Geochemical Analyses on Prospective Gas Shale Reservoirs at Perth Basin, Western Australia*

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Abstract

The decisive link between organic geochemistry and determining shale gas reservoirs necessitates us to qualify shale layers with respect to their geochemical characteristics as well as accounting for geochemical commonalities. Lucrative gas shales mostly contain up to 3% TOC along with a vitrinite reflectance of more than 1.1%. Having sufficient thickness is another crucial criteria as dialectically these layers may consist of either type II or type III kerogen. Shale thermal maturation can be identified based on measuring T_{max} with consideration of its relation with other geochemical properties such as TOC, remaining gas potential, and Hydrogen Index (HI). The HI value in shale gas systems is considered to be >350 mg HC/g rock. Geochemical parameters of various wells indicates higher TOC value in the Carynginia formation compared to the Kockatea Shale, with more than 3 wt% showing a potentially reasonable shale reservoir. Vitrinite reflectance measurements suggest mainly type II and III kerogen for the studied shale reservoirs. Van Krevelen diagrams confirm kerogen types of II and III for both the Kockatea and Caryngínia formation. The diagram of TOC versus remaining gas potential (mg HC/g rock) implies higher maturation in the Caryngínia formation as opposed to Kockatea, which plotted an oil and gas prone-area with mixed type II/III kerogen. The Caryngínia formation plotted an inside gas prone area with only type III kerogen. Geochemical analysis on likely gas shale systems within Perth Basin (Permo-Triassic intervals) predicts an eligible gas shale potential due to desired organic richness, organic maturity and sufficient thickness in organic rich strata.

Introduction

The Perth Basin, which extends up to 1,000 km in the south-west of Australia (Figure 1) (Wilkes et al., 2011), is considered one of the prospective shale gas reservoirs in Western Australia (WGP, 2010). Two formations of Caryngínia (Permian) and Kockatea (Triassic) are discussed as a major gas shale potential in the basin (EIA, 2011). The first priority in characterising target formations is evaluating the source rocks potential of being a self-contained source reservoir shale system capable of generating gas. Geochemical properties are highly responsible for the most desirable shale layers, with particular emphasis on their organic richness, maturity, and thickness.

Initial geochemical analyses including biomarker dispensation, rock-eval pyrolysis and vitrinite reflectance measurement on the Carynginia and Kockatea formations by Thomas and Barber (2004), showed a range of immature to the late mature intervals (Geological Survey of Western Australia, 2005). However, the focus of these studies was conventional sandstone resources.

The main goal of this study is to, by geochemical analysis, determine the target shales in terms of organic richness, thermal maturity, kerogen type and thickness using rock-eval pyrolysis and vitrinite reflectance measurement.

Methods

Rock-eval pyrolysis and vitrinite reflectance measurement were studied on the 38 wells containing the Kockatea and Carynginia formations by Department of Petroleum and mining (DMP), the results are shown in Table 1, Table 2 and Table 3. Using acquired data such as TOC, S_2, HI and T_{max} helps us in detecting variant organic matter sources through recognising the kerogen type of the organic matter as well as their thermal maturity by measuring vitrinite reflectance.

Results

Plots of TOC versus HI (Van Krevelen diagram) in target shale intervals shows that the Carynginia formation contains more kerogen type III than the Kockatea Shale, with regard to their greater dispersion in gas-prone areas (Figure 2). The diagram of TOC versus remaining hydrocarbon potential (S_2) at Figure 3 confirms a higher maturity at the Carynginia formation. Plotting R_o versus depth classifies hydrocarbons within samples based on their maceral type (Figure 4). Figure 5 also displays maturity of shale intervals in target formations through plotting T_{max} versus depth.

