



Australian Government
Geoscience Australia

Otway Basin Sherbrook SS GDE Mapping: Perspectives from Core and Cuttings

APPEA Conference 2023 | Adelaide May 15 – 18|

Chris Cubitt

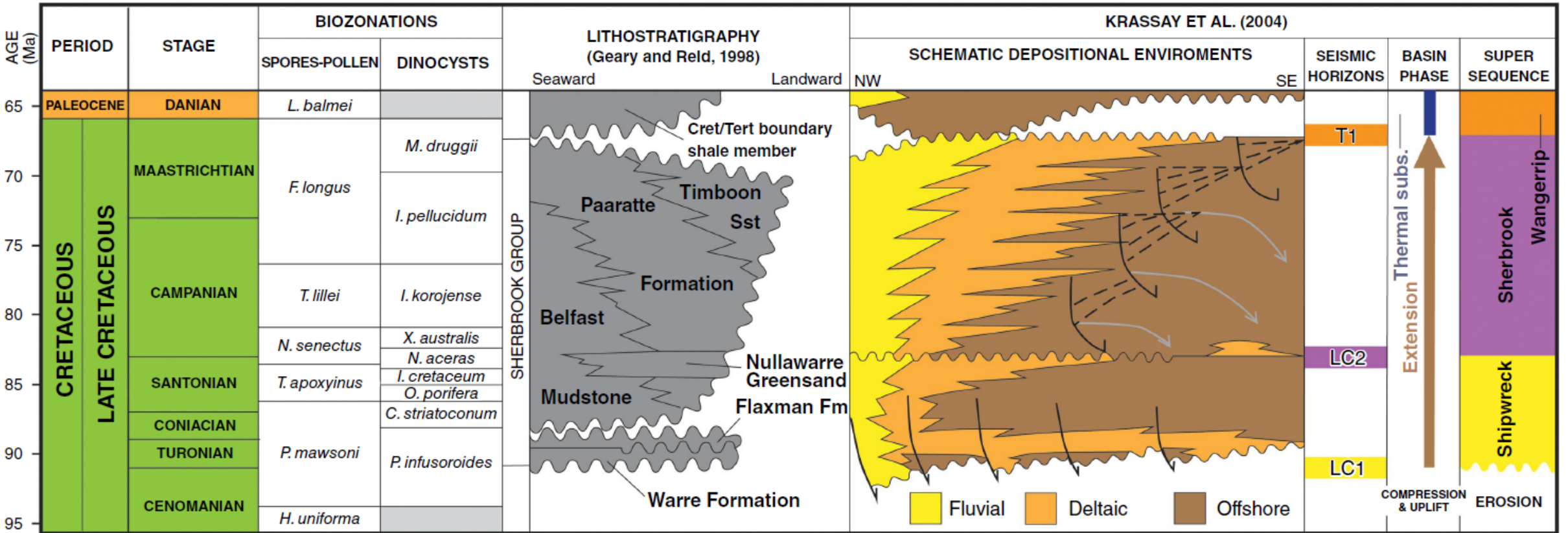
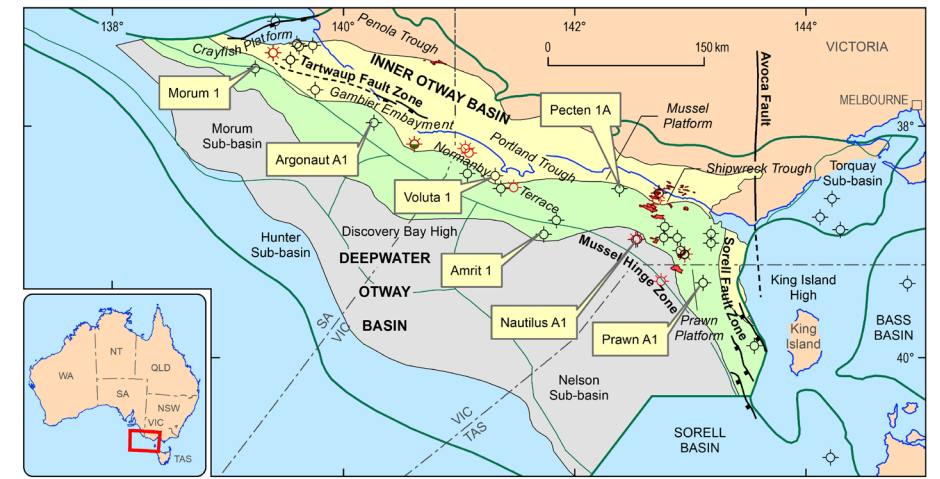


© Commonwealth of Australia (Geoscience Australia) 2023.

Earth sciences for Australia's future | ga.gov.au

Otway Stratigraphy: Sherbrook SS Interval

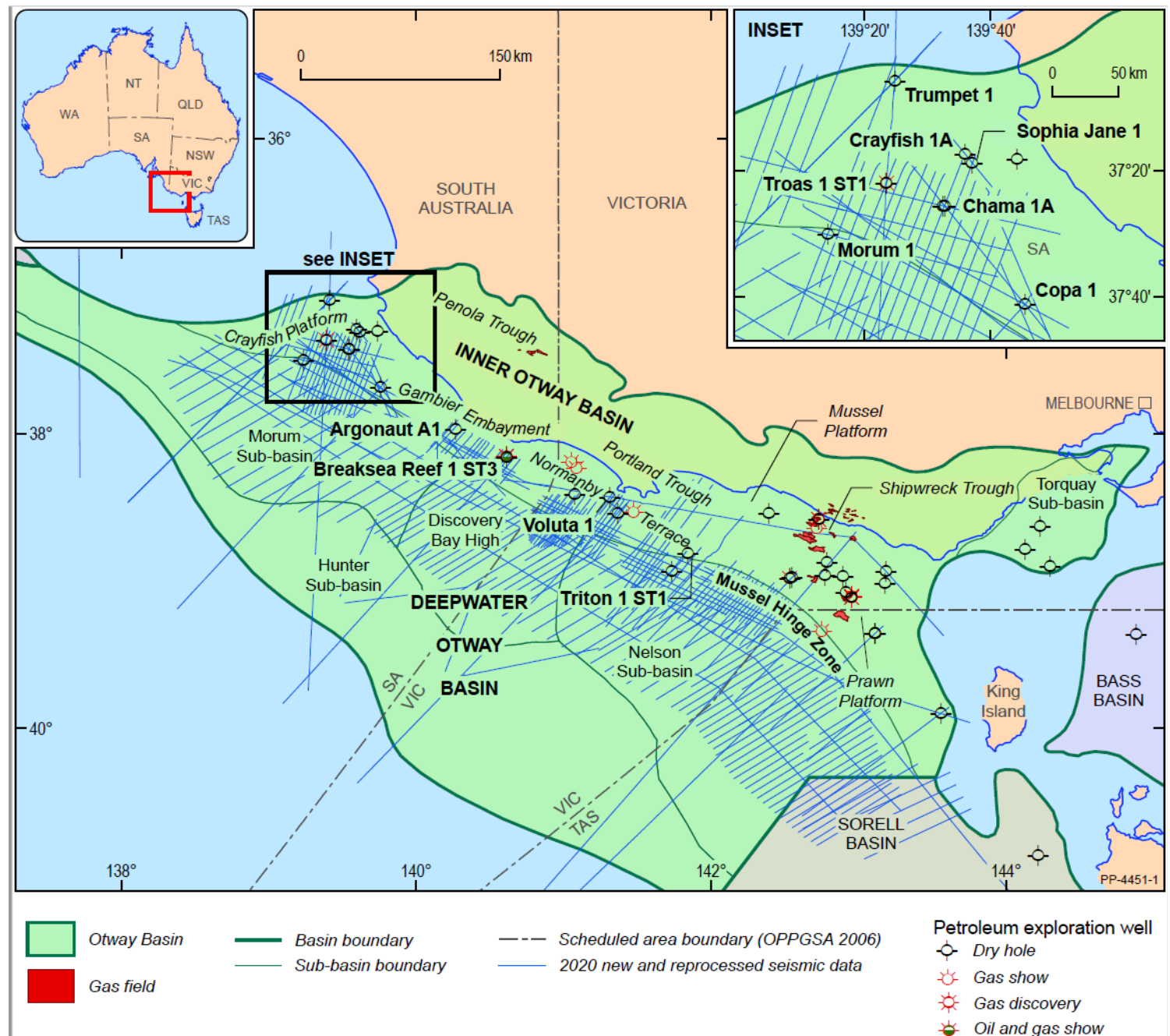
This work focuses on the Sherbrook SS across the whole offshore Otway Basin



From Krassay et al 2004

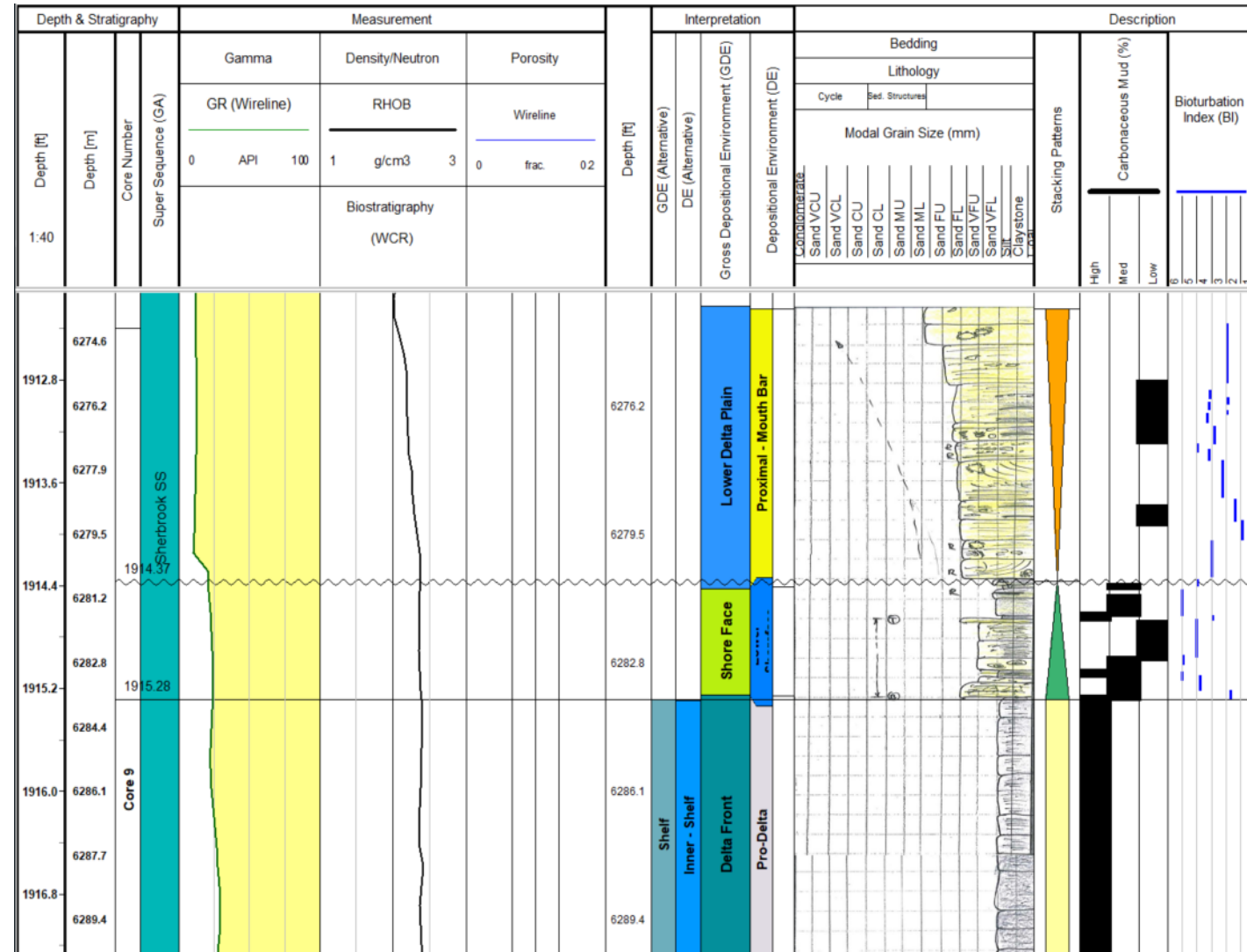
Otway Basin Snapshot

- Focussed on the deep water Otway
- A newly acquired seismic and reprocessed 2D lines formed the basis of the project
- Re-interpreted biostratigraphy
- This fostered a new
 - basement definition
 - stratigraphic understanding
 - structural understanding
 - source rock understanding
 - DE and GDE distribution.....



