Carbonate reservoir development in the Canning Basin, Western Australia

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SUMMARY

We present a multidisciplinary study investigating deposition and diagenetic impacts on pore system variability in carbonate systems from the Canning Basin. With some of Australia’s only known commercially viable carbonate reservoirs the Canning Basin is a region of renewed industry interest and considerable national importance having both recent discoveries (Ungani Far West-1, 2011) and recent historical production from the Blina field (discovered 1981). Detailed core, microscopy, geochemical and petrophysical studies combined with some seismic work are beginning to reveal significant variations in pore system development from the shallow-water carbonate systems on the northern versus southern margins of the Fitzroy Trough within the broader Canning Basin. A strong association is emerging between reservoir quality, dolomitisation and/or earlier cavity system development on the basis of preliminary results.

Key words: Canning Basin, Carbonate Reservoir, deposition, diagenesis, dolomitisation, pore systems.

INTRODUCTION

The recent petroleum find of oil in massive dolomites (Ungani Dolomite) in Buru’s Ungani Far West-1 2011 discovery has refocused interest on understanding carbonate systems and their reservoir potential in the Canning Basin, Western Australia (Then et al., 2018). Despite a history of hydrocarbon production from carbonate systems since the 1980’s (Blina Oilfield) there is almost no detailed research evaluating controlling influences on reservoir development from one of Australia’s only known regions of hydrocarbon production within subsurface carbonates. The aim here is a detailed sedimentological, diagenetic, petrophysical, log and seismic study to better understand pore system generation, occlusion, variability and controlling influences within little studied petroleum systems of national importance. In particular, we evaluate depositional and diagenetic influences on the considerable differences seen in reservoir development between the northern and southern margins of the Fitzroy Trough within the broader Canning Basin (Figures 1 and 2; Lennard Shelf versus Jurgurra Terrace, respectively; Seyedmehdi, 2011; 2019; Copp, 2016; Wilson, 2016; Long et al., 2018; Then et al., 2018).

OBJECTIVES AND METHODOLOGY

Specific research objectives and the associated methodologies are:

Detailed core logging of some of the thickest cored intervals through varied reservoir and non-reservoir quality units of shallow water deposits from the Devonian to Lower Carboniferous carbonate systems (Yellow Drum and Ungani Dolomite of the Fairfield Group as well as Nullara and Windjana Limestones of the Napier Formation Group; Playford et al., 2009; Edwards and Streitberg, 2013). Key cores already studied in detail include those from the Blina field, Senagi-1, Ungani, and Ungani Far West-1 with additional wells being evaluated over the course of this year. Detailed facies, component, sedimentary structure, post-depositional alteration and pore system variability observations are to evaluate depositional and diagenetic controls on reservoir potential.

Integration of further detailed petrography of new and existing thin sections, together with new scanning electron microscopy (SEM), geochemical (stable isotopic) as well as core-plug porosity/permeability data with existing wireline logs is to better understand controls on petrophysical and pore system variability. This petrographic and geochemical research is specifically targeted at understanding the impacts of secondary alteration on primary depositional features and the associated evolution of pore systems through evaluating paragenetic relationships. Where possible information will be combined from MicroCT to further quantify lithological and petrophysical features at the grain-scale. On a core- to well-scale some borehole image logs, CT scans of core as well as hyperspectral (hylogger) logging data is available from recent wells on the southern Fitzroy Trough margin allowing for better understanding and quantification of mineralogical and petrophysical variability (Then et al., 2018).

Some evaluation of 2-D and new 3-D seismic datasets is to characterise carbonate platform evolution and sequence development. The seismic research, in combination with the core and analytical studies, will be focused on understanding the importance of intertidal to shallow-subtidal carbonate facies development, dolomitisation, large-scale cavernous porosity generation through subaerial exposure, marine neptunian systems or potentially fault-controlled hydrothermal alteration.
PREVIOUS WORK AND PRELIMINARY RESULTS

Preliminary results are starting to reveal some of the variability in porosity/permeability within carbonate systems across the Canning Basin, despite much of the core, microscopy, geochemical and petrophysical work still being ongoing. There is a strong combined link to both depositional and diagenetic features to pore system development. Across the Canning Basin there appears to be a common associated between reservoir potential with dolomitisation and/or cavity system generation with the origins of these alteration processes being further investigated through this ongoing research (Figure 3; see also Wallace, 1990).