Discussion

The determination of kerogen is a key in recognising types of organic matter, maturity, depositional environment and gas potential in shale layers. According to the plotted points from the Kockatea and Carynginia formations on the Van Krevelen diagrams, the most plotted points of Carynginia Formation are located at gas-prone areas with kerogen type III, while Kockatea points are mostly plotted in the mixed type II/III kerogen oil and gas generation areas. The graph shows a HI value of Kockatea Shale in the range of 0-680 mg HC/g rock and between 0-350 mg HC/g rock for Carynginia Formation, which displays higher maturity and gas susceptibility. The existence of mostly kerogen type II at Kockatea Shale in the TOC diagram versus remaining gas potential is an indicator of depositing under marine conditions. This is in comparison to the Carynginia Formation that was likely constituted within terrestrial conditions. The remaining potential and T_{max} values at Table 2 illustrates the highest T_{max} within Kockatea Shale at wells of Jurien #1 and Woolmulla #1, whereas Wattle Grove #1 with the highest remaining potential value of 9.84 shows the lowest T_{max}. In Carynginia Formation, the highest amounts of T_{max} are related to the wells of Jurien #1, Geelvink 1A and Woodada #6. Available R_o data for Kockatea and Carynginia formation confirms mainly kerogen types of II and III for our target shale reservoirs. It should be noted that there is a possibility of higher indication of thermal maturity than measured by R_o due to the suppression of vitrinite reflectance (Comer et al.,1994) Containing little vitrinite applied for assessing maturity can be pointed out as another disadvantage of this method.

Conclusion

Geochemical analyses plays an essential role in determining critical parameters of appropriate shale gas reservoirs by identifying organic richness and thermal maturity as well as thickness of organic matter. Acquired kerogen types for Kockatea Shale were a mixture of type II/III that mostly relates to both oil and gas-generating organic matter while the Carynginia Formation mainly contains kerogen type III located in a gas-generating area. The different placements of points within our target formations can be explained by greater depositing of the Kockatea Shale under marine conditions than the Carynginia Formation. Crucial geochemical data such as TOC, remaining gas potential (S_2), HI, T_{max} and R_o within studied formations predict a desirable organic richness and maturity along with high gas potential at their shale layers.

Selected References

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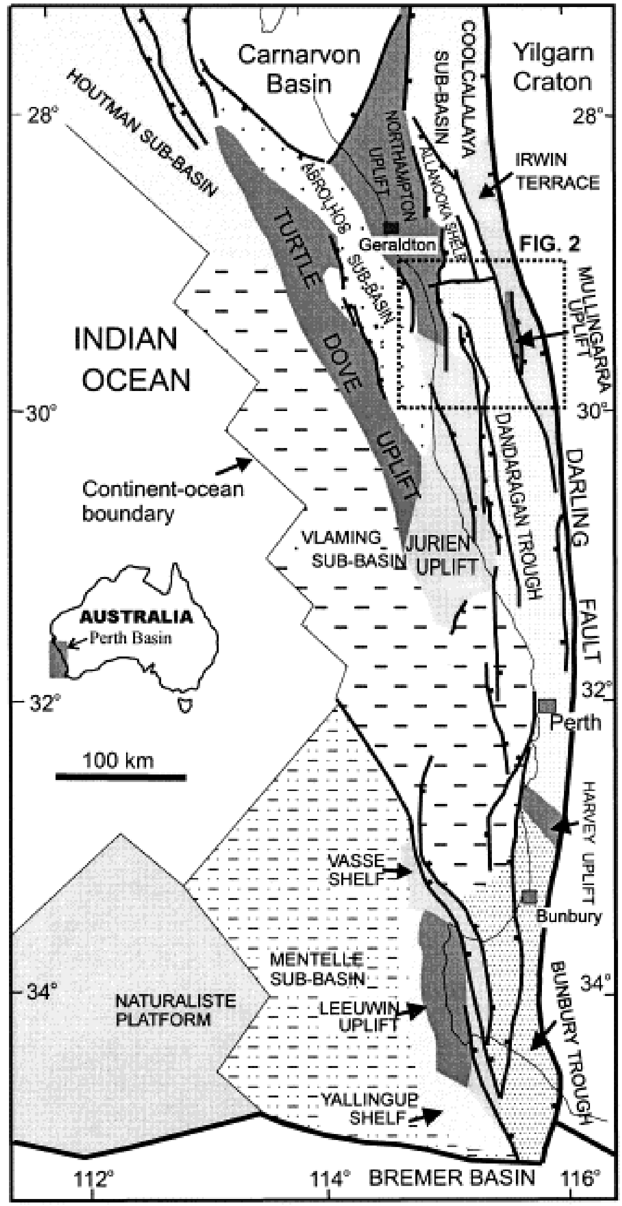