Definition: Depositional Environments (DEs)

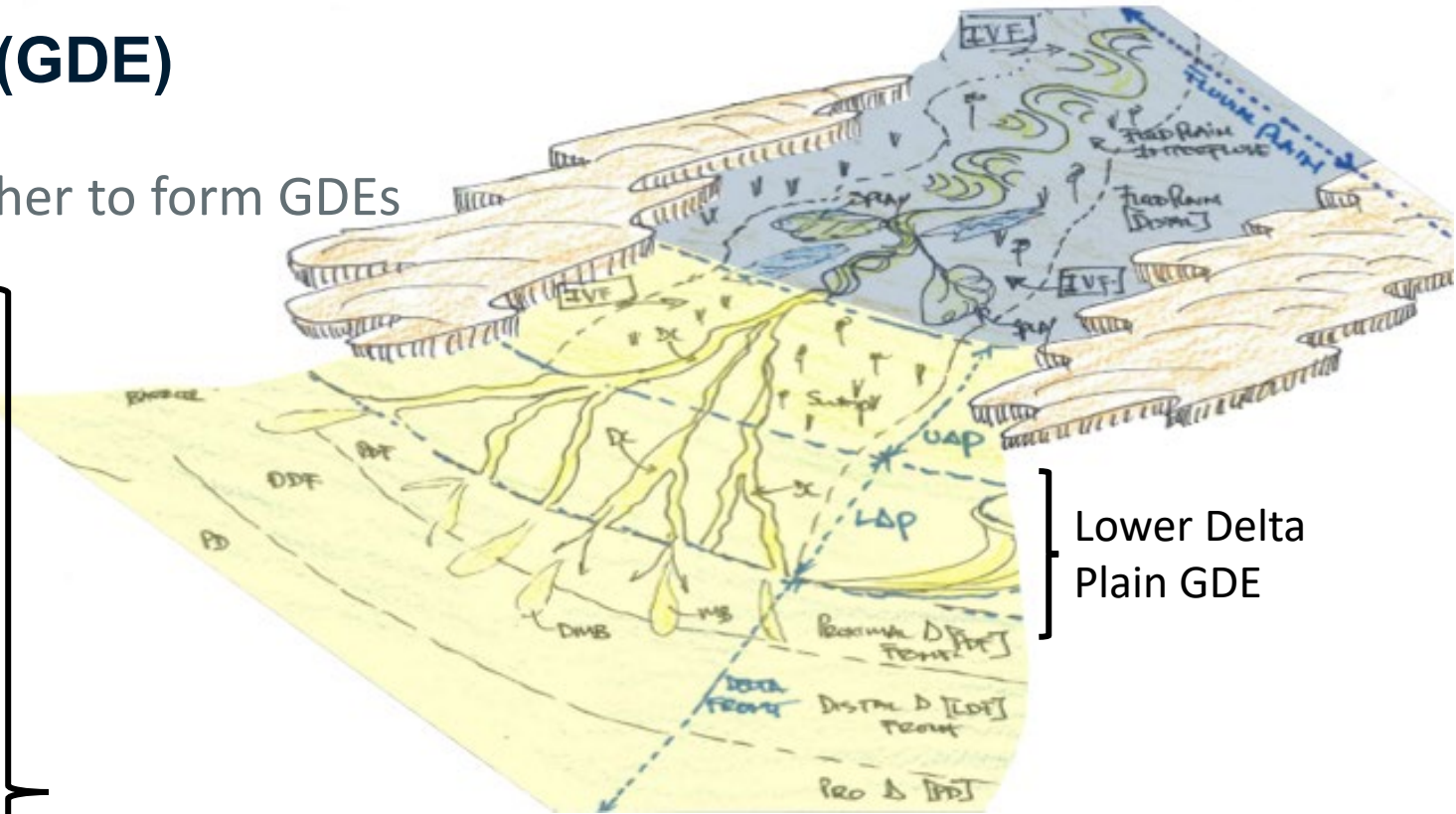
- Depositional environments (DEs) are defined as packages of sediment that have formed in specific geological conditions
- These packages of sediment are typically composed of multiple lithology types and are pragmatically defined according to a set of pre-defined criteria which include:
 - grain size (and wireline) trends
 - lithology assemblages
 - sedimentary features
 - bioturbation (type, location and BI)
 - depositional package juxtaposition
 - regional context



Gross Depositional Environment (GDE)

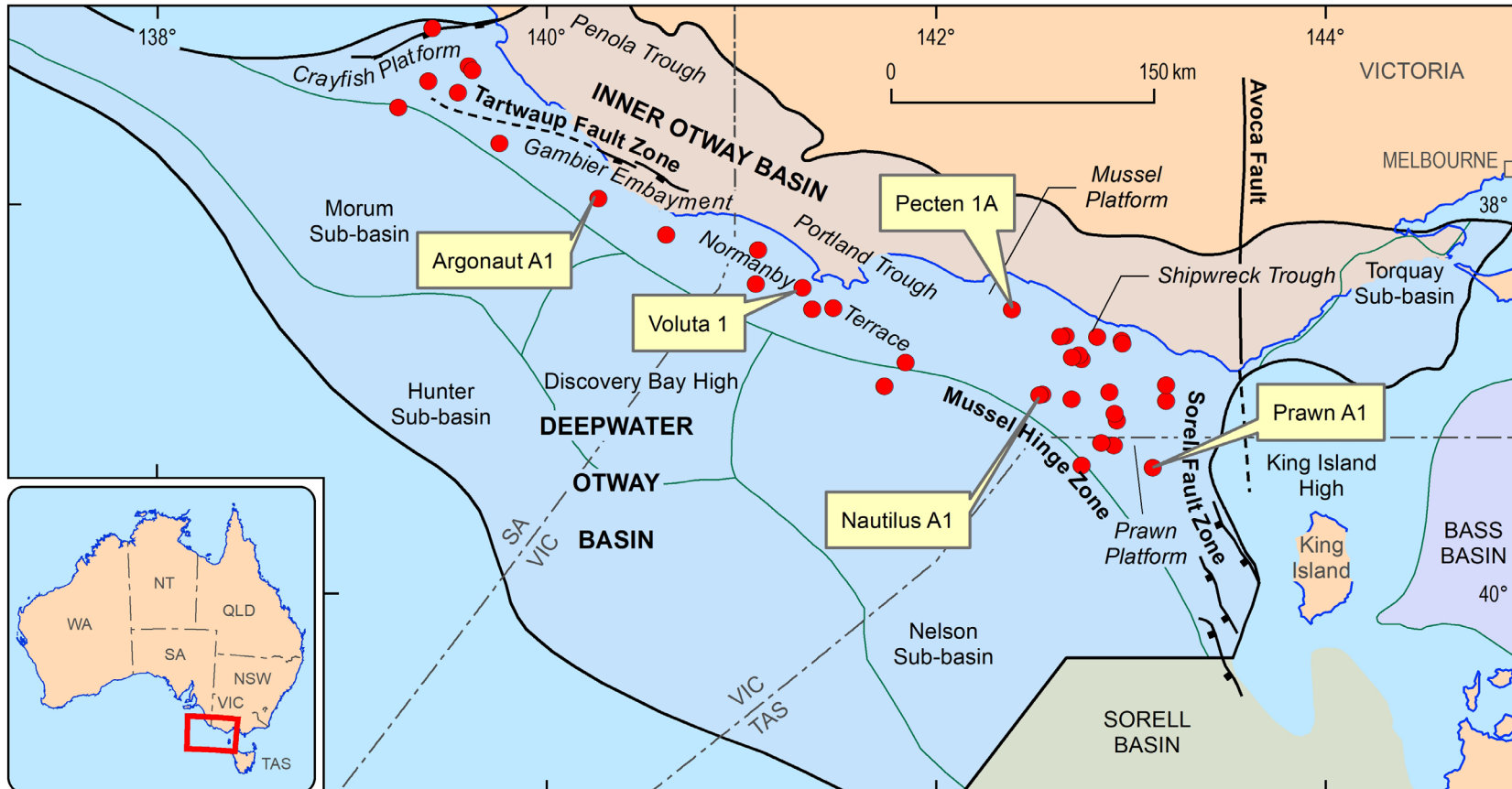
Genetically related DEs are grouped together to form GDEs

- *Delta (mouth bar)* - deposits are defined as those sections which are coarsening upwards, sand dominated (fine grained and coarser) with massive, planar and horizontal bedding common. The same coarsening upward profile is mirrored in the gamma curve. If an abandonment section exists, then bioturbation is a common feature.
- *Delta (distributary channel)* – deposits are defined as fining upwards sections juxtaposed with mouth bar intervals. Distributary channel sections are often capped by abandonments where bioturbation is a common feature.
- *Delta Front (proximal and distal)* - depositional environments are defined within the deltaic context. Proximal delta fronts are defined as sandstone dominated intervals associated with mouthbar and distributary channels. Distal delta front deposits are defined as claystone/heterolithic dominated intervals associated with mouthbar and distributary channels.

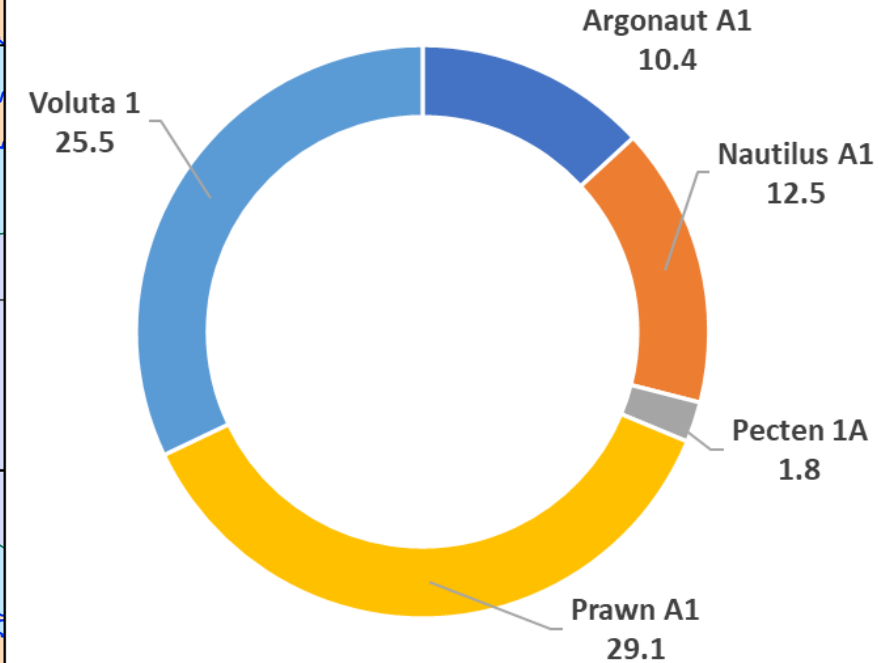


GDEs are a collection of related DEs. For example, a lower delta plain GDE may include flood plain DE, crevasse splay DE, distributary channel DE and mouth bar DE.

Offshore Otway Basin: Sherbrook SS Interpreted Well and Core Locations



Offshore Otway Core Logging
Sherbrook SS (m)



The Core Dataset.....

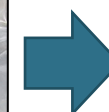


Unbagging



Prawn A1 ~ Core 8 [6669' - 6663']

Unbagged



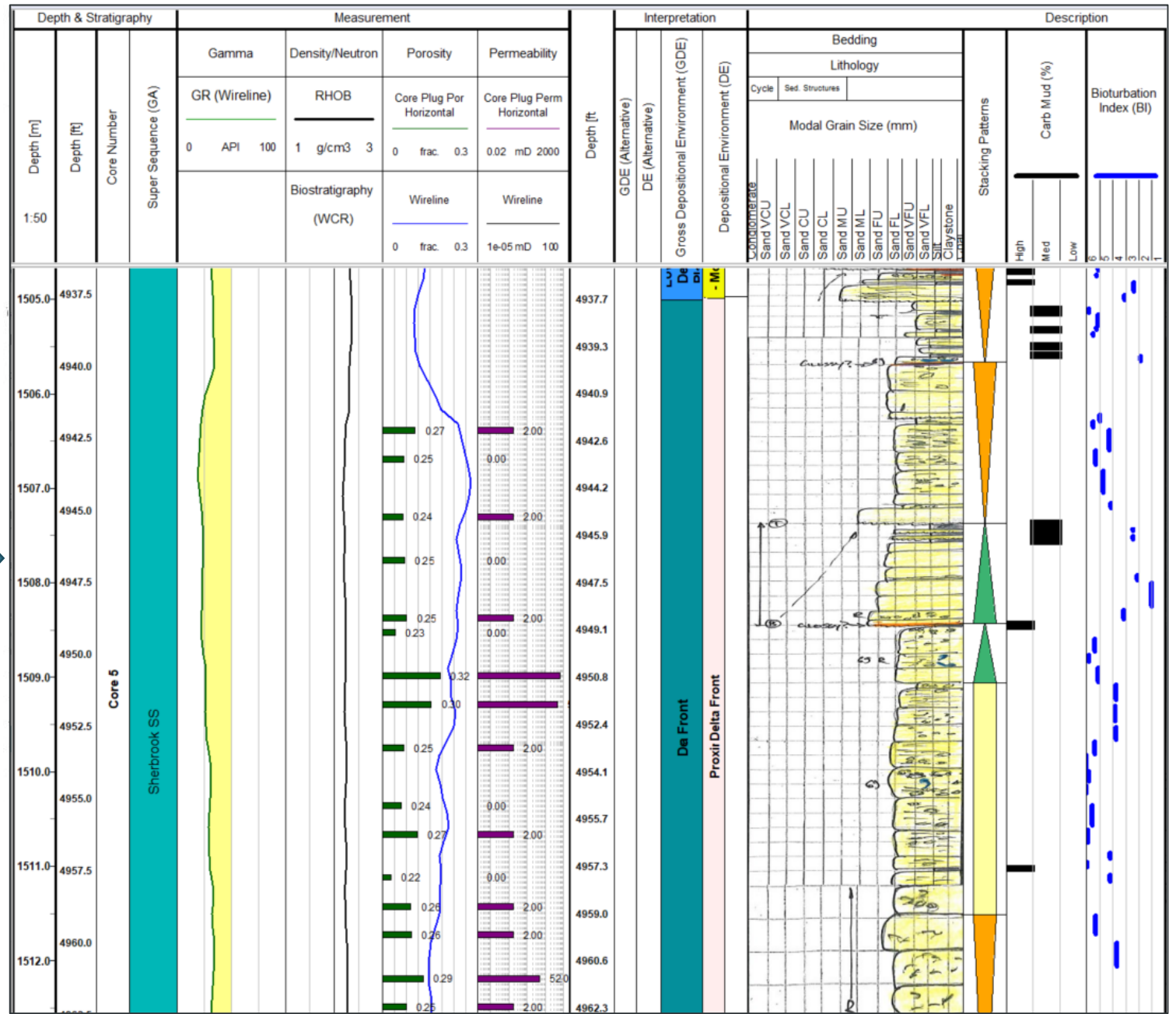
All bags are cut open, the core is orientated and depth checked. Note: The bag is kept writing side up under the orientated core piece

