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Palaeogeographic reconstructions:

Revealing the lithological variability of the Gage Sandstone and South Perth Shale, offshore Vlaming Sub-basin

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Introduction

The Early Cretaceous Gage Sandstone and the overlying South Perth Shale are a prospective reservoir-seal pair both for petroleum and CO_2 storage in the offshore Vlaming Sub-basin.

Potential hydrocarbon plays include post-breakup pinch-outs of the Gage Sandstone against the Valanginian Unconformity with the South Perth Shale forming a top seal, whereas the thick laterally extensive part of the Gage reservoir may be suitable for long-term storage of CO_2. The Gage reservoir was deposited in palaeo-topographic lows on the Valanginian breakup unconformity and is the lowstand component of the thick deltaic South Perth (SP) Supersequence.

Data and methodology

To characterise the reservoir-seal pair, a sequence stratigraphic analysis was conducted by integrating 2D seismic interpretations, well log analysis and new biostratigraphic data. Palaeogeographic reconstructions for the SP Supersequence were derived by mapping higher-order prograding packages and documenting changes in relative sea level and sediment supply. High resolution reconstructions of the Gage reservoir were based primarily on seismic facies mapping integrated with the well data.

Results

The SP Supersequence is interpreted to comprise three third-order sequences spanning 5.5 million years (Figure 1). The palaeogeographic reconstructions (Figure 2) show multiple transgressive-regressive cycles that infill the central depocentre. Variations in thickness of the SP Supersequence in the north compared to the south relate to differences in palaeotopography and sediment supply. Composed of pro-delta shales, the interpreted regional seal is thickest (around 580 m) between Gage Roads 1 and Rottnest Island and is mostly over 200 m thick in the northern Vlaming Sub-basin and immediately south of Warnbro 1.

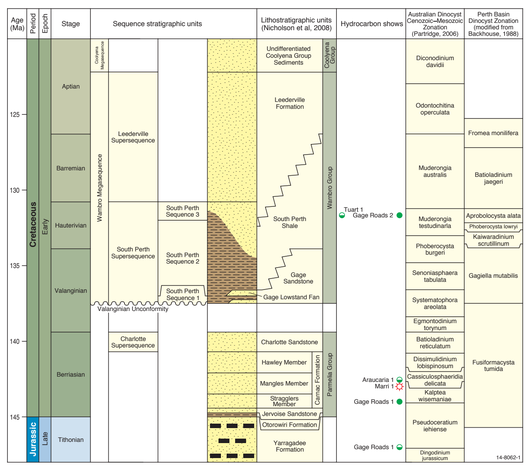


Figure 1: Vlaming Sub-basin Upper Jurassic to Cretaceous stratigraphy showing sequences and supersequence, lithostratigraphy and hydrocarbon shows.

The Gage Lowstand Fan (LSF) reservoir, previously mapped lithostratigraphically as Gage Sandstone, is defined by the lower G. mutabilis dinoflagellate zone.

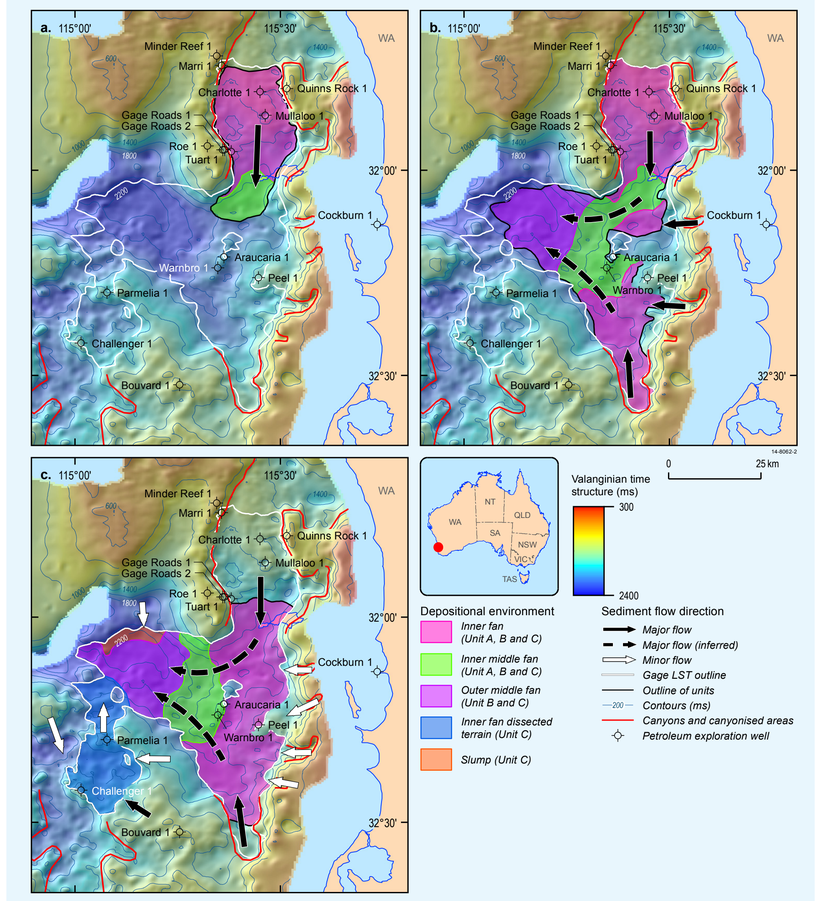
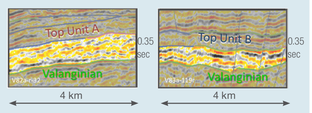
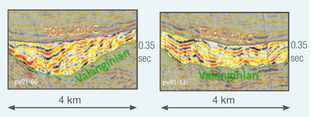
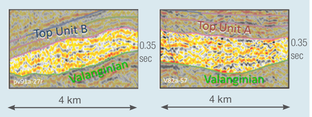
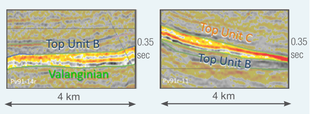
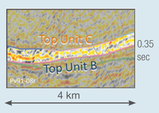