Figure 1. The location of Perth Basin in southwest of Australia, The divided sub-basins are shown in the figure.

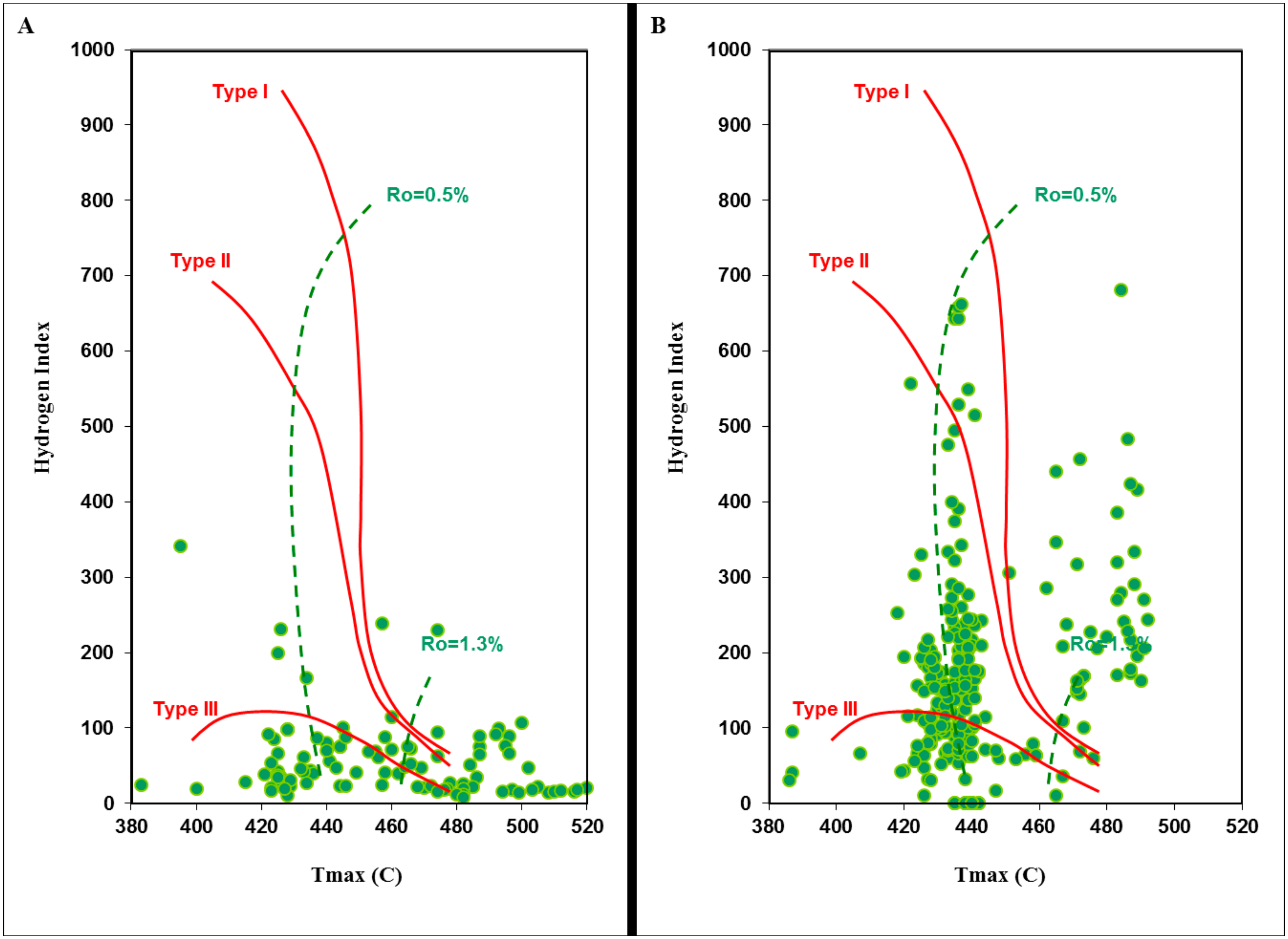

Figure 2. Van Krevelen diagrams of Carynginia Formation (A) and Kockatea Shale (B).