Core Logging – Hand Drawn

Prawn A1 ~ 4287' 8" – 4278' 9" [1306.9m – 1304.2m]



Prawn A1 Core Log

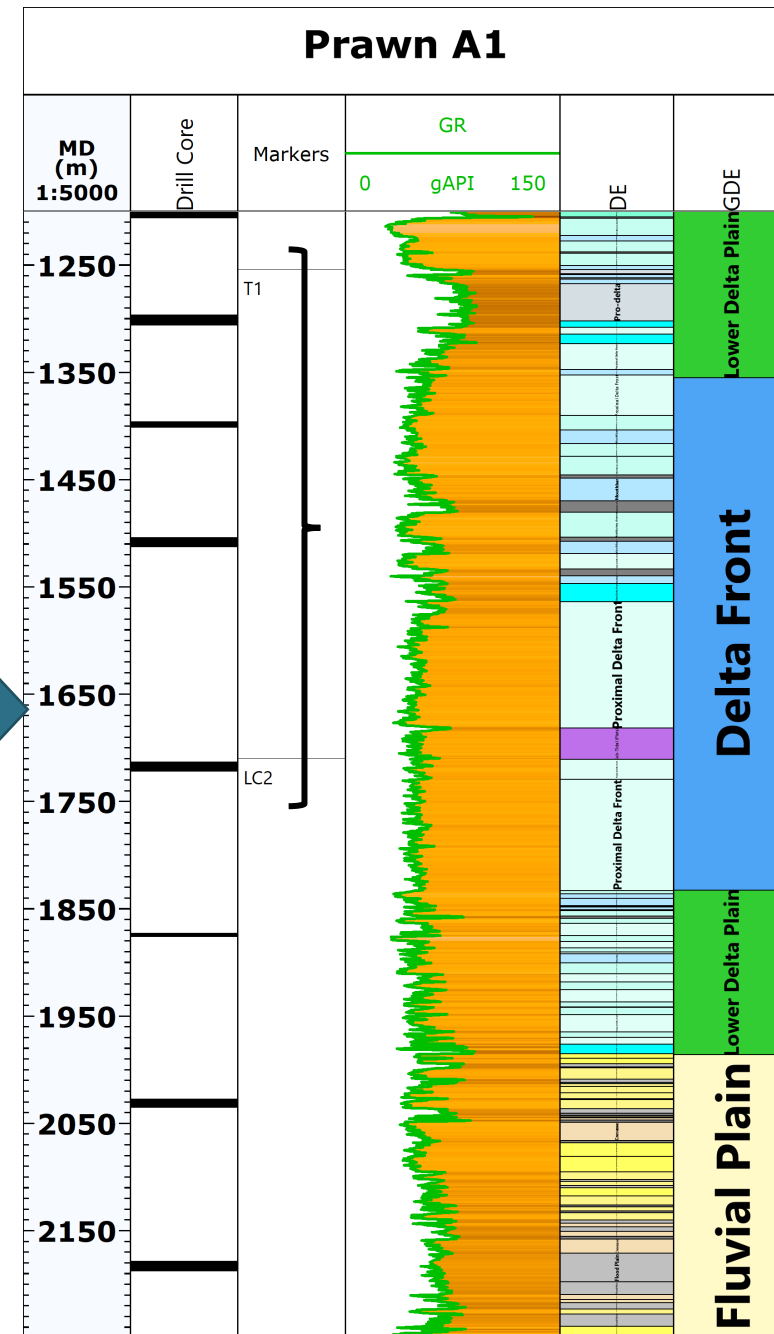
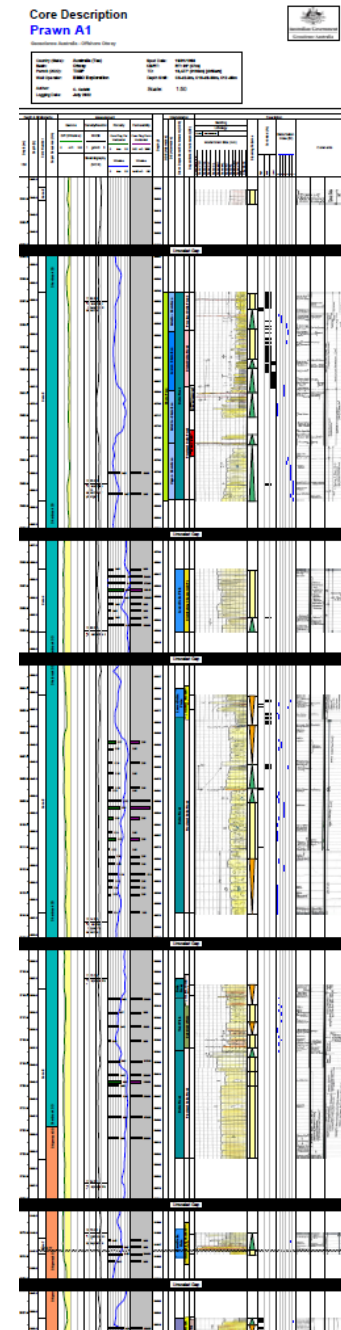


Integration: Core to Wireline

All cores were converted to metric and matched to wireline depth

Well name	Core No.	Core to Wireline		Top Driller	Bottom Driller
		Shift (m)	Stratigraphy GA	Depth (m)	Depth (m)
Argonaut A1	Core 1	0	Sherbrook SS	640.4	647.3
Argonaut A1	Core 2	0	Sherbrook SS	804.9	813.4
Argonaut A1	Core 3	0	Sherbrook SS	981.1	989.3
Argonaut A1	Core 4	2.4	Sherbrook SS	1143.6	1152.7
Argonaut A1	Core 5	0	Sherbrook SS	1305.2	1311.6
Argonaut A1	Core 6	-3	Sherbrook SS	1472.6	1475.6
Argonaut A1	Core 7	0	Sherbrook SS	1638.7	1646.3
Argonaut A1	Core 8	0	Sherbrook SS	1805.8	1808.8
Argonaut A1	Core 9	0	Sherbrook SS	2226.5	2227.1
Argonaut A1	Core 10	0	Sherbrook SS	2475.0	2478.0
Argonaut A1	Core 11	0	Sherbrook SS	2733.2	2740.9
Nautilus A1	Core 8	0	Sherbrook SS	1729.4	1734.6
Nautilus A1	Core 9	0	Sherbrook SS	1859.9	1864.5
Nautilus A1	Core 10	0	Sherbrook SS	2003.2	2010.8
Pecten 1A	Core 1	0	Sherbrook SS	576.2	583.8
Pecten 1A	Core 2	0	Sherbrook SS	1556.1	1559.1
Prawn A1	Core 3	0	Sherbrook SS	1296.6	1305.8
Prawn A1	Core 4	0	Sherbrook SS	1396.3	1401.2
Prawn A1	Core 5	0	Sherbrook SS	1504.2	1512.7
Prawn A1	Core 6	-2.3	Sherbrook SS	1713.3	1721.8
Voluta 1	Core 6	0	Sherbrook SS	1508.8	1511.5
Voluta 1	Core 7	0	Sherbrook SS	1670.3	1671.5
Voluta 1	Core 8	1.5	Sherbrook SS	1792.2	1798.3
Voluta 1	Core 9	1	Sherbrook SS	1913.2	1920.9
Voluta 1	Core 10	0	Sherbrook SS	2036.1	2039.7
Voluta 1	Core 11	1.5	Sherbrook SS	2159.8	2165.9

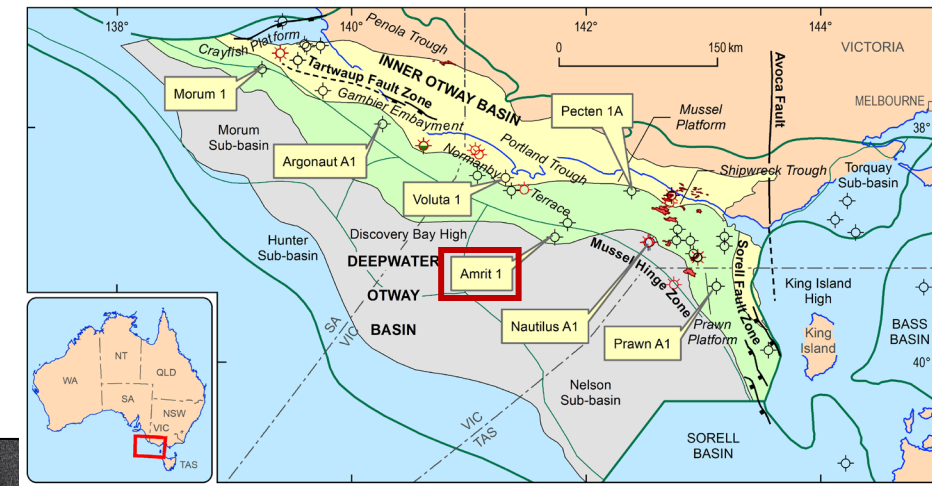
Core to Wireline Depth Matching Table



Methods: Drill Cuttings Analysis

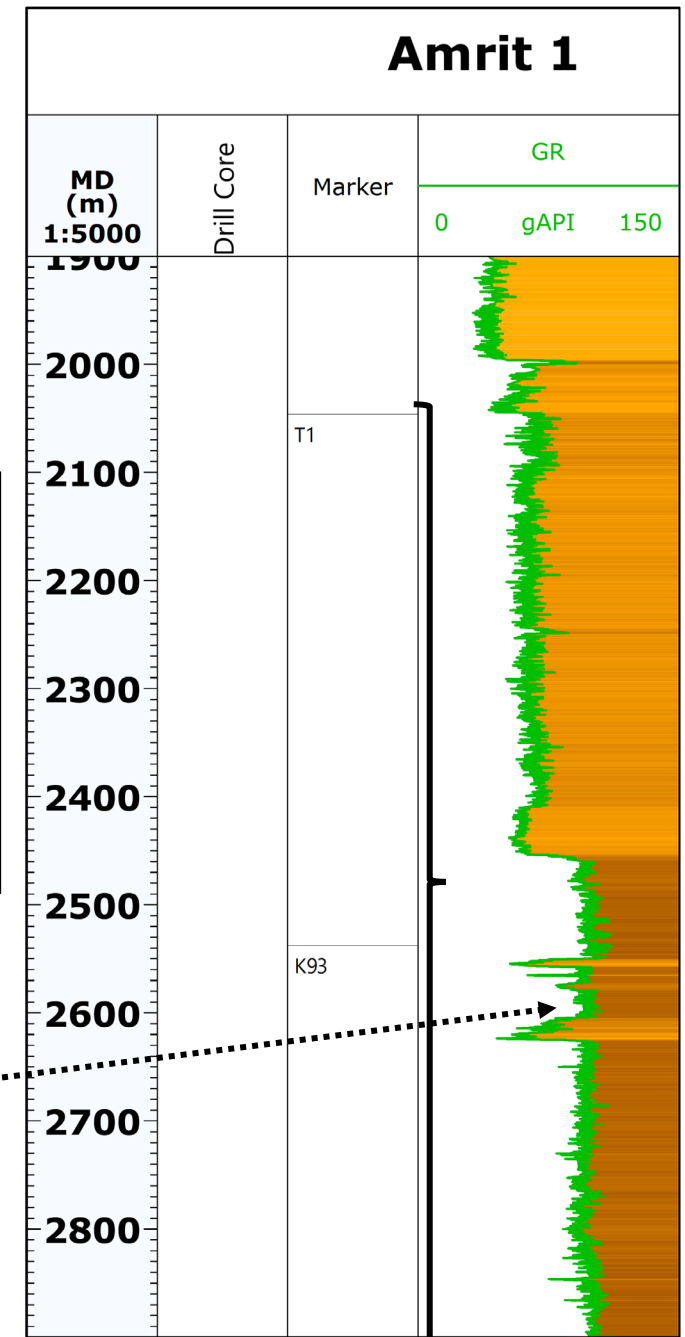
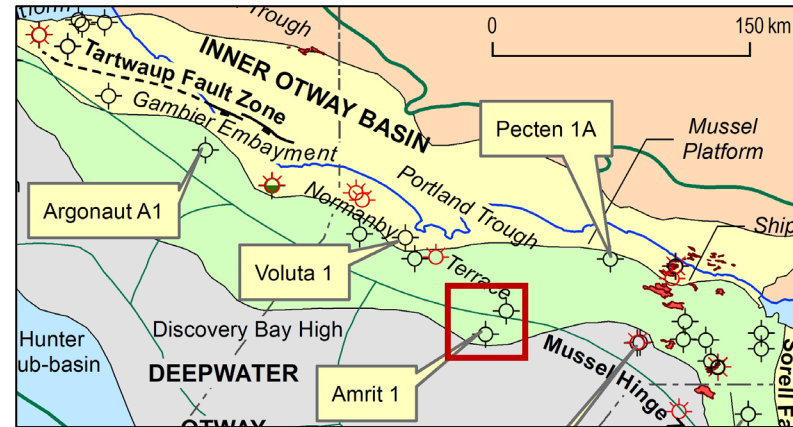
A quick look.....

