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Addressing exploration uncertainties in the southern Bonaparte Basin: enhanced stratigraphic control and post drill analysis for upper Permian plays

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Enhanced stratigraphic control and post drill analysis for upper Permian plays

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Introduction

The upper Permian to Lower Triassic sedimentary succession in the southern Bonaparte Basin (SBB) represents an extensive marginal marine depositional system that hosts several gas accumulations, including the Blacktip gas field that has been in production since 2009. Development of additional identified gas resources has been hampered by reservoir heterogeneity, as highlighted by preliminary results from a post drill analyses of wells in the study area that identify reservoir effectiveness as a key exploration risk.

A post drill analysis and an evaluation of the stratigraphic and depositional history of the Late Permian succession aims to provide a robust framework from which the distribution and quality of petroleum systems elements can be assessed.

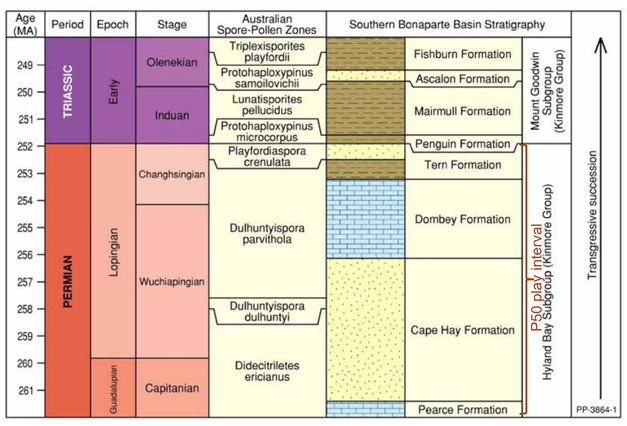


Figure 1: . Upper Permian to Lower Triassic lithostratigraphy in the southern Bonaparte Basin and Australian generalised spore pollen zones. Geologic Time Scale after Gradstein et al (2020).

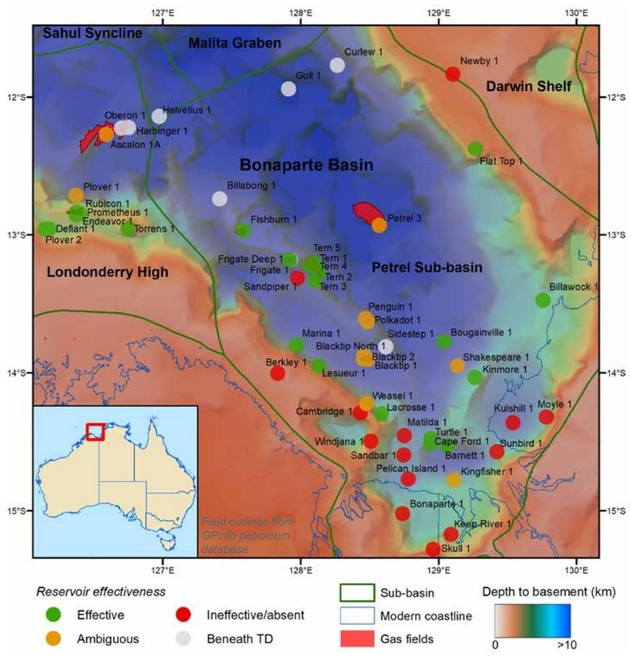


Figure 2: Map of the southern Bonaparte Basin showing preliminary outcomes of the post drill analysis of reservoir effectiveness for the P50 play interval (Hyland Bay Subgroup). Base map shows depth to basement (OZ SEEBASE®; Geognostics, 2020).

Parasequence interpretation

- New and revised biostratigraphic data are integrated with well log interpretations and correlations to subdivide the upper Permian and Lower Triassic succession into broad parasequences (Figure 4)
- The vertical stacking pattern of parasequences in the Dombey–Tern–lower Penguin succession are broadly consistent with a progradational model of deposition
- Variability in the nature and arrangement of the parasequences reflect subtle differences in depositional environments and evolution across the basin
- Integration of biostratigraphic control with the parasequence interpretation highlights the apparent diachrony of facies as they develop later in a basinward direction.