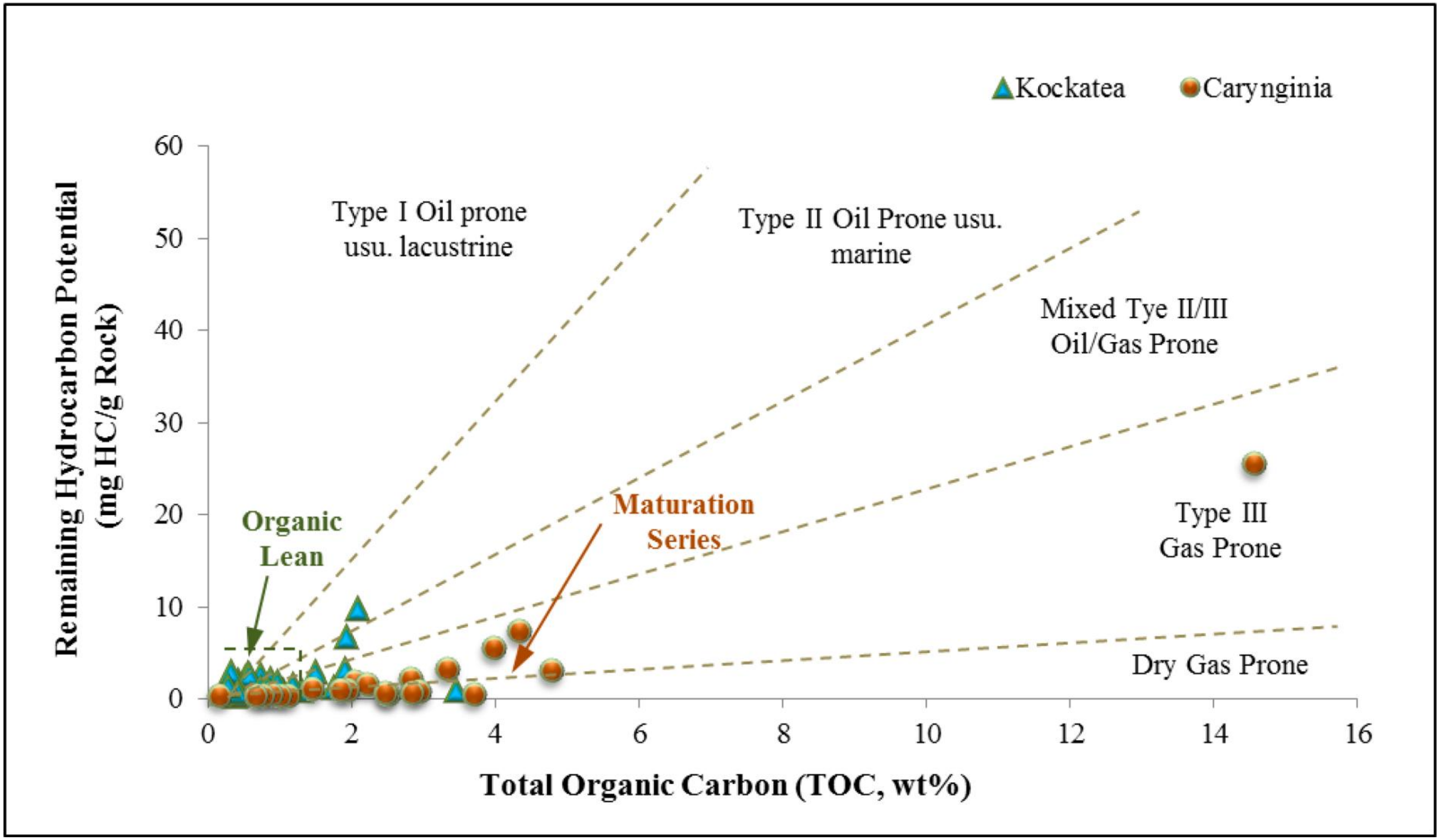

Figure 3. TOC versus remaining hydrocarbon potential, displaying different types of kerogen as a function of thermal maturity.