- Drill cuttings analysis were performed on GA's Amrit 1 archive drill cuttings set to determine the depositional setting (GDE) of the Sherbrook SS section in this critically located well
- The analysis was done on the unwashed GA drill cuttings set
- The microscopic analysis was made using GA's Olympus SZX12 stereo microscope



Drill Cuttings Analysis Depth Correction: 2450 – 2466m

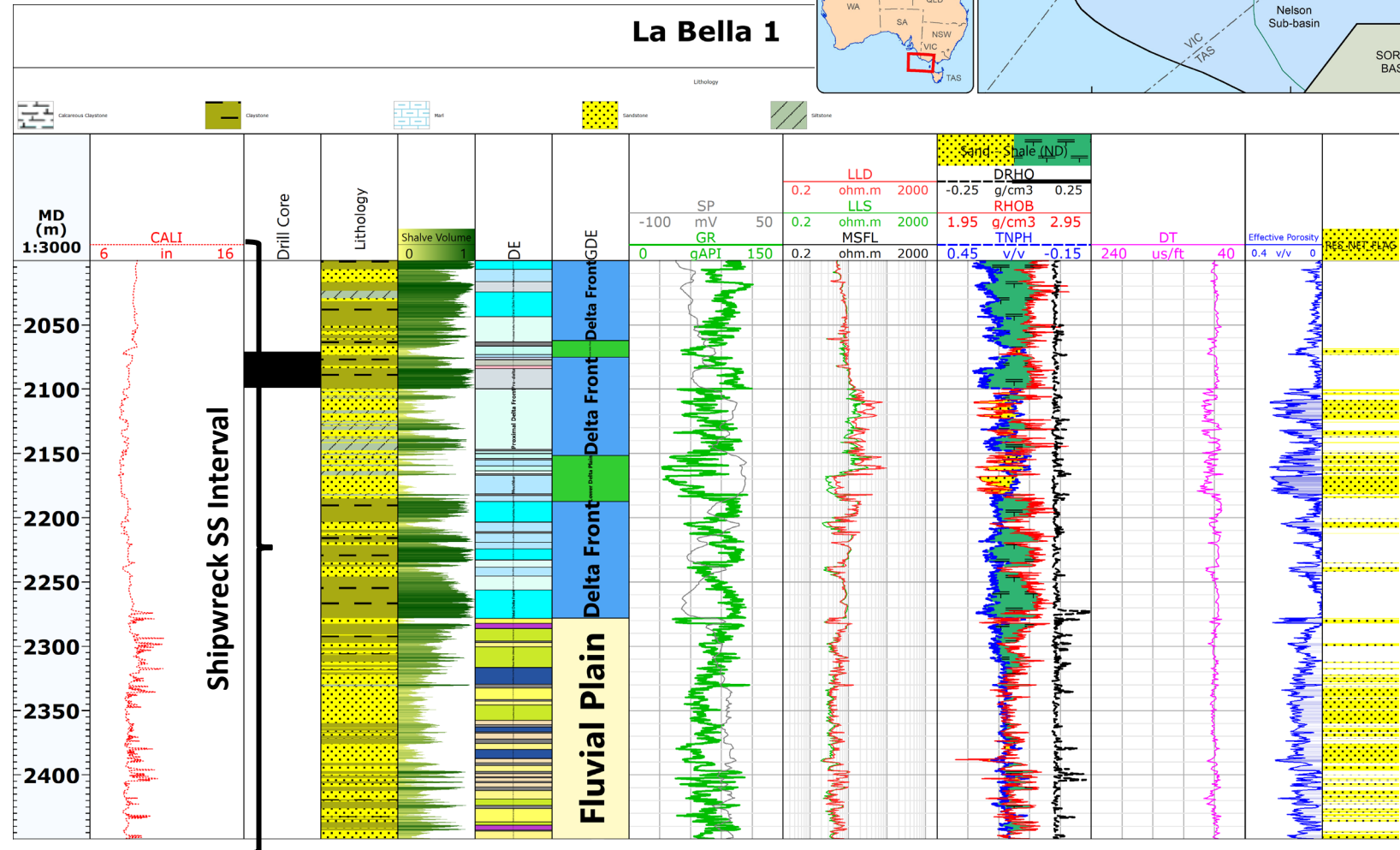
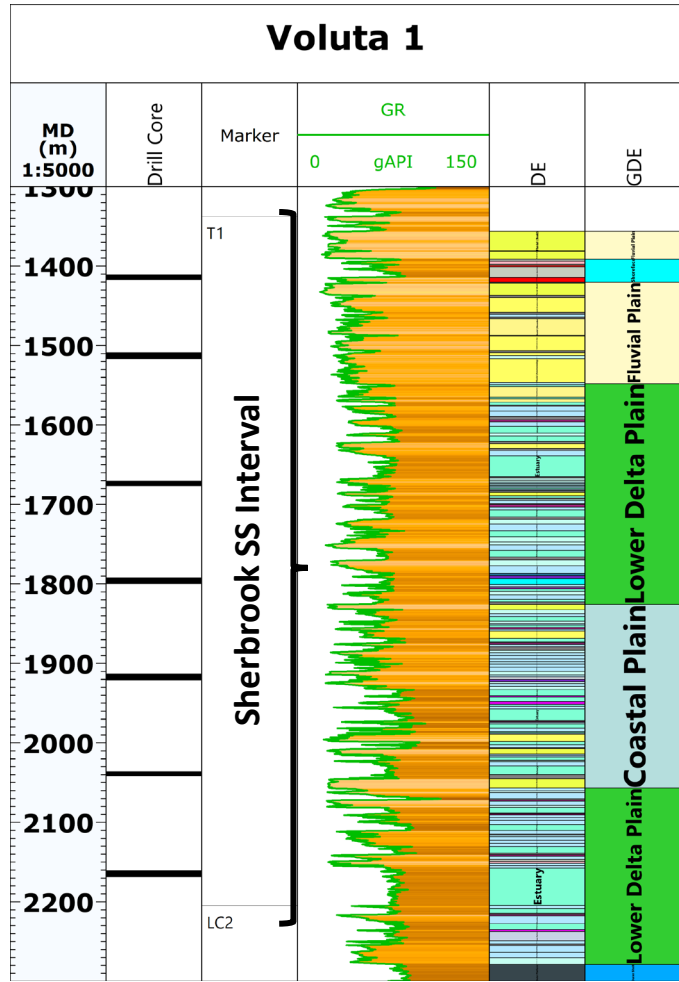
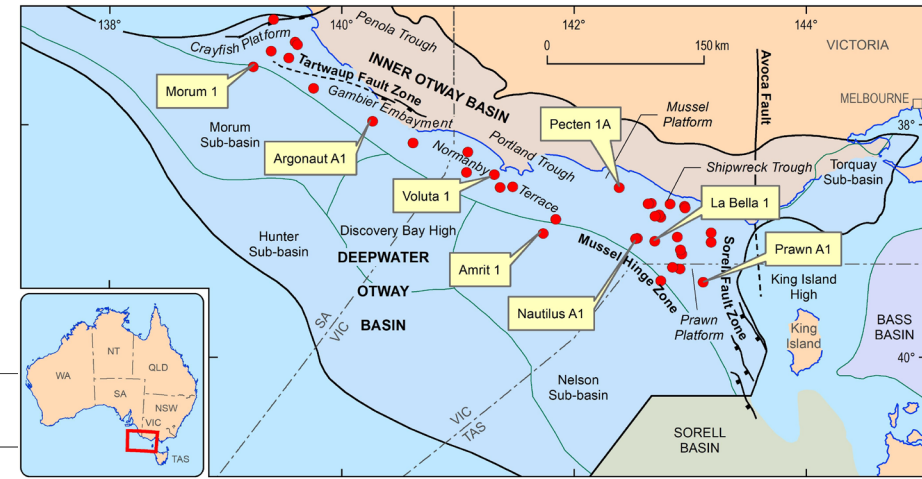
Depth correction was approximately 6m upwards



Top	Base	Skipped	Marker	Interval	Poor	Fair	Good	Sample (Note all skipped samples visually inspected wrt lithology)	GDE	Sandstone	Conglomer	SiltStone (W)	SiltStone (B)	Mudstone	Coal	Limestone	Carbonace	LCM	Rock Flour	Artificial Ag	Lithology	256 +mm	128-256mm	64-128mm
2450	2459	Yes	Timboon	Sherbrook SS																	Silty mudstone dark brown			
2459	2463	Microscope	Timboon	Sherbrook SS	100			Aggs clumped and reconstituted													Silty mudstone dark brown			
2463	2465	Microscope	Timboon	Sherbrook SS	100			Aggs clumped and reconstituted		50			50								ROCK CHANGE: Light grey to white sst/siltstone			
2466	2470	Microscope	Timboon	Sherbrook SS	100			Aggs clumped and reconstituted		100											Light grey to white sst/siltstone			
2469	2472	Microscope	Timboon	Sherbrook SS	100			Aggs clumped and reconstituted		100											Light grey to white sst/siltstone			
2472	2475	Microscope	Timboon	Sherbrook SS	100			Aggs clumped and reconstituted		100											Light grey to white sst/siltstone			
2475	2478	Microscope	Timboon	Sherbrook SS	100			Aggs clumped and reconstituted		100											Light grey to white sst/siltstone			
2478	2481	Microscope	Timboon	Sherbrook SS	100			Aggs clumped and reconstituted		80				20							Light grey to white sst/siltstone			
2481	2484	Microscope	Timboon	Sherbrook SS	100			Aggs clumped and reconstituted		70				30							Light grey to white sst/siltstone			
2484	2487	Microscope	Timboon	Sherbrook SS	100			Aggs clumped and reconstituted		20				80							ROCK CHANGE: Silty mudstone dark brown			

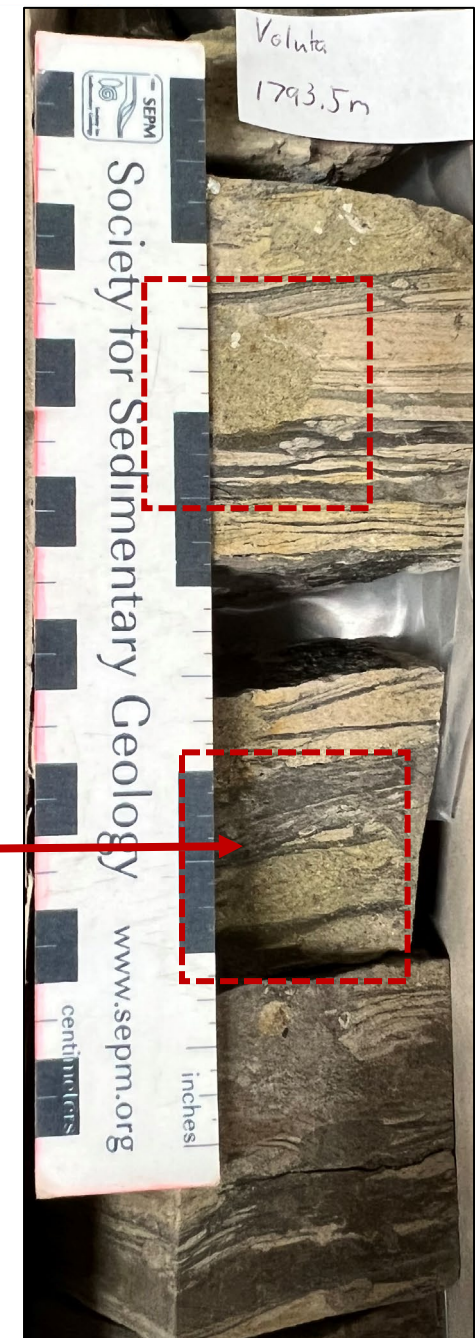
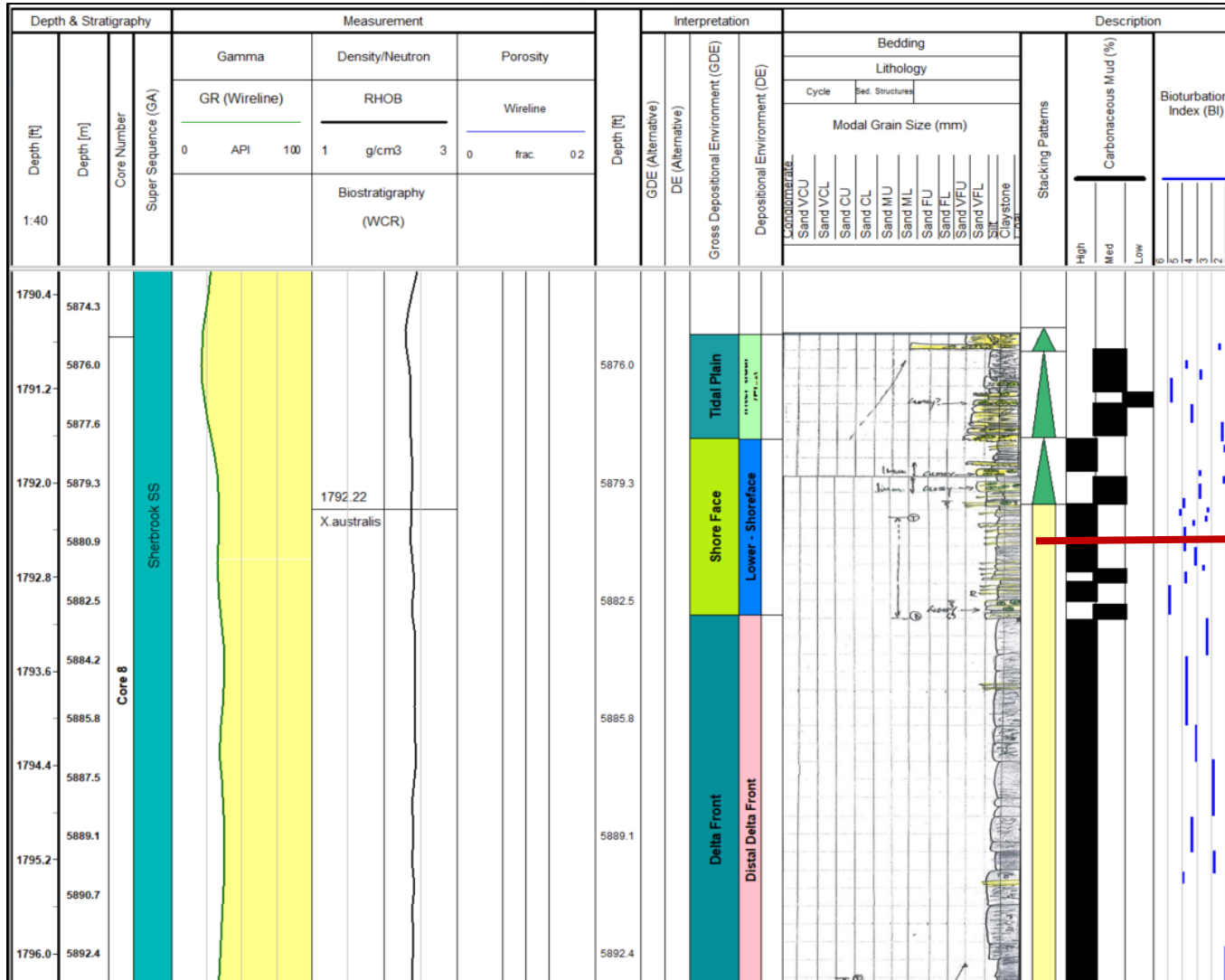
DE/GDE to Wireline Interpretations

