Modelling reservoir deliverability within the Northern Beagle Sub-basin, Western Australia

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SUMMARY

Reservoir deliverability is a critical component affecting the viability of petroleum systems within a sedimentary basin. Deliverability can be described as the ability of a given rock to flow hydrocarbons to the surface. Calculating deliverability relies on estimates of reservoir pressure, permeability and thickness as well as fluid viscosity, all of which are difficult to predict in a frontier basin. Burial and erosional processes exert a fundamental control on these rock and fluid properties. If this erosion is not uniformly distributed across an area then complex variations in deliverability may result. This paper presents a novel approach to quantifying predictions of reservoir deliverability within the Northern Beagle Sub-basin of Western Australia, via the use of a 3D basin-scale model that provides spatial and temporal estimates of variations in rock and fluid properties.

Active extension began in the Northern Beagle Sub-basin during the Early Jurassic and resulted in deposition of proposed source and reservoir intervals. A thick (>5km) succession of progradational Middle Jurassic deltaics overlies the early Jurassic petroleum system. During the Late Jurassic, the basin underwent a complex phase of erosion (attributed to rift flank uplift), which resulted in upwards of 3km of sediment being locally removed on footwall blocks of active faults, as well as over structural highs. In other areas, however, such as contemporaneous structural lows, amounts of erosion are minimal. This complex spatial pattern of erosion has implications for both the thermal history (affecting fluid viscosity), as well as reservoir quality (permeability).

The final product generated from this workflow was an integrated, basin-scale 3D model of reservoir deliverability for the Northern Beagle Sub-basin.

Key words: Northwest Shelf, Beagle Sub-Basin, Deliverability, Reservoir Model

INTRODUCTION

Reservoir deliverability is a critical risk addressed during the exploration phase of a frontier basin and is loosely described as the ability of a given rock to flow hydrocarbons to the surface. This parameter quantifies hydrocarbon mobility and the ability of a proposed reservoir to deliver a sufficient flow rate, and is therefore a fundamental control on the commercial prospectivity within a sedimentary basin.

Deliverability ***(Q)*** is dependent on four variables: Reservoir permeability ($\boldsymbol{K}$), Reservoir Pressure ($\triangle\boldsymbol{p}$) Reservoir thickness ($\boldsymbol{H}$) and Fluid viscosity ($\boldsymbol{\mu}$) (Equation 1):

$$Q = \frac{\Delta P\ KH}{\mu} \qquad \textit{Equation 1}$$

These four variables vary spatially and temporally within a basin. For example, deep basinal areas may expel more highly mobile fluids from source intervals that have been subjected to higher thermal stresses. Conversely the highest reservoir quality is often found in shallower regions as both porosity and permeability are preserved through lower compaction and temperatures. The interplay of these physical processes is a complex three dimensional problem that must be understood at the basin-scale in order to make a valid prediction about the expected deliverability. This paper explores a unique and novel approach to quantifying reservoir deliverability via the use of a 3D basin-scale model.

BASIN SETTING

The Northern Beagle Sub-basin (Figure 1) sits within the greater Northern Carnarvon Basin (Figure 1A) and contains Palaeozoic through Cenozoic sediments (Paschke, et al 2018). This paper focusses on the Jurassic history, in particular the phase of active extension that spans the Pliesnbachian – Oxfordian (Figure 1B). This phase of basin development was responsible for a thick early Jurassic shale prone interval (Athol-Murat Fm, EJ28 – LJ13) which is overlain by a thick succession of mid-late Jurassic deltaic sequences (Legendre Fm). This Jurassic deposition was followed by extensive phases of erosion during the Callovian and Oxfordian, which was associated with the eventual breakup of continental fragments from the Australian Craton. Post-Jurassic history of the basin is recorded primarily by progradational carbonates deposited in a passive margin setting