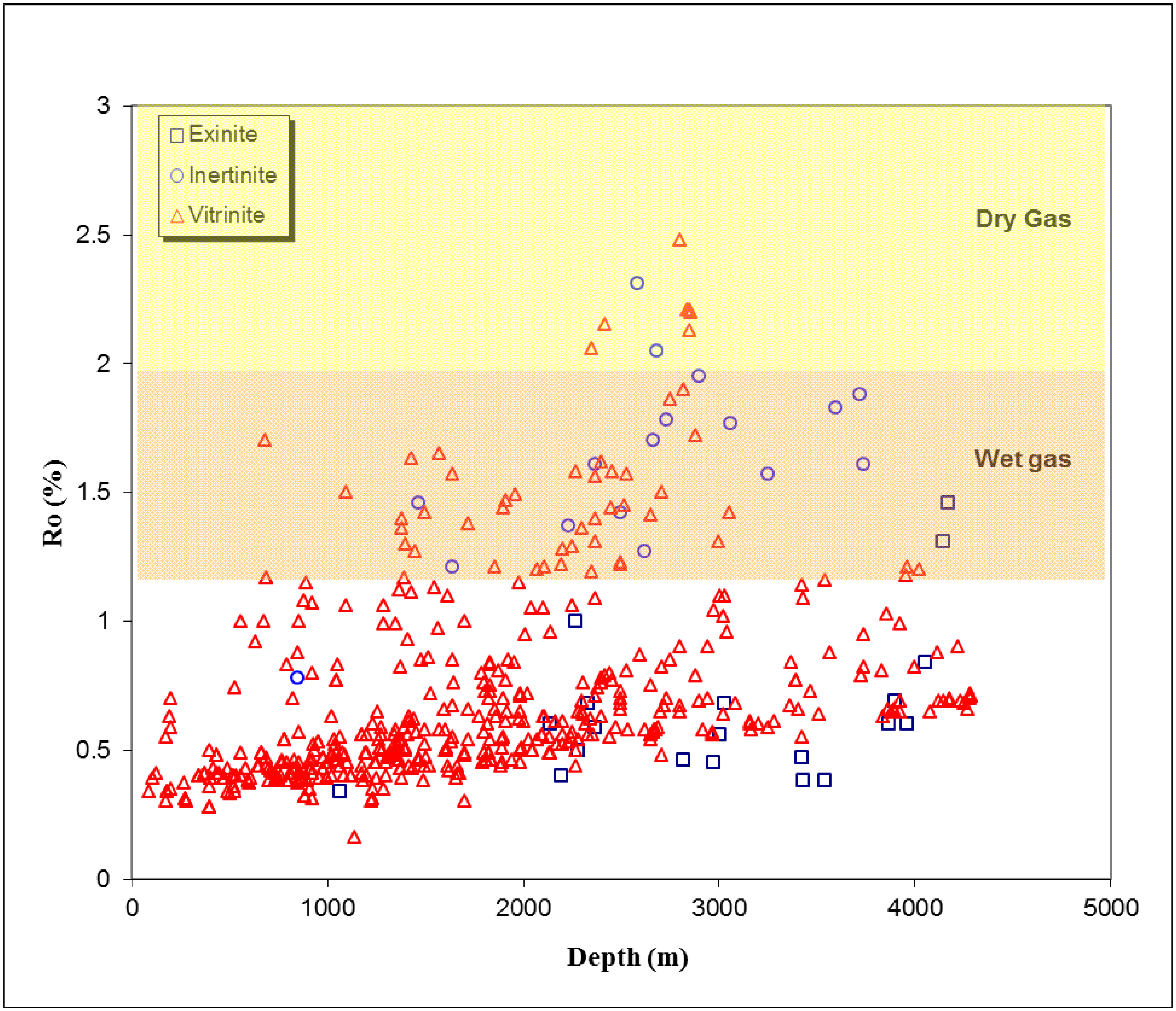

Figure 4. R_o versus depth, Perth Basin.