Wireline signatures in 37 wells were interpreted using core interpretations as a control. Section interpreted = TD to T1



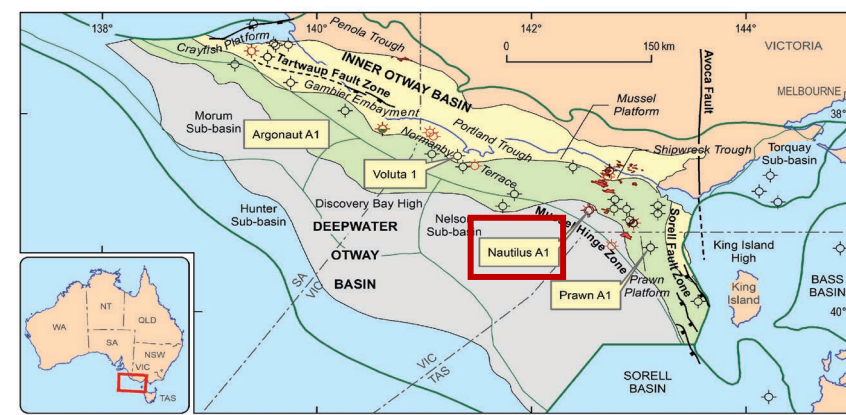
Key Sedimentary Features – Voluta 1 Example

Sedimentological features illustrate tidal/deltaic deposition dominates



Key Sedimentary Features – Nautilus A1 Example

Sedimentological features illustrate shelfal deposition dominates

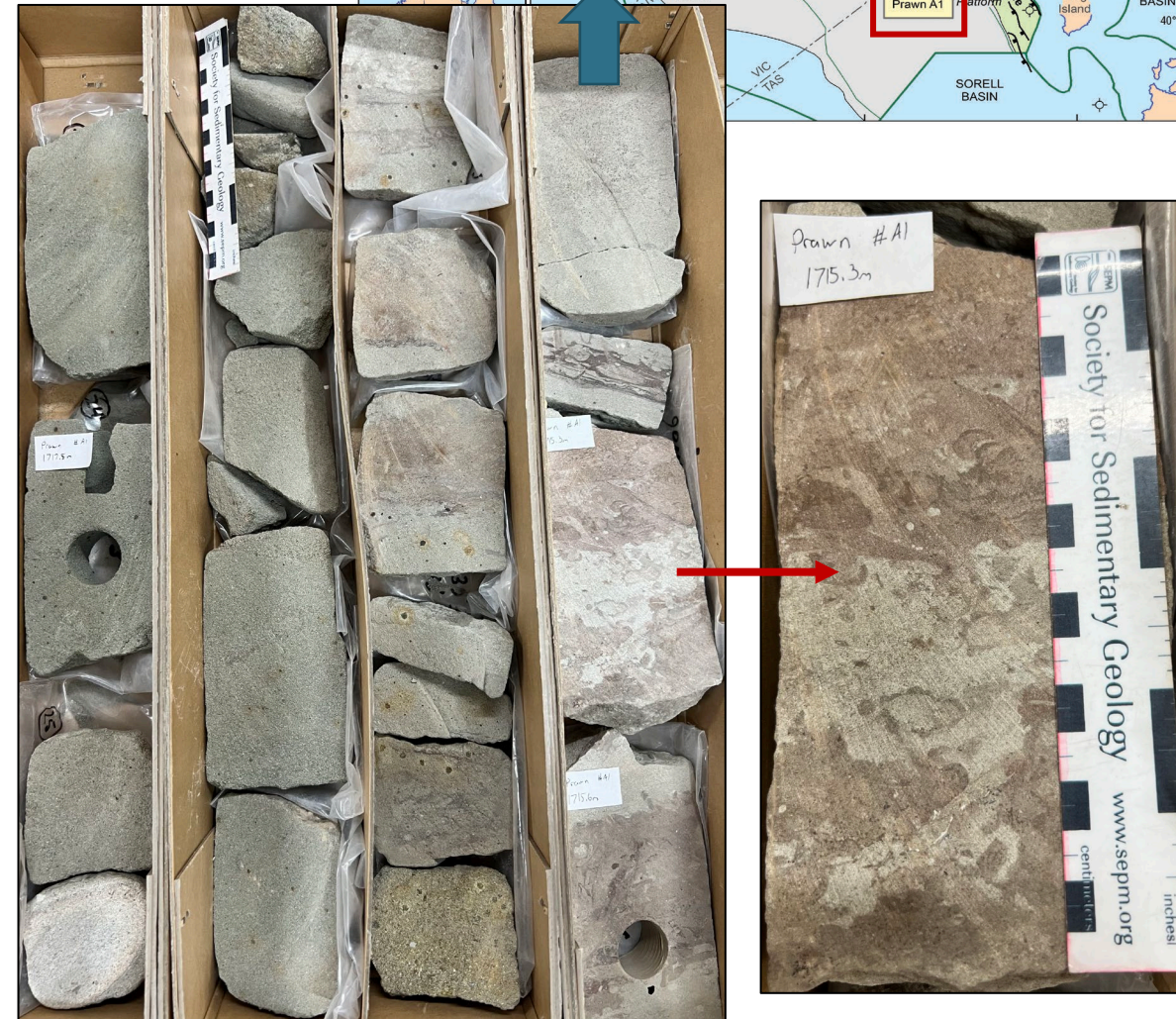
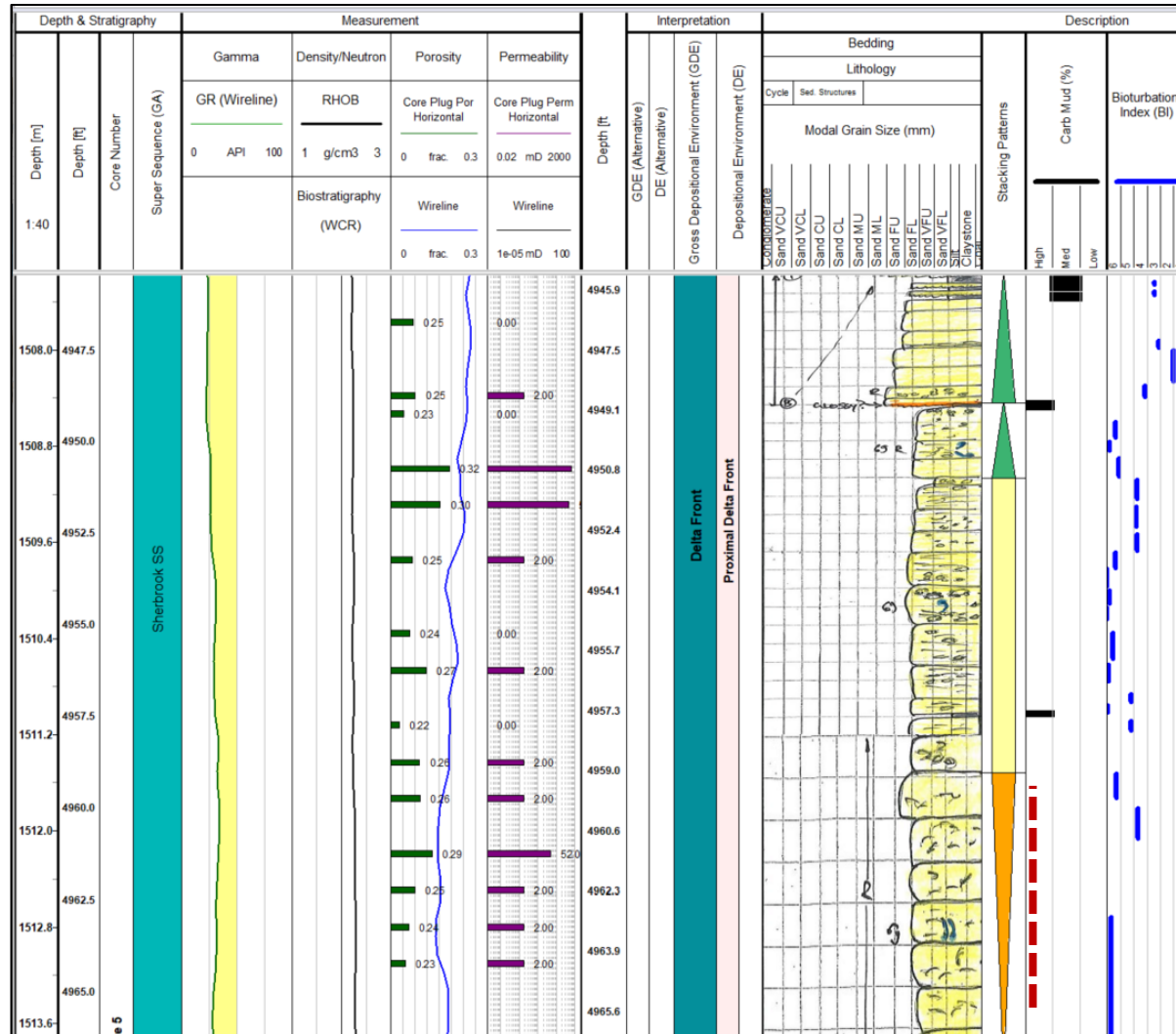
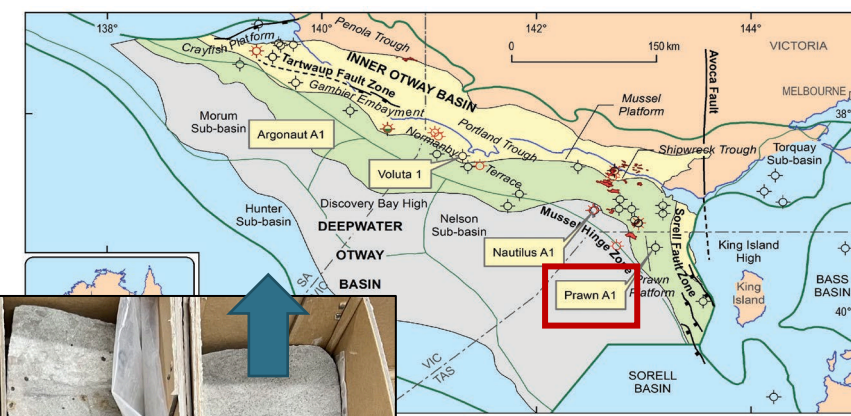


Depth & Stratigraphy		Measurement				Depth [ft]	Interpretation		Description	
Depth [m]	Depth [ft]	Gamma	Density/Neutron	Porosity	Permeability		Gross Depositional Environment (GDE)	Depositional Environment (DE)	Carb Mud (%)	Bioturbation Index (BI)
1:40		GR (Wireline)	RHOB	Core Plug Por Horizontal	Core Plug Perm Horizontal					
		0 API 100	1 g/cm ³ 3	0 frac. 0.3	1e+05 mD 100					
			Biostratigraphy (WCR)	Wireline	Wireline					
			0 frac. 0.3	1e+05 mD 100						
2004.0-6574.8						6575.0				
						6576.4				
2004.8						6577.0				
6578.1						6578.0				
6579.7						6579.0				
2005.6						6580.0				
6581.4						6581.0				
2006.4						6582.0				
6583.0						6583.0				
6584.6						6584.0				
2007.2						6585.0				
6586.3						6586.0				
6587.9						6587.0				
2008.0						6588.0				
6589.6						6589.0				
2008.8						6590.0				
6591.2						6591.0				
6592.8						6592.0				
2009.6						6593.0				



