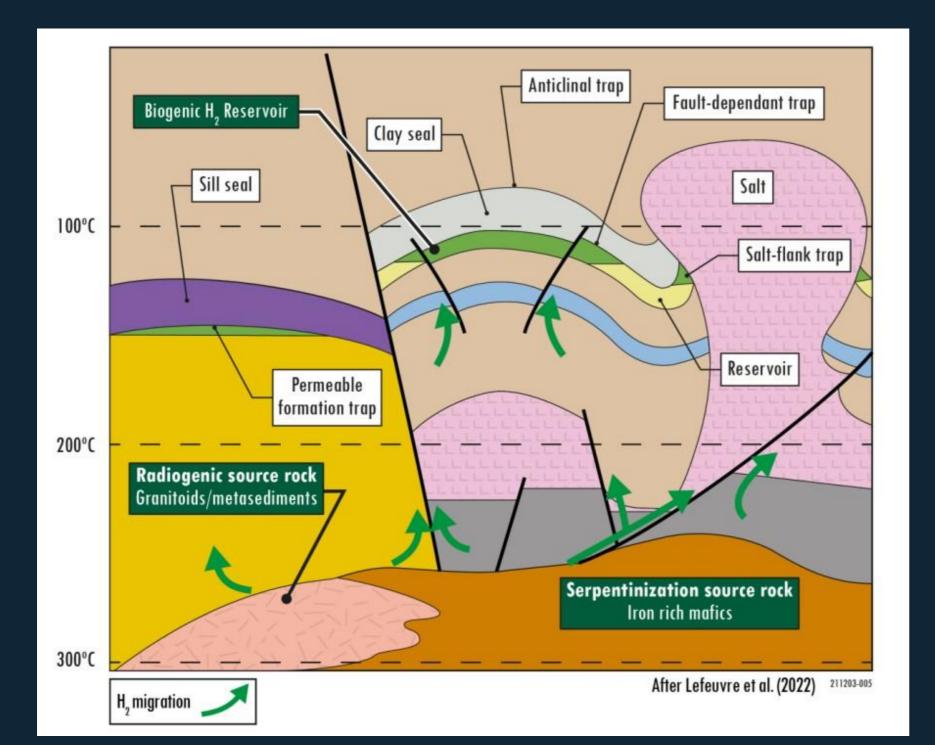


Natural Hydrogen Exploration



Natural Hydrogen

Natural Hydrogen Exploration

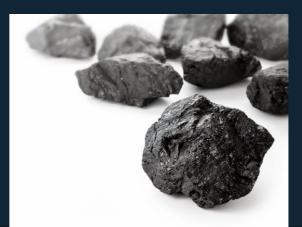


- carnallite
- basement source



 Early biodegradation of interbedded organic shales or coal where trapped hydrogen is within the crystalline halite or potash fluid inclusions Production by radiolysis associated with sylvite and Migration from an underlying





Conclusions

Location within Australia	Research type	Salt caverns	CO ₂ storage	Geothermal energy	Mineral deposits	Natural hydrogen
Willouran Ranges	Outcrop	✓	1	✓	✓	1
Flinders Ranges		✓	1	✓	✓	1
Gammon Ranges		×	~	✓	1	1
Amadeus Basin	Subsurface	✓	1	✓	1	1
Officer Basin		✓	1	✓	1	1
Polda Basin		✓	✓	✓	1	1
Canning Basin		✓	1	✓	1	1
Adavale Basin		✓	✓	1	✓	1

- Australia's salt basin outcrops provide rare and exceptional sedimentological, stratigraphic, and structural parameters \bullet that can be used as analogues for improved interpretation of sparse or poor-quality subsurface datasets globally.
- These analogue studies provide the opportunity to improve computational and physical models for subsurface ulletapplication and develop a predictive framework for characterizing the sustainable development potential of salt basins.
- To maximize the valuable resources offered by salt basins in the energy transition, we must consider the integrated \bullet potential of these systems and how they can co-exist within an individual basin.
- Considering all sustainable geo-energy systems and the fundamental role of salt basin research in enabling these \bullet applications will decarbonization be possible and have enough impact to reach net zero by 2050.

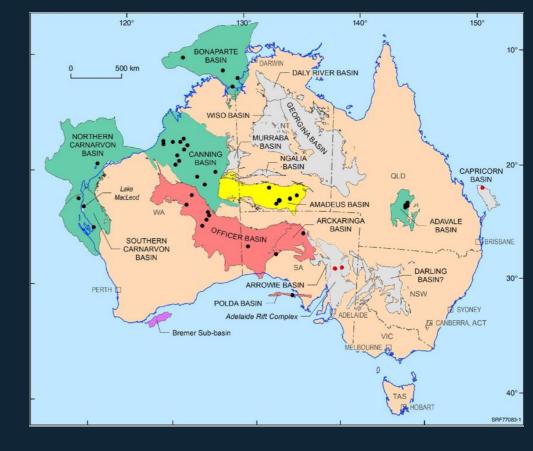
Research Priorities

Key opportunity - utilizing Australia's world-famous outcrops

- Develop models based on outcrops and ulletapply to subsurface
- Synthetic seismic & physical modelling ullet

Research foci

- Improve understanding of diapiric bodies ullet
- Substantial implications both for cavern ulletstorage viability and critical minerals
- Integrate knowledge from Quaternary ulletevaporates and ancient deposits to improve characterization



Current Sponsors for ARC Industry Fellowship



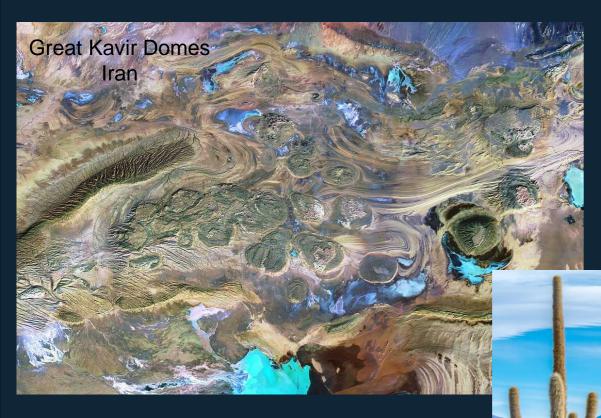


- Funded collaboration with CNRS 2024
- Ranges

HILT CRC sponsored PhD project beginning Q3 2024 Active field analogue investigations: Enorama Diapir, Blinman Diapir, Worumba Diapir, Bunkers Graben in Central Flinders

Thank you!

rachelle.kernen@adelaide.edu.au





Salar de Uyuni Boliva



<image>