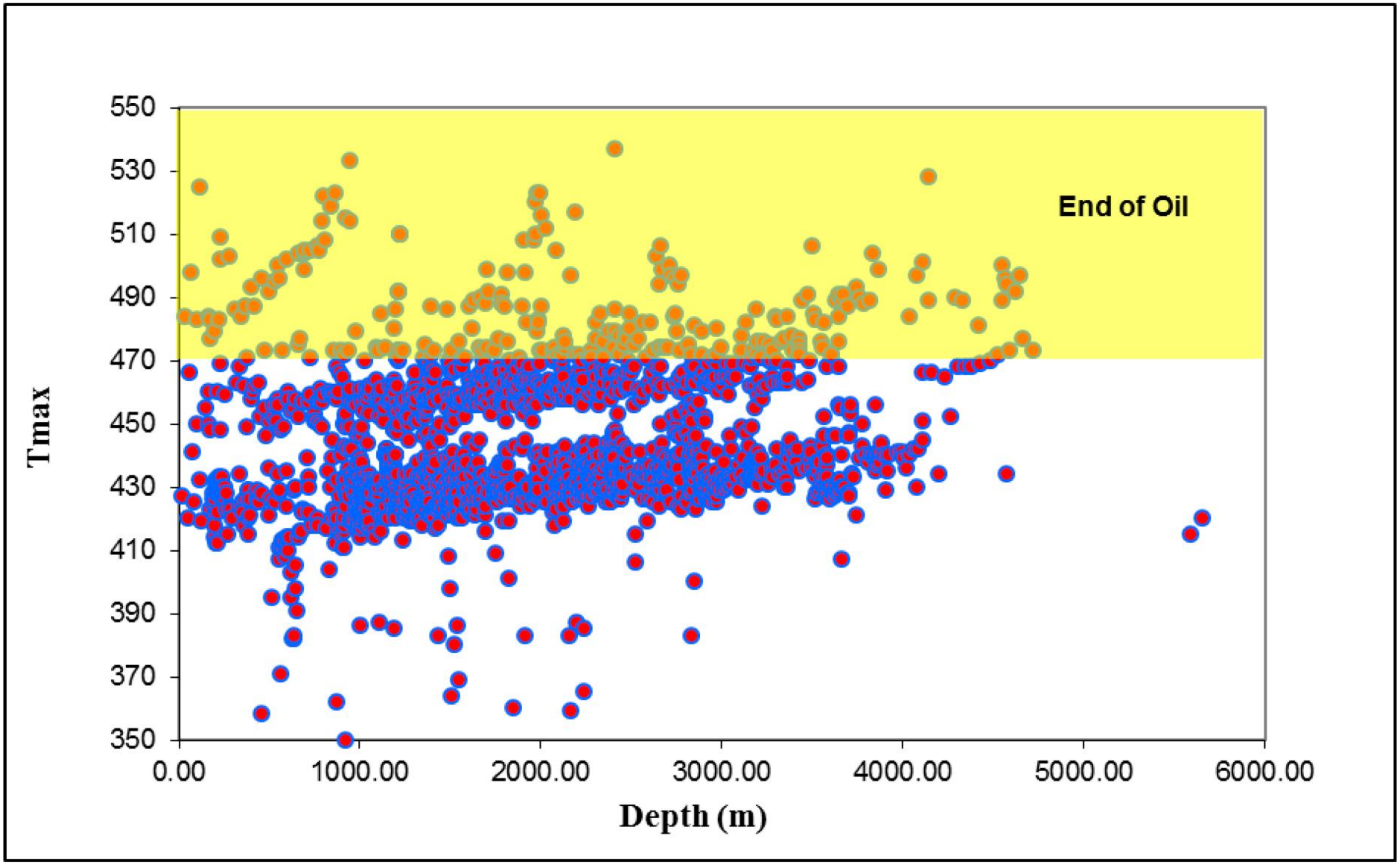

Figure 5. T_{max} versus depth for shale samples of Kockatea and Carynginia in the Perth Basin.

Well name	Formation	TOC-mean	Well Name	Formation	TOC-mean
Jurien#1	Kockatea	0.51	Jurien#1	Carynginia	2.80
Woolmulla#1	Kockatea	0.41	Woolmulla#1	Carynginia	1.11
Yardarino#1	Kockatea	3.46	Yardarino#1	Carynginia	0.99
Mungarra#5	Kockatea	1.34	Mungarra#5	Carynginia	1.32
Mt Horner#1	Kockatea	1.50	Mt Horner#1	Carynginia	14.55
Eurangoa#1	Kockatea	1.05	Eurangoa#1	Carynginia	4.31
Mt Adams#1	Kockatea	1.90	Mt Adams#1	Carynginia	0.87
Beharra#2	Kockatea	0.36	Beharra#2	Carynginia	0.75
Mondarra#1	Kockatea	0.38	Mondarra#1	Carynginia	0.15
Narlingue#1	Kockatea	0.21	Narlingue#1	Carynginia	4.76
Heaton#1	Kockatea	1.92	Heaton#1	Carynginia	1.43
South-Turtle Dove 1B	Kockatea	0.55	South-Turtle Dove 1B	Carynginia	2.93
Geelvink 1A	Kockatea	0.41	Geelvink 1A	Carynginia	2.02
Batavia#1	Kockatea	0.51	Batavia#1	Carynginia	3.97