Figure 2: Depositional environments of the Gage LSF showing changes in sediment input and deposition through time a) time slice for Unit A, b) time slice for Unit B, and c) time slice for Unit C.

Table 1: Seismic examples of the Gage LSF depositional environments.

Depositional Environment	Depositional processes & lithofacies	Examples of seismic
Inner fan—inclined canyon floor and rise	Confined stacked coarse-grained gravity and debris flows with silty interchannels; onlaps. Intersected in Peel 1, Mullalloo 1 and Charlotte 1.	
Inner fan—moderately dissected topography	Stacked high energy turbidity currents; channelised flow exhibiting lateral accretion in canyons; minor debrites. Intersected in Challenger 1 and Parmelia 1.	
Inner middle fan	Channelised depositional lobes at confluence of multiple sources; sandy facies of stacked channelised sands and mass transport flows. Intersected in Warnbro 1.	
Outer middle fan—basin plain	Non-channelised depositional lobe; bedded turbidity currents. Depositional lobe with limited channels; bedded turbidity currents. No wells intersect.	
Slump	Stratigraphic trapping of detached slumped sediments in mounds at base of slope on basin plain; no wells intersect large slump apron.	

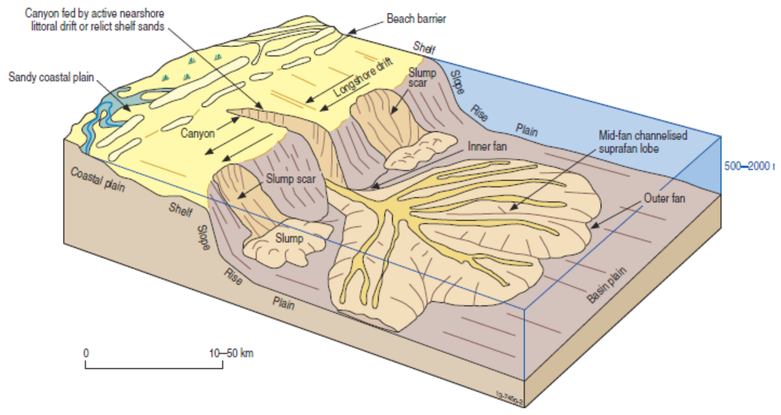


Figure 3: Block diagram of a sand-rich deep marine submarine fan (modified from Richards et al., 1998).