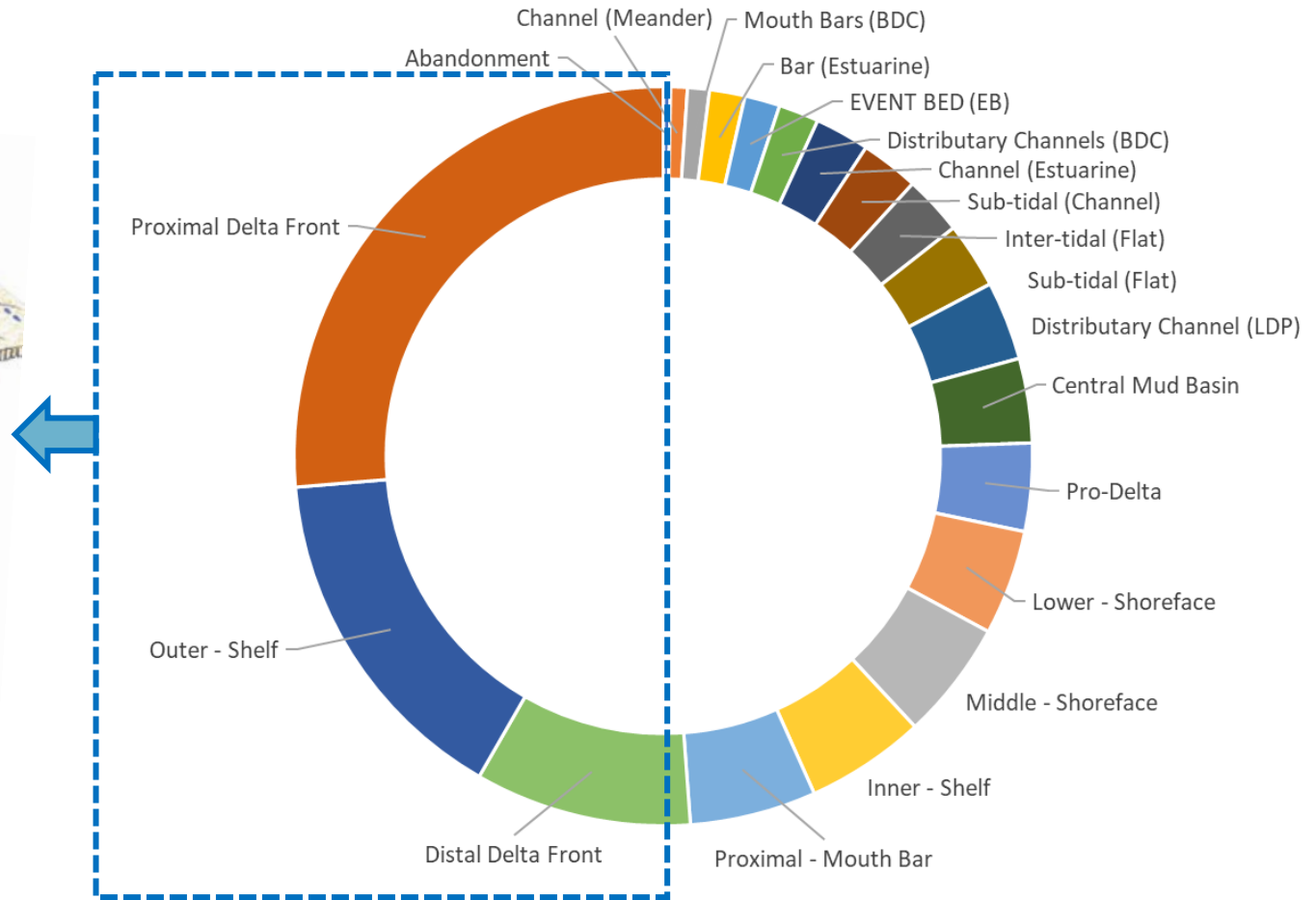
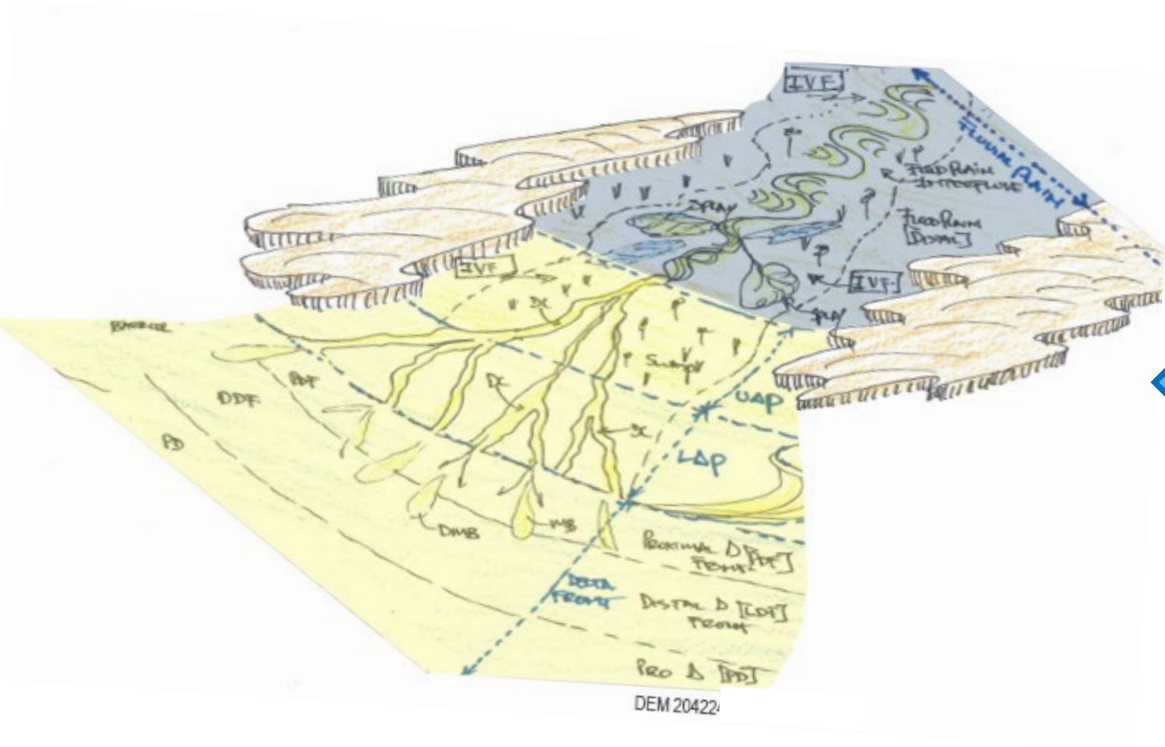
Key Sedimentary Features – Prawn A1 Example

Sedimentological features illustrate deltaic deposition dominates



Analysis: Sherbrook SS DE Proportions [Core]

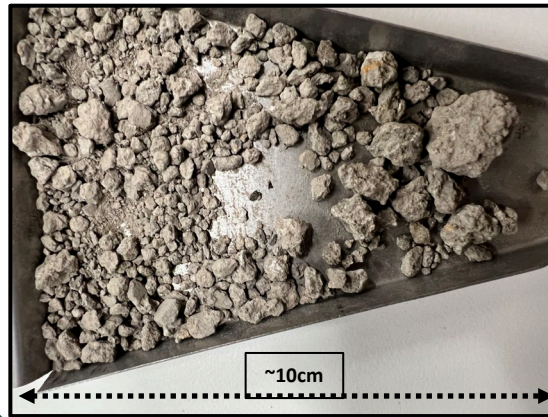
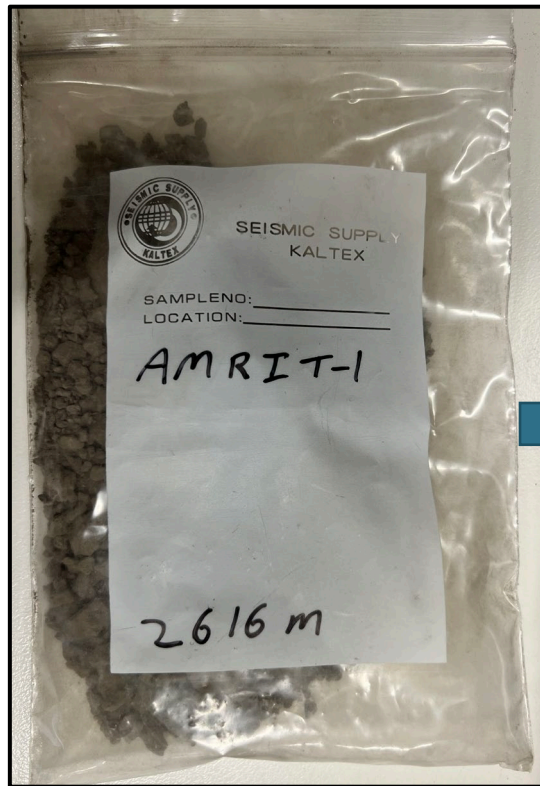
20 DEs were interpreted from 5 wells across the offshore Sherbrook SS: No.1 = Proximal Delta Front



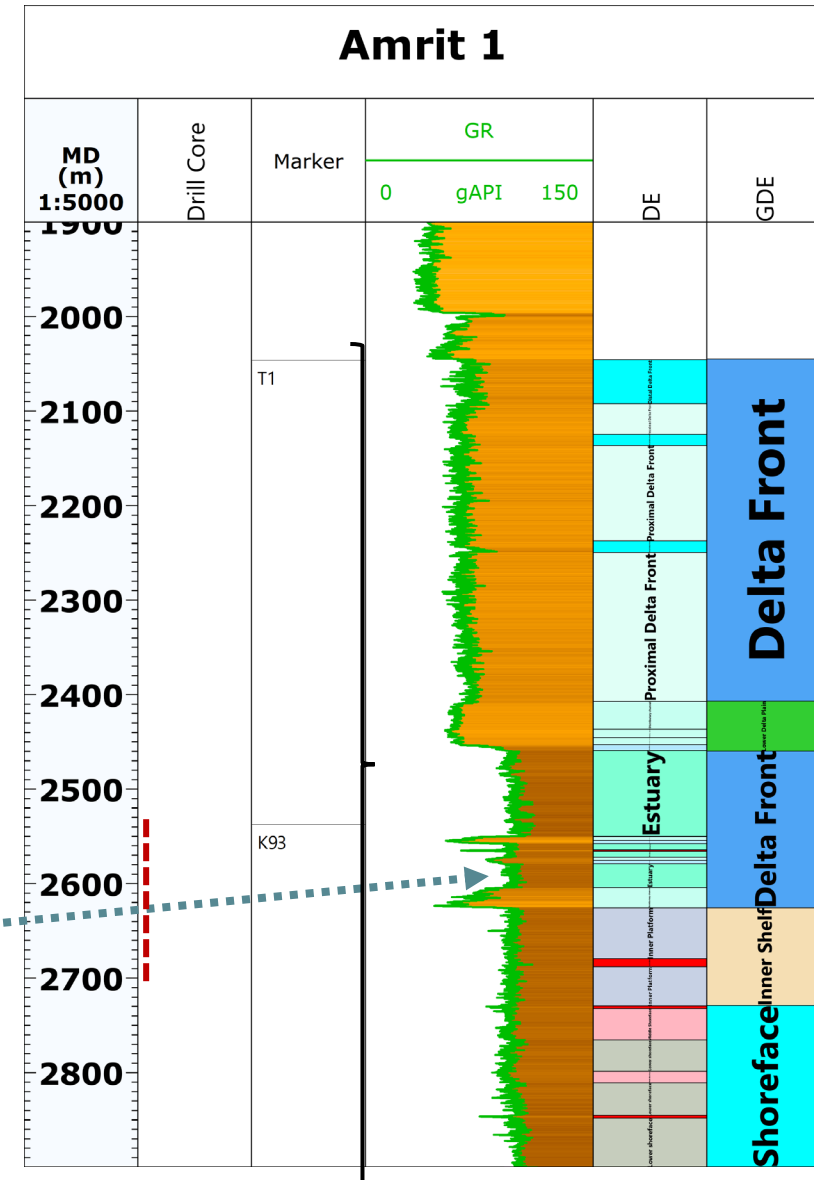
Drill Cuttings Analysis DE Interpretation: Estuary and Estuarine Channels

Despite poor quality drill cuttings a geological signal is observed

- *In situ* coal was observed in 2616m & 2619m samples. Carbonaceous fragments were common throughout [black flecks in a brown mudstone substrate]. Both observations suggest a terrestrial, not a marine [shelfal] setting
- No glaucony was observed in any sample between 2550m-2660m [red line]