Woodada#5	Kockatea	0.53	Woodada#5	Carynginia	2.50
Woodada#6	Kockatea	1.30	Woodada#6	Carynginia	3.69
Robb#1	Kockatea	0.53	Robb#1	Carynginia	2.20
Peron#1	Kockatea	0.61	Peron#1	Carynginia	2.82
Depot hill#1	Kockatea	0.60	Depot Hill#1	Carynginia	1.93
Diamond Soak#1	Kockatea	0.38	Diamond Soak#1	Carynginia	2.45
Leander Reef#1	Kockatea	0.73	Leander Reef#1	Carynginia	1.82
Wittecarra#1	Kockatea	0.33	Wittecarra#1	Carynginia	0.65
Central Yardarino#1	Kockatea	0.57	Central Yardarino#1	Carynginia	3.32
Eneabba#1	Kockatea	0.74	Abbarwardoo#1	Carynginia	0.95
Mt Hill#1	Kockatea	1.75	Woodada#2	Carynginia	1.65
Arrowsmith#1	Kockatea	0.60	Conder#1	Kockatea	0.96
Cadda#1	Kockatea	0.54	Connelly#1	Kockatea	0.42
Erregulla#1	Kockatea	0.47	Eleven mile#1	Kockatea	0.84
North Erregulla#1	Kockatea	0.86	Rakrani#1	Kockatea	0.28
Strawberry Hill#1	Kockatea	1.19	Livet#1	Kockatea	0.28
Wattle grove#1	Kockatea	2.09			

Table 1. TOC values of Kockatea and Carynginia formations in the Perth Basin.