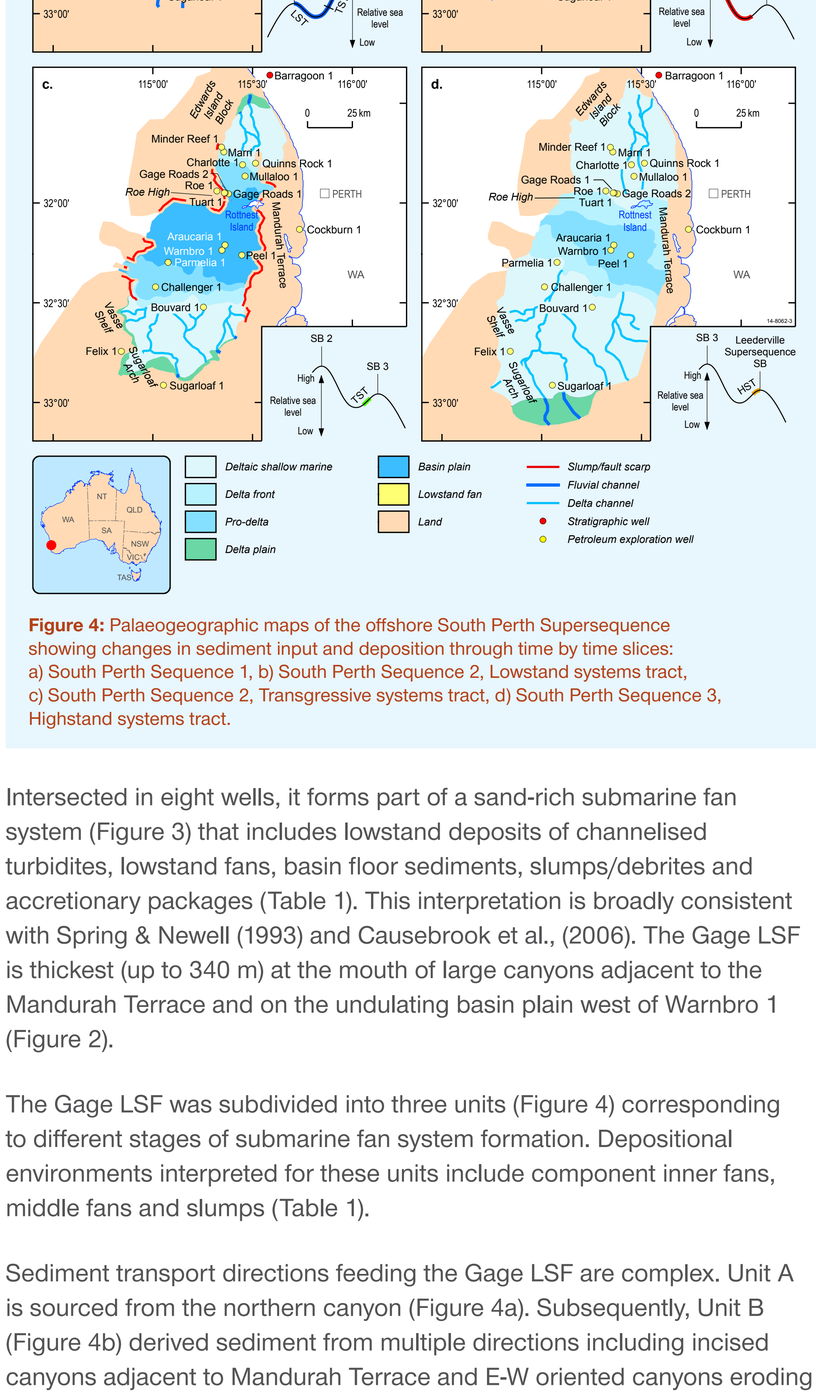


Figure 4: Palaeogeographic maps of the offshore South Perth Supersequence showing changes in sediment input and deposition through time by time slices: a) South Perth Sequence 1, b) South Perth Sequence 2, Lowstand systems tract, c) South Perth Sequence 2, Transgressive systems tract, d) South Perth Sequence 3, Highstand systems tract.

Intersected in eight wells, it forms part of a sand-rich submarine fan system (Figure 3) that includes lowstand deposits of channelised turbidites, lowstand fans, basin floor sediments, slumps/debrites and accretionary packages (Table 1). This interpretation is broadly consistent with Spring & Newell (1993) and Causebrook et al., (2006). The Gage LSF is thickest (up to 340 m) at the mouth of large canyons adjacent to the Mandurah Terrace and on the undulating basin plain west of Warnbro 1 (Figure 2).

The Gage LSF was subdivided into three units (Figure 4) corresponding to different stages of submarine fan system formation. Depositional environments interpreted for these units include component inner fans, middle fans and slumps (Table 1).

Sediment transport directions feeding the Gage LSF are complex. Unit A is sourced from the northern canyon (Figure 4a). Subsequently, Unit B (Figure 4b) derived sediment from multiple directions including incised canyons adjacent to Mandurah Terrace and E-W oriented canyons eroding into the terrace. These coalesce on an undulating basin plain west of Warnbro 1. Minor additional input for the uppermost Unit C (Figure 4c) is derived from sources around Challenger 1.

Summary and Conclusions

- The Gage reservoir is a sand-rich submarine fan system and ranges from canyon-confined inner fan deposits to middle fan deposits on a basin plain. Sediment sources are multidirectional. The dominant supply is from canyons adjacent to the Mandurah Terrace.
- A better understanding of the spatial extents and thicknesses of the Gage reservoir and the overlying seal provides important new information for identifying potential stratigraphic plays for petroleum in the Vlaming Sub-basin.
- Mapping changes in depositional environments through time and identifying different facies within the SP Supersequence helped to achieve a more realistic representation of reservoir heterogeneity in a 3D static geological model of the Gage reservoir. The maps were used to guide extrapolation of reservoir properties away from the wells which resulted in a more accurate estimate of the potential CO_2 storage capacity in the Vlaming Sub-basin.
- The most lithologically prospective sites for potential CO_2 storage are channel sands in canyon-confined inner fan deposits southeast of Gage Roads 1 where thick pro-delta shales act as a seal.

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