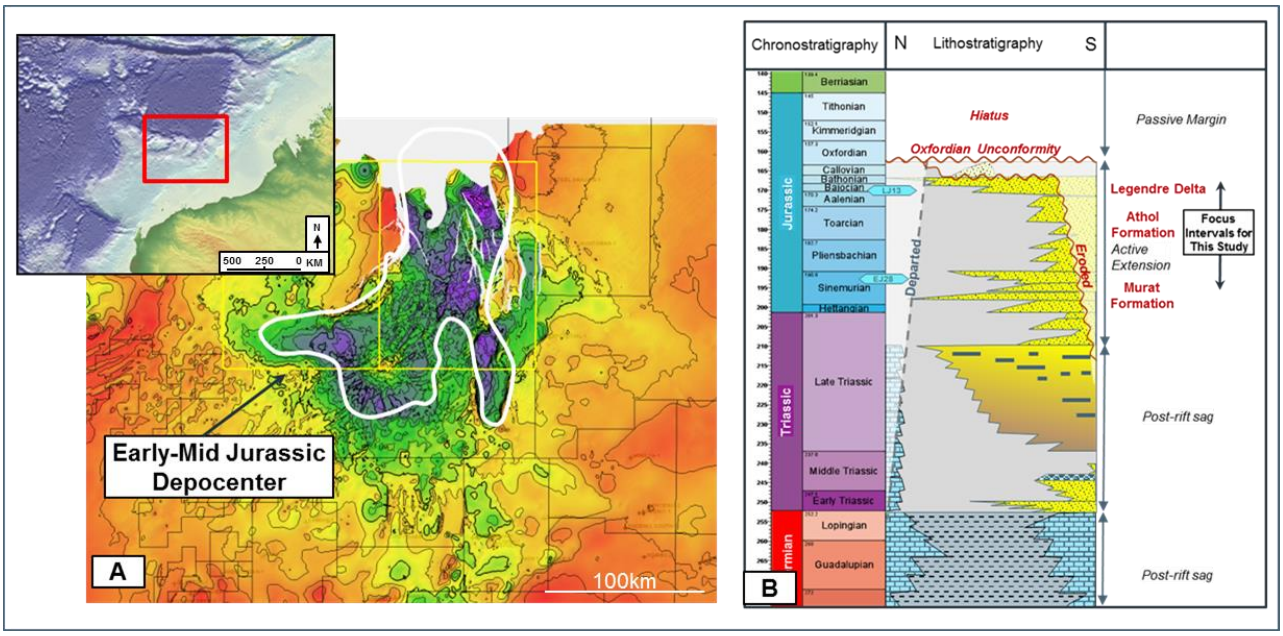

Figure 1: a) Location of Northern Beagle Sub-basin. Map is an early-mid Jurassic thickness map (blues are thick) b) Stratigraphy of the Northern Beagle Sub-basin showing focus intervals discussed in this paper

3D RESEVOIR DELIVERABILITY MODEL

A basin-scale 3D geo-cellular model has been constructed to calculate deliverability within the early Jurassic intervals of the Northern Beagle Sub-basin. The structural framework is based upon detailed seismic interpretation and incorporates key horizons as well as major faults. Layering within the model delineates each stratigraphic interval with cell sizes (generally 10m thick) capturing the detail required in the intervals of interest – in this case the Jurassic sequences directly beneath the Legendre delta (Figure 2).

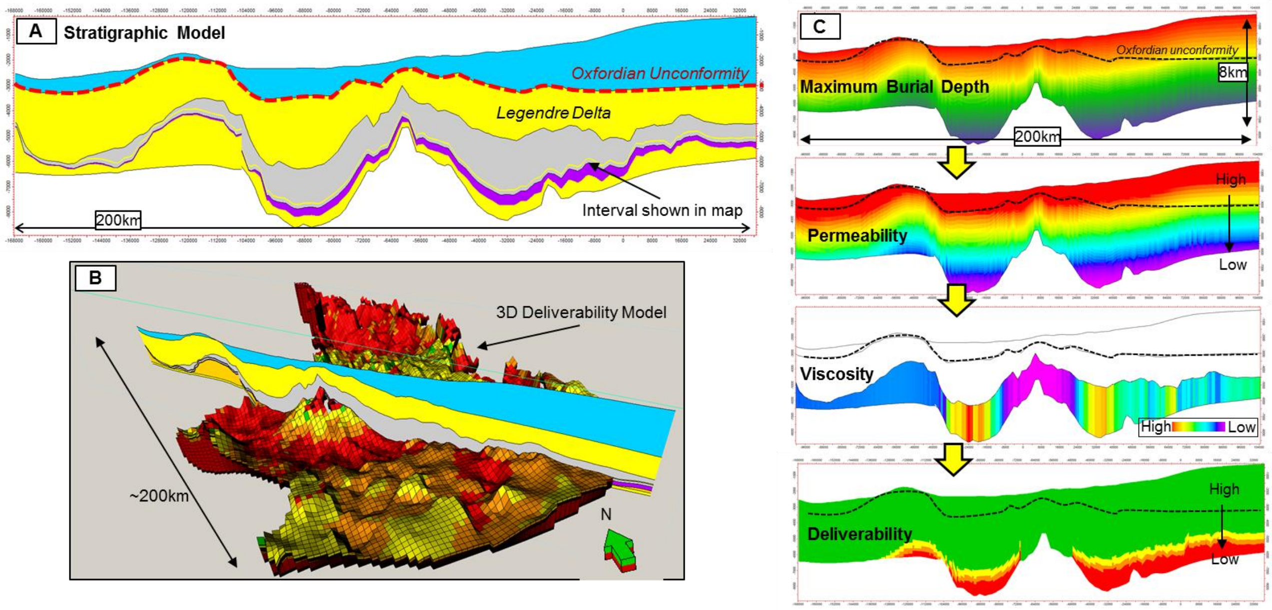

Figure 2: Deliverability model a) Stratigraphic model b) 3D view of final deliverability grid c) example cross-sections showing the properties used in calculating deliverability.