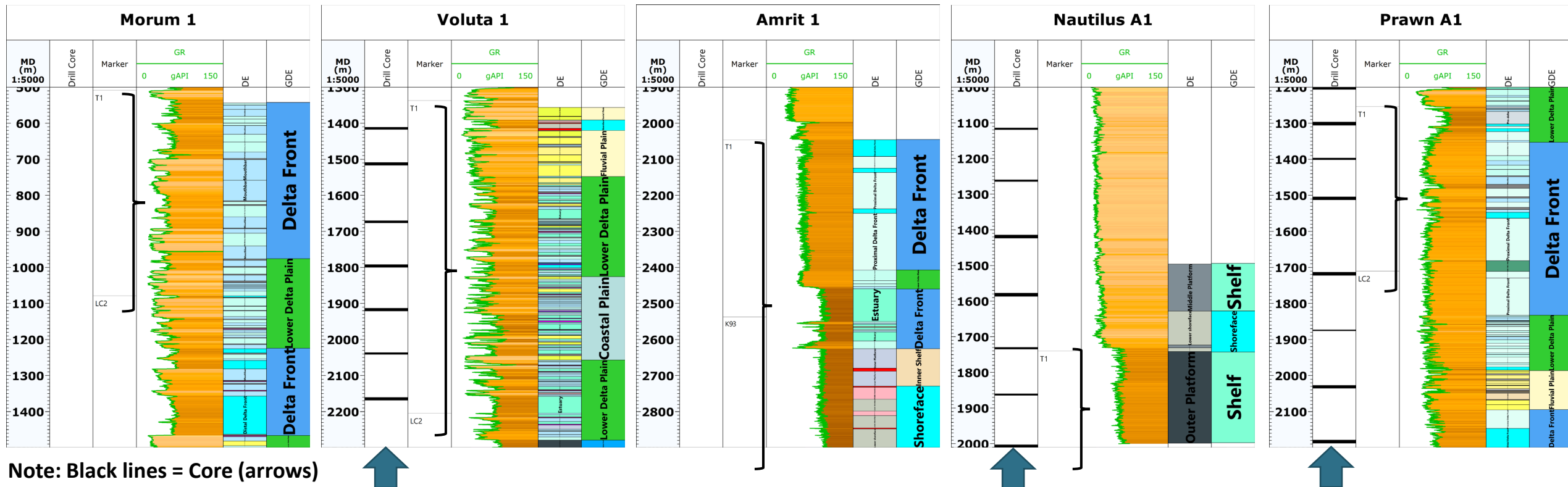
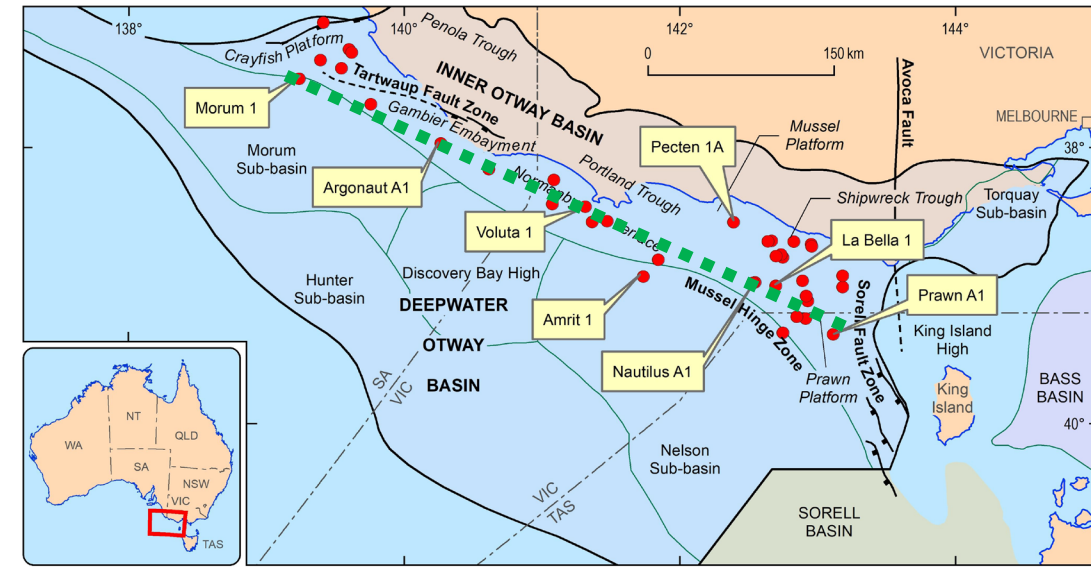
Coal (*in situ*)



Results: Core/Cuttings to Wireline

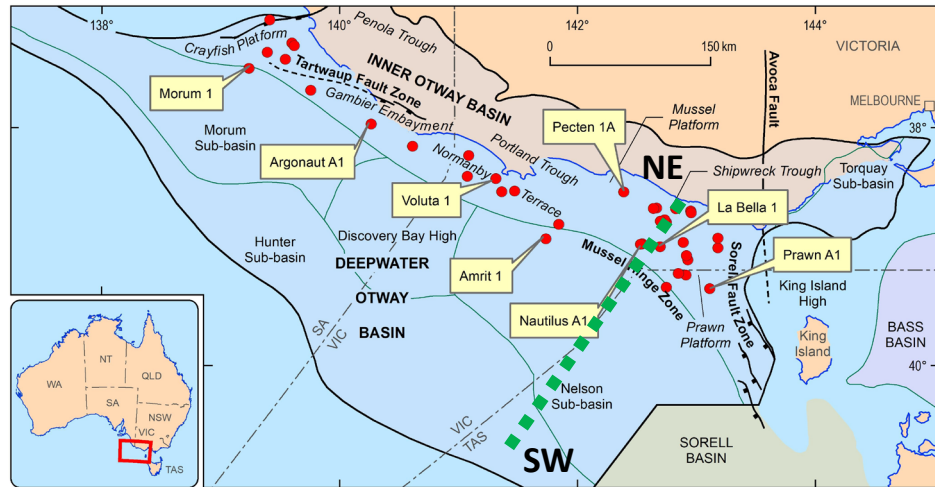
Following depth matching:

- Core and cuttings DE/GDE interpretations were used as control to interpret the wireline dataset [note: the Sherbrook SS interval is indicated by the black brackets]
- 37 wells across the whole offshore margin were interpreted
- These interpretations were then upscaled and integrated with seismic facies

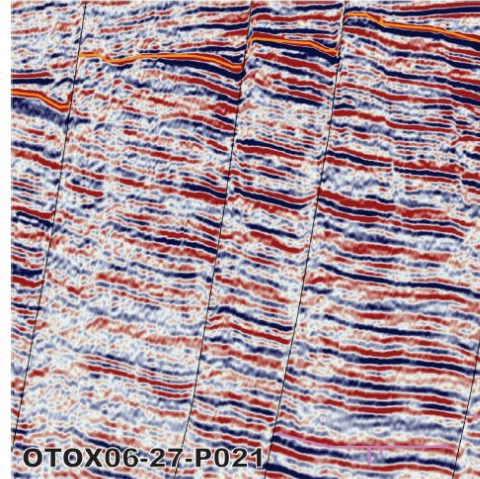


Scaling Up: Seismic Facies

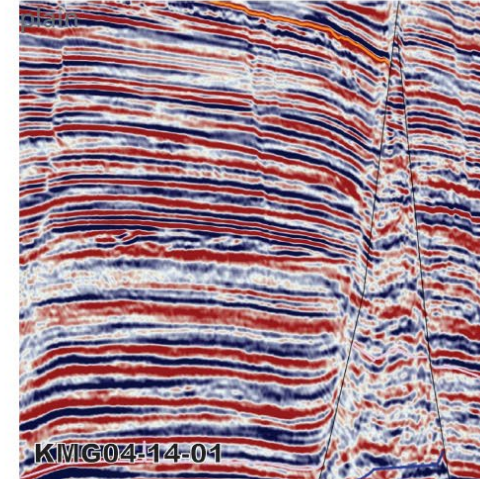
Seismic facies interpretations are tied to core controlled wireline interpretations underpinning maps



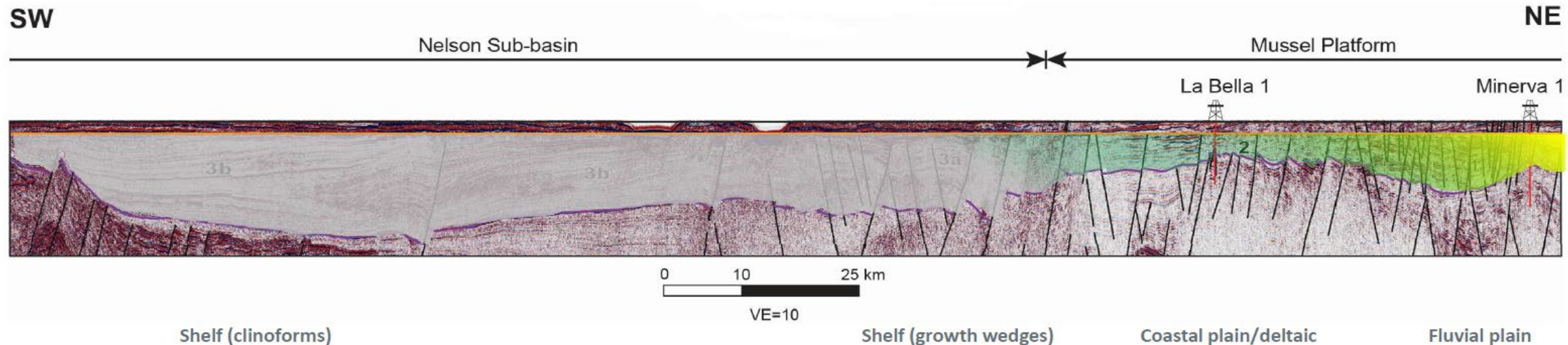
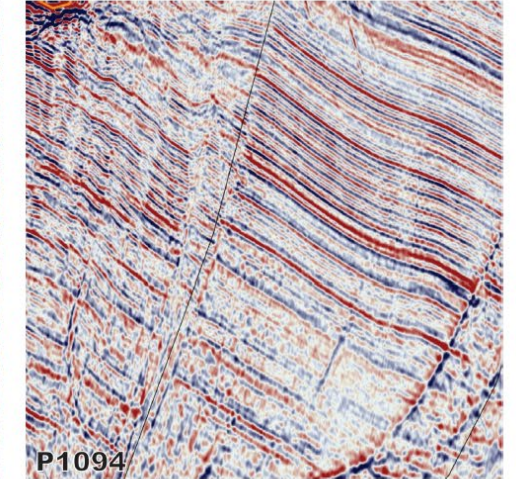
1. Fluvial plain



2. Coastal/deltaic



3a. Shelf (growth-wedges)



From Abbott et al 2023

From Abbott et al 2023

Sherbrook SS: Distribution of GDEs

All interpretations were posted on an Otway Basin base map

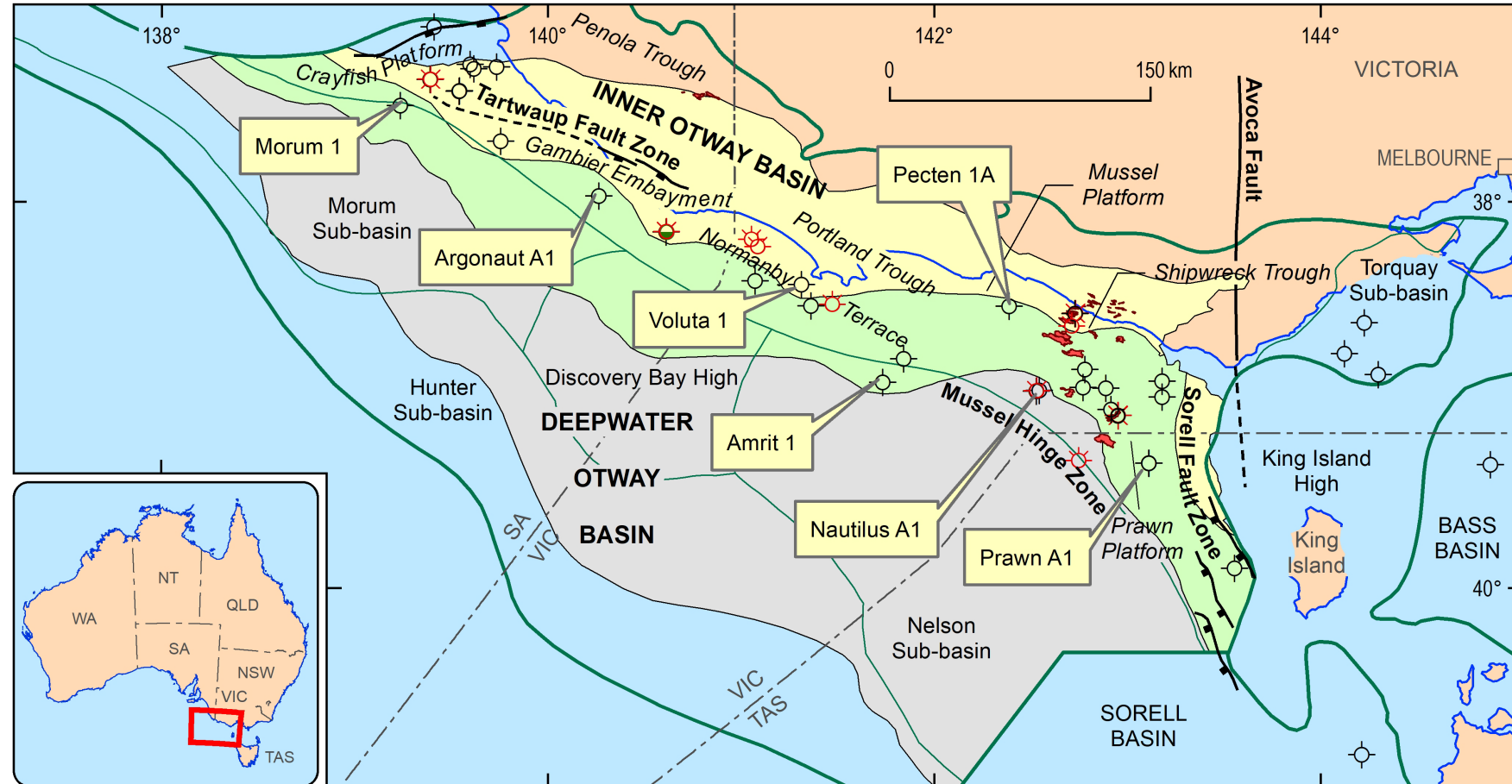
- Core (and cuttings) constrained wireline (GDE) and seismic (RGDE) interpretations were posted on an Otway Basin base map to visualise the distribution of GDEs across the whole margin