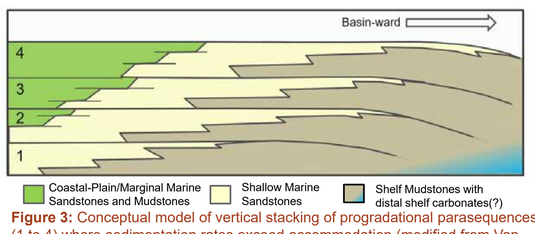
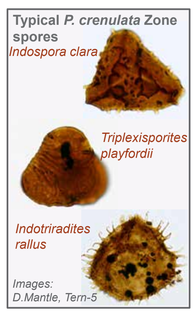


Figure 3: Conceptual model of vertical stacking of progradational parasequences (1 to 4) where sedimentation rates exceed accommodation (modified from Van Wagoner et al, 1990). Our observations of the Dombey to Tern to lower Penguin development in the Petrel Sub-basin conform to this model.

Biostratigraphic review

- Existing biostratigraphic data across the Permo-Triassic transition were inconsistent
- Available data reviewed, infill palynological sampling and analysis undertaken (MGPalaeo)
- 156 new analyses across 11 wells
- Consistent and better resolved palynological dataset available for key wells across the area
- *P. crenulata* and *P. microcorpus* zones resolved in most studied wells



Post drill analysis

P50 play interval

- Comprises the Tern, Dombey, Cape Hay and Pearce formations (Phillips et al, 2019; Figure 1)
- Extends across much of the offshore SBB, not deposited/eroded over the southern-most flanks of the Petrel Sub-basin, the Berkley Platform and the Darwin Shelf (Figure 2)
- Eleven successful gas tests associated with 4-way dip-closed anticlines and high-side fault-block traps
- Reservoir effectiveness identified as the primary risk
  - Interpreted porosities good to excellent (15–30%)
  - Permeabilities tend to be low (10s to low 100s mD) → result of silica and/or calcareous cements or high clay contents
  - Commercial flow rates may be challenging
- Fault seal and hydrocarbon charge represent secondary risks

Reservoir effectiveness

- The P50 is generally deeply buried where it has been the target for exploration
  - reservoir depths of >2450 m and >3550 m in the Tern and Petrel fields, respectively
- Preservation of porosities and permeabilities dependent on the presence of clay coatings around detrital quartz grains, which inhibit siliceous cementation during diagenesis (Bhatia et al, 1984; Saïag et al, 2016)
- Presence of clay coatings is linked to the depositional environment of reservoir sandstones (Wooldridge et al. 2019) → refined depositional models required to reduce risk and uncertainty for the P50 play interval.