In spite of extensive exploration efforts on the northern Canning Basin margin the Blina Field remains the only commercial discovery (1981) reservoir in carbonate rocks on the Lennard Shelf. Copp (2011) noted that the reservoir rocks of the Blina field are atypical of much of the northern Canning Basin margin where reef-associated rocks of mainly latest Devonian age are commonly affected by extensive early calcite cementation. The reservoir unit at Blina is developed in dolomitised (‘predominantly) Early Carboniferous Fairfield Group carbonates that formed in a ramp type setting (Druce and Radke, 1979; Jonasson and Reiser 2002, Seyedmehdi 2011; Seyedmehdi et al., 2016). There is considerable variability in the ramp-type deposits of the Fairfield Group including grain-rich and finer ‘muddy’ carbonates, with some interdigitation of siliciclastics as well as admixed carbonate-clastic units (Seyedmehdi 2011; Seyedmehdi et al., 2016). The porous units at Blina consist of dolomitised packstones to grainstones with ooids, peloids and some ooids as well as dolomitised finely laminated microbial to peloidal mud/wackestone facies deposited in shallow subtidal ‘shoal’ to inter-/supra-tidal flat settings, respectively (Figure 3). Textures in the porous dolomites are commonly idiotopic sucrosic to ‘partially interlocking’ with up to 30% intercrystalline and some vuggy porosity mostly on sub-mm to millimetre scales (Figure 3).

On the southern Fitzroy Basin margin reservoir units (e.g. the Ungani Far West-1 2016 discovery) or carbonates with reservoir quality (e.g. Senagi-1) are associated with dolomitisation, albeit on the basis of limited well control. As with the Lennard Shelf dolomitisation is localised, but differs on the southern margin in being more extensive, up to 100’s of metres thickness of massive fabric-replacive dolomite. There is commonly a greater range of dolomite types including replacive and planar dolomites, to non-planar interlocking mosaics as well as higher-temperature saddle dolomites in the south. Porosity is typically vuggy to cavernous, with some of the caverns being remnant pore spaces after complex infill and partial cementation of earlier cavity systems (Figure 3). Porosity is locally up to 30-35% with pores mainly on few mm, to cm to 10’s of centimetres scale (Figure 3).

CONCLUSIONS

This multidisciplinary core, microscopy, geochemical and petrophysical study is ongoing with the aim of characterising and understanding differences in deposition, diagenesis and their impacts on pore system variability in key wells that penetrated carbonate rocks in the Canning Basin. Preliminary results are revealing an initial association between reservoir quality with dolomitization and/or cavity system development. This study is anticipated to significantly enhance our understanding of depositional and diagenetic impacts on reservoir development within one of Australia’s only known economic hydrocarbon discoveries within carbonate systems from the Canning Basin. Further implications are for evaluating global carbonate systems reservoir variability as well as regional palaeoenvironmental change and basin evolution.

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REFERENCES


Copp, I. A. 2016. Ungani FW 1 core description: Jurgurra Terrace, Canning Basin: Good Earth Consulting for Buru Energy, 50p (unpub.).

Edwards, P. B. & Streitberg E., 2013. Have we deciphered the Canning? Discovery of the Ungani Oil Field. West Australian Basins Symposium IV.


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Figure 1. Location map with tectonic elements and Top Dolomite depth map (after Then et al., 2018).

Figure 2. Cross section across the Fitzroy Trough and adjacent terraces (after Then et al., 2018).
Figure 3. Examples of core and microscopy images showing some of the variability in facies, and their diagenetic character and how these influence differences in reservoir potential in different parts of the Canning Basin. 

Left: core photograph of Blina 1 (Core 2: 1210.5 m) showing grey clay-rich to pale brown dolomitised laminated mudstone from inferred intertidal setting with microbial laminates and mottled textures. 

Top middle: Intercrystalline microporosity in sucrosic dolomite imaged via SEM from Blina 2: 1221.57 m. 

Top right dolomitised complex breccia zone from Ungani Far West-1 (2397 m). 

Bottom middle: Plane-(left) and cross-polarised light photomicrographs showing complex interlinked cavernous porosity (blue in PPL, black in XPL) in breccia zone (Horizontal field of view in each 5 cm). Brecciation and cavernous porosity development post-dates early marine radiaxial cement (upper right clast), early dark grey crinoidal-rich breccia infill (upper middle clast) and some fracture filling cements, but is post-dated by wallrock dolomitization, further dolomite, and also silica, cements. Bottom right: Close-up core photographs showing intergranular but mainly mm to sub-mm scale vuggy to biomoldic porosity in dolomitised packstone (Blina-1, 1221.7 m, horizontal field of view 4 cm).