The next step in generating the model was to populate each cell with the key parameters required to calculate deliverability – namely thickness, porosity, permeability and fluid viscosity. It is at this stage of the process that the obvious consideration of maximum burial needs to be addressed and quantified as this fundamentally affects each of the main parameters from which deliverability is derived (Figure 2).

Estimates of Erosion and Maximum Burial

Within the Northern Beagle Sub-basin up to 3km of sediment has been eroded at the Callovian and Oxfordian unconformities (Figure 3). This has implications for the burial and thermal history of the basin and is a major control on both expulsed fluids as well as reservoir quality. Accurate mapping of these unconformities, as well as reconstruction of the Legendre Delta to its pre-erosion thickness are crucial steps in estimating the amount of missing section. Once an 'erosion estimate' map has been made it is possible to build the basin-scale model upon maximum estimates of burial depth.

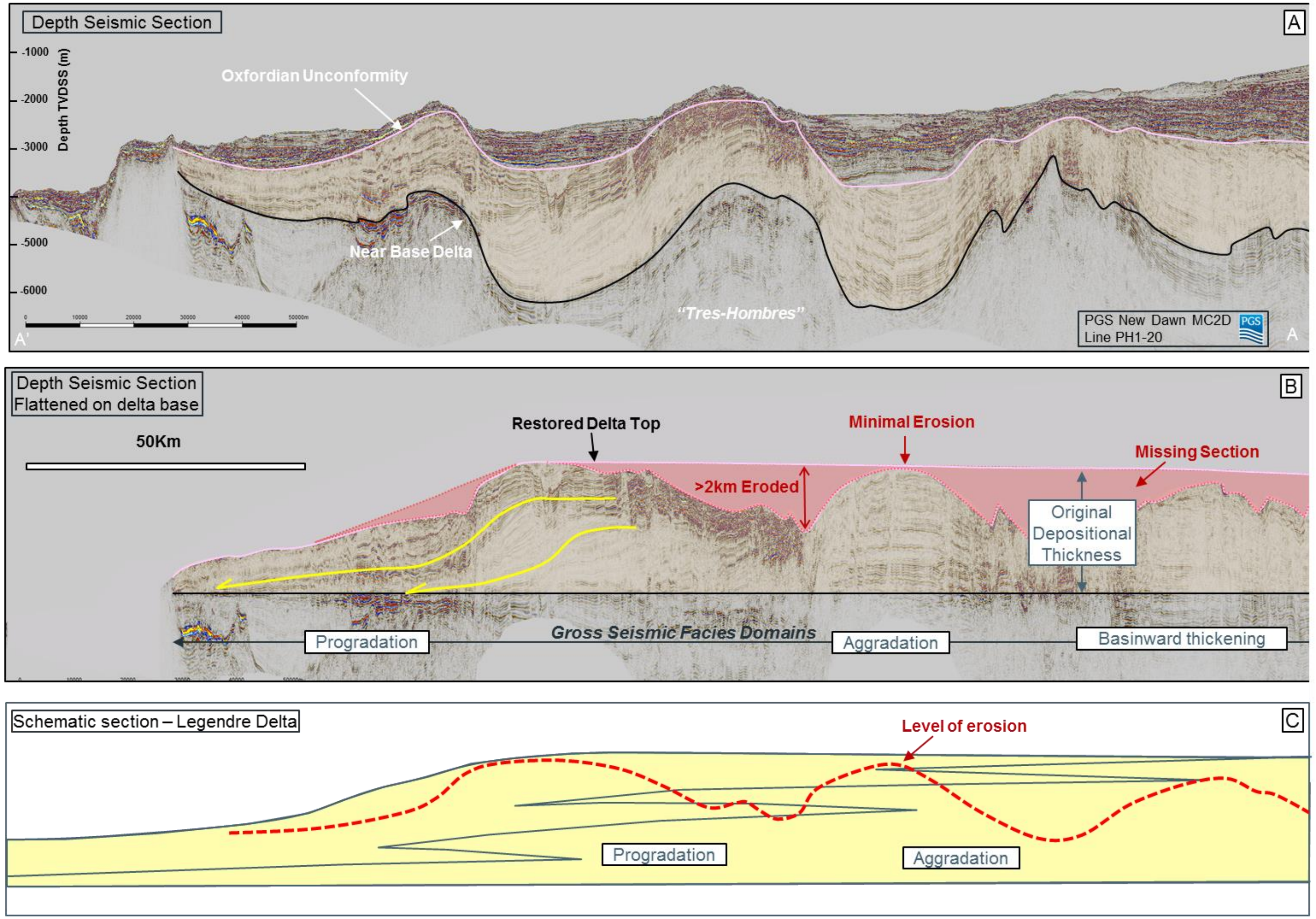

Figure 3: A. Seismic line over the Northern Beagle Sub-basin showing structural and stratigraphic relationships. B and C. Flattened seismic line and schematic showing nature of erosion. A map of the thickness of missing section was generated to quantify maximum burial trends across the basin

Deliverability and Uncertainty Modelling

Once the 3D basin-scale structural model had been constructed, it was then possible to generate an estimate of deliverability within any given grid cell (Figure 2). This deliverability property within the model could then be converted into a deliverability map for any given interval and be used for play fairway mapping. One benefit of the 3D