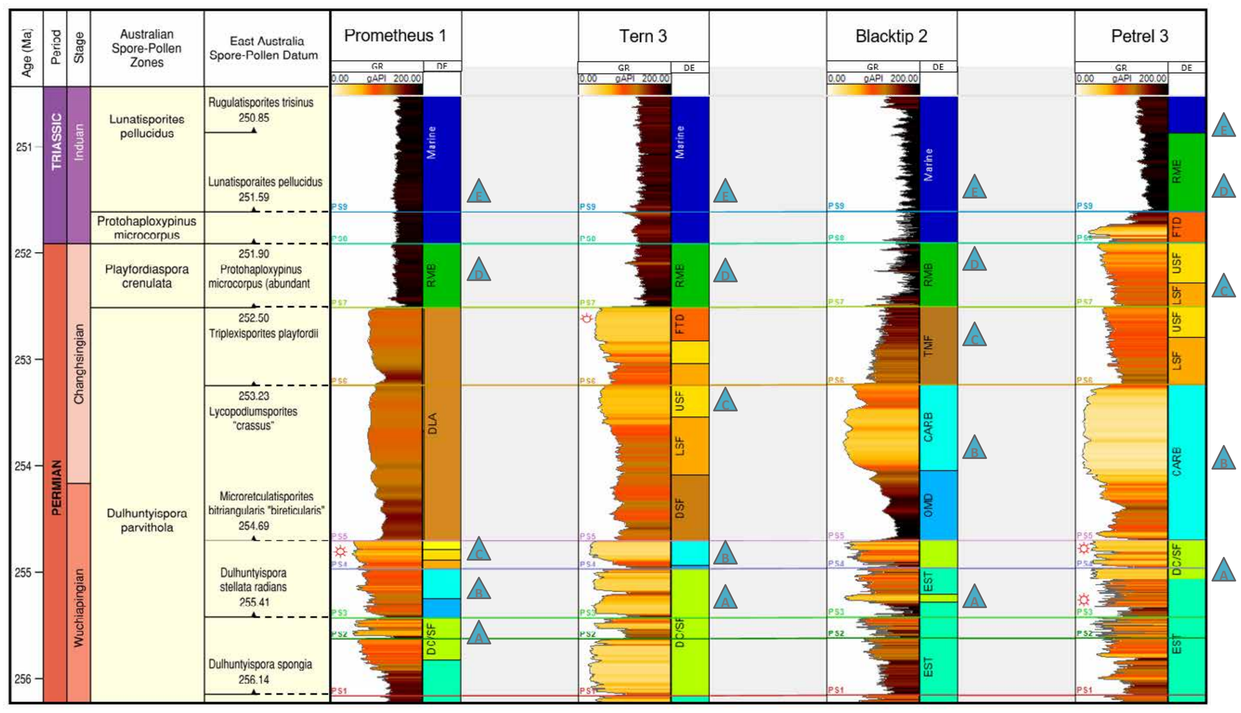


Figure 4: Well correlation for key wells in the southern Bonaparte Basin scaled to age using updated biostratigraphic data and parasequence interpretation (PS1 through PS9). Depositional environment for each parasequence is also shown: CARB, carbonate facies; DSF, distal shoreface; LSF, lower shoreface; USF, upper shoreface; FSB, foreshore/beach; DC/SF, distributary channel/sandflat; EST, estuarine; TMF, tidal mudflat; FTD, flood tide delta; DLA, delta-lagoonal; RMB, restricted mud basin; OMD, offshore muds.

Depositional history

A. Deposition of the transgressive Cape Hay Formation in a protected to restricted estuarine embayment
  - Initially tide-dominated sand and mud flats with a fluvial component
  - Increasingly sand-dominated, includes tidal channel/bar complexes and sandy tidal flats → stronger marine influence

B. Marine flooding of the estuarine embayment → shelfal to shallow marine
  - Reduction in fluvial/terrestrial sediment input key
  - Deposition of Dombey Formation muds and carbonates

C. Progradational shoreface system established → resumption of siliciclastic deposition
  - Relatively stable eustatic sea-level → offshore to lower shoreface siltstones & sandstones of the Tern Formation
  - Repeated filling of accommodation, at least two cycles coarsen to upper shoreface sandstones

D. Continued progradation of the shoreface system
  - Transitional section interpreted as flood tide delta/tidal channel facies preserved in some wells (e.g. Tern 5, Bann et al, 2004).
  - Deposition of restricted mud basin deposits of the lower Penguin Formation

E. Early Triassic marine transgression → flooding of the restricted mud basin
  - Deposition of marine siltstone and mudstones of the upper Penguin and Mairmull formations in an open marine embayment.

Conclusions

- Post drill analysis of the P50 play interval across the SBB highlights that while several gas discoveries have been made, reservoir effectiveness is a key exploration risk.
- New and revised biostratigraphic and palynofacies data for the upper Permian and Lower Triassic succession has enabled refinements of the depositional models for the P50 play interval.
- The diachronous deposition of facies during the latest Permian to earliest Triassic reflect a prograding paralic system, comprising a transgressive systems tract between the low stand sediments of the Permian Cape Hay Fm and the high stand sediments of the Triassic Mairmull Fm.
- The refined depositional model advances understanding of the spatiotemporal distribution of depositional environments during the late Permian and Early Triassic, helping to predict the spatial distribution of effective reservoir fairways.

Acknowledgements

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