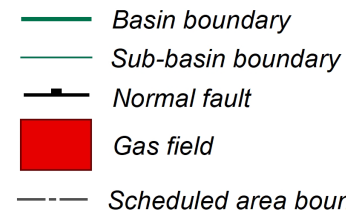
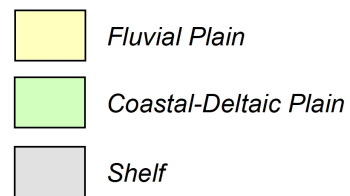
Sherbrook SS: GDE Map

The final product. A whole of margin GDE map of the offshore Sherbrook SS

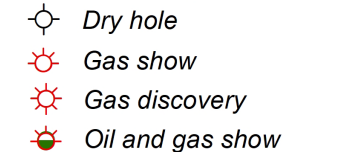
- A clear division of RGDEs were seen with fluvial, coastal/deltaic and shelfal sections trending as belts along the margin
- RGDE belts show a predictable progression towards the basin depocenter from terrestrial fluvial to shelfal



Regional Gross Depositional Environment (RGDE)



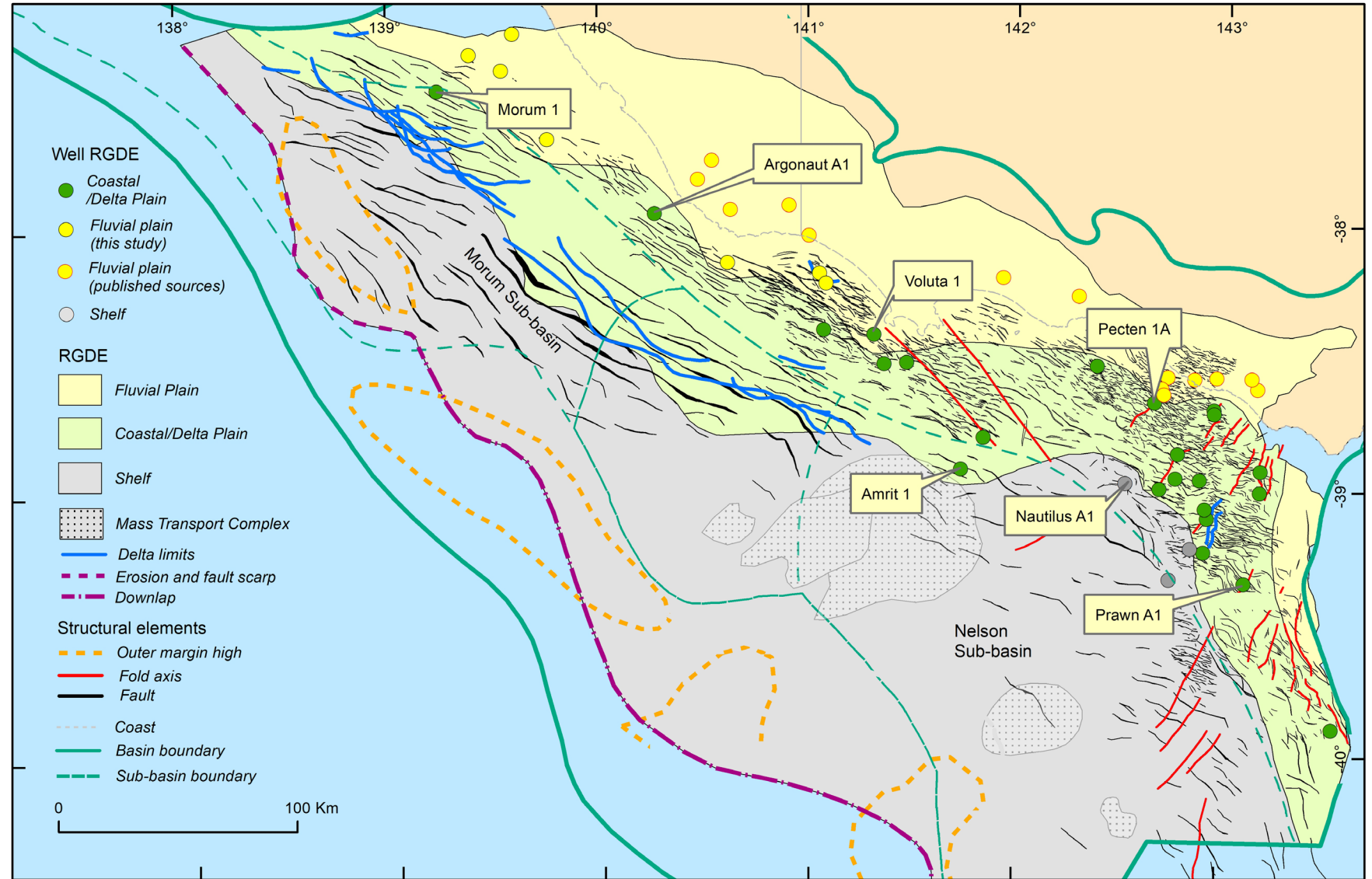
Petroleum exploration well



GDE Map: Sherbrook SS

The Sherbrook SS GDE map helps focus the exploration potential of deepwater plays in the Otway Basin

- The Sherbrook SS GDE map was populated with other key data:
 - structural elements
 - basinward delta lobes
 - shelfal mud filled sub-basins
 - outer basin highs
 - mass transport complexes



From Abbott et al 2023

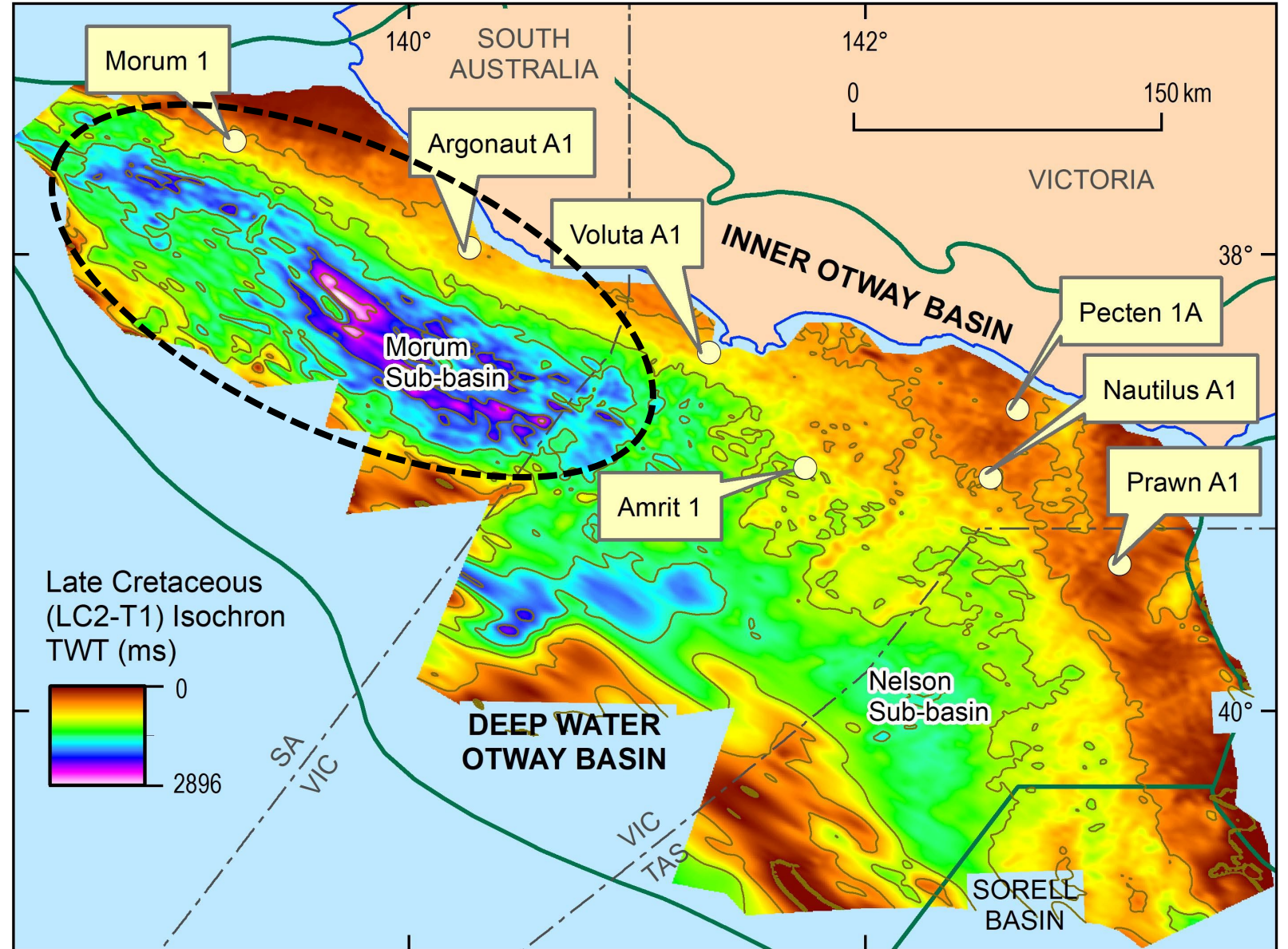
Conclusions

- Archival cores in five wells across the offshore Otway Basin were ‘rejuvenated’ and subjected to modern core description and core data visualisation techniques.
- Drill cuttings were used to ID an estuarine setting in a critically placed well
- DE and GDE interpretations from core and cuttings were used to constrain wireline and seismic interpretations
- Subsequent interpretations were spatially rendered with constrained seismic facies underpinning the formulation of a whole-of-margin Sherbrook SS GDE map
- The Sherbrook GDE map and the integration of archival core data represents a significant step forward in the understanding of deep water plays in the Otway Basin



Implications

- The work presented here represents a significant step forward towards the understanding of plays in the deep water Otway Basin.
- The presence of thick intervals of marine mudstone associated with the shelf GDE across the deep-water Otway Basin indicates the potential for productive source rocks and effective cross-fault seal in these areas (Morum sub-basin in SA).



From Abbott et al 2023

Acknowledgements

- We would like to thank Geoscience Australia's Repository for core handling and management of core data. A huge undertaking to say the very least!
- Barry Bradshaw and Adam Bailey are thanked for their constructive reviews.
- This abstract is published with the permission of the CEO, Geoscience Australia. © Commonwealth of Australia (Geoscience Australia) 2023.



Thank You

...and don't
forget to look at
your rocks!

Further information

Contact Geoscience Australia

Cretaceous depositional environment interpretation of offshore Otway Basin cores and wireline logs; application to the generation of basin-scale gross depositional environment maps

Chris Cubitt^{A,*§}, Steve Abbott^A, George Bernardel^A, Merrie-Ellen Gunning^A, Duy Nguyen^A, Chris Nicholson^A and Alan Stoaite^A

For full list of author affiliations and declarations see end of paper

*Correspondence to:
Chris Cubitt
Deputy Director Geoscience & Exploration, Geoscience and Exploration Branch, Energy Resources Division – DEM, Department for Energy and Mining, 11 Waymouth Street, Adelaide, SA, 5000
Email: Chris.Cubitt@sa.gov.au

§Chris Cubitt is now Deputy Director at Exploration Geoscience, Department for Energy and Mining, South Australia.

Accepted: 20 February 2023
Published: DD MM YYYY

Cite this:
Cubitt C *et al.* (2023)
The APPEA Journal
doi:10.1071/AJ22090

© 2023 The Author(s) (or their employer(s)). Published by CSIRO Publishing on behalf of APPEA. This is an open access article distributed under the Creative Commons Attribution 4.0 International License (CC BY).

OPEN ACCESS

ABSTRACT

Gas production from the Inner Otway Basin commenced in the early 2000s but the deep-water part of this basin remains an exploration frontier. Historically, the understanding of plays in this region were largely model driven and therefore the ground-truthing of depositional environments (DE) and gross depositional environments (GDE) are critical. This aspect has been investigated for the Sherbrook Supersequence (SS) by the integration of legacy wireline and core data, with regional 2D seismic facies mapping of new and reprocessed data from Geoscience Australia's 2020 Otway Basin seismic program. Core observations were matched to wireline logs and seismic facies with resulting well-based DE interpretations calibrated to seismic resolution Regional GDE intervals. Integration of well and seismic observations lead to the compilation of a basin-wide Regional GDE map for the Sherbrook SS. This GDE map indicates the distribution of Sherbrook SS play elements such as source rock, seal and reservoir, especially across the Deep-water Otway Basin where well data is sparse.

Keywords: Australia, core, delta front, depositional environment, gross depositional environment, mouthbar, offshore Otway Basin, shelf, Sherbrook Supersequence, tidal, wireline log.

Introduction

The Late Cretaceous succession of the Otway Basin (Fig. 1a) includes some of the key hydrocarbon producing intervals in southern Australia. This study has focussed on the Upper Cretaceous Sherbrook Supersequence (SS) forming part of the ongoing interpretation of newly acquired regional 2D seismic and reprocessed data as part of the 2020 Otway Basin seismic program (Nicholson *et al.* 2022). This abstract investigates how the use of archival cores supports the formulation of the upper Sherbrook SS gross depositional environment (GDE) map (Fig. 1b).

Depositional environments (DEs) and gross depositional environments (GDEs) were interpreted from 18 Sherbrook SS cores from four widely separated offshore wells (Argonaut A1, Voluta 1, Nautilus A1 and Prawn A1 – Fig. 1b). Wireline log motifs were used to extend DE and GDE interpretation across the entire Cretaceous succession in each well. The integration of well-based DEs with basin-wide seismic facies interpretation has resulted in the generation of basin-scale GDE maps, such as that developed for the Sherbrook Supersequence (SS) (Fig. 1b) by Abbott *et al.* (2023).

Methods

Archival cores from offshore Otway Basin wells were accessed from Geoscience Australia's Repository. The cores were in good condition with very little discolouration,