model approach is that updates to the interpretation can be quickly incorporated and used to revise play maps. Another benefit is that uncertainty workflows can be applied to the model. Through this process a range and distribution can be applied to each input variable in order to modify them probabilistically in order to generate multiple deliverability scenarios. The results can then be interrogated by visually inspecting the P10-P50-P90 models / maps (Figure 4), with high deliverability shown in green, and low being red. Each map represents an alternative realisation of the spatial distribution of deliverability across the basin. The P90 case shows the outcome where low side assumptions are used for erosion, permeability and viscosity, whereas the P10 case uses the high side assumptions.

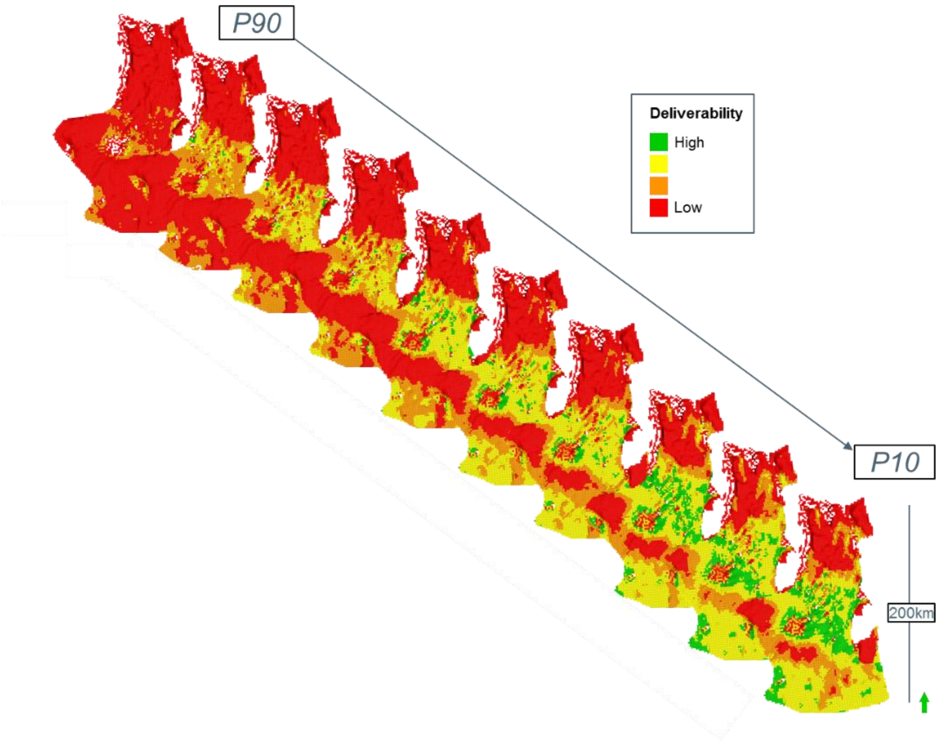

Figure 4: Example P90 – P10 deliverability map results from basin scale model.

CONCLUSIONS

In this study we have shown that the application of a 3D basin-scale model can be used to estimate basin wide deliverability which can then be used for regional play assessments. Not only can such models help quantify deliverability in areas within basins that have a complex burial and erosion history, but they can also be used in uncertainty modelling to estimate the sensitivity of each variable. This approach moves away from the ‘hard’ boundaries typically used in play based exploration and encourages a thorough interrogation of map based risking.

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REFERENCES

Paschke, C.A., O’Halloran, G., Dempsey, C. and Hurren C., 2018, Interpetation of a Permian conjugate basin margin preserved on the outer Northwest Shelf of Australia: in editors needed, 2018 Proceedings AEGC conference.