Well name	Formation	Remaining Potential	Tmax	Well Name	Formation	Remaining potential	Tmax
Jurien#1	Kockatea	2.32	483.4	Jurien#1	Carynginia	2.15	492.08
Woolmulla#1	Kockatea	0.78	488.0	Yardarino#1	Carynginia	0.31	425.00
Yardarino#1	Kockatea	0.87	443.4	Mt Horner#1	Carynginia	25.5	474.00
Mt Hill#1	Kockatea	1.12	454.0	Eurangoa#1	Carynginia	7.30	456.80
Mt Horner#1	Kockatea	2.94	462.2	Beharra#2	Carynginia	0.30	426.00
Arrowsmith#1	Kockatea	0.43	428.7	Mondarra#1	Carynginia	0.36	432.00
Eurangoa#1	Kockatea	0.90	461.7	Narlingue#1	Carynginia	3.13	465.00
Mt Adams#1	Kockatea	3.15	449.9	Heaton#1	Carynginia	1.13	465.50
Erregulla#1	Kockatea	0.41	437.8	South Turtle Dove 1B	Carynginia	0.71	428.00
Beharra#2	Kockatea	0.34	424.4	Geelvink 1A	Carynginia	1.90	474.00
North Erregulla#1	Kockatea	2.16	436.1	Batavia#1	Carynginia	5.48	454.66
Mondarra#1	Kockatea	0.27	433.7	Woodada#5	Carynginia	0.52	462.00
Strawberry Hill#1	Kockatea	1.56	434.7	Woodada#6	Carynginia	0.49	478.80
Narlingue#1	Kockatea	0.60	462.0	Robb#1	Carynginia	1.53	440.00
Heaton#1	Kockatea	6.66	435.2	Peron#1	Carynginia	0.55	469.60
South-Turtle Dove 1B	Kockatea	2.76	439.6	Depot Hill#1	Carynginia	0.86	426.14
Geelvink 1A	Kockatea	2.01	452.7	Diamond Soak#1	Carynginia	0.57	426.75
Batavia#1	Kockatea	1.32	439.2	Leander Reef#1	Carynginia	0.88	446.94
Woodada#5	Kockatea	0.79	439.5	Wittecarra#1	Carynginia	0.28	421.50
Woodada#6	Kockatea	0.92	435.1	Central Yardarino#1	Carynginia	3.26	442.20
Robb#1	Kockatea	1.00	438.6	Wittecarra#1	Kockatea	2.89	439.33
Peron#1	Kockatea	0.64	443.4	Conder#1	Kockatea	1.78	422.42
Depot hill#1	Kockatea	0.66	422.0	Conelly#1	Kockatea	0.72	428.00
Diamond Soak#1	Kockatea	0.59	424.7	Eleven mile#1	Kockatea	1.16	429.75
Leander Reef#1	Kockatea	2.60	433.8	Central Yardarino#1	Kockatea	2.62	437.00
Wattle grove#1	Kockatea	9.84	425.0	Eneabba#1	Kockatea	1.21	395.65

Table 2. Remaining potential and T_{max} values of target formations in the Perth Basin.

Well name	Formation	Ro-Mean	Well Name	Formation	Ro-Mean
Eneabba#1	Kockatea	0.88	Yardarino#1	Carynginia	0.59
Yardarino#1	Kockatea	1.37	Diamond soak#1	Carynginia	0.56
Erregulla#1	Kockatea	0.64	Robb#1	Carynginia	1.65
Beharra#2	Kockatea	0.50	Peron#1	Carynginia	1.49
Mondarra#1	Kockatea	1.07	Depot Hill#1	Carynginia	0.57
Strawberry Hill#1	Kockatea	1.93	Wattle grove#1	Carynginia	0.64
Diamond soak#1	Kockatea	0.48	Wittecarra#1	Carynginia	1.91
Geelvink 1A	Kockatea	0.67	Central Yardarino#1	Carynginia	0.77
Robb#1	Kockatea	0.86	Geelvink 1A	Carynginia	1.31
Peron#1	Kockatea	0.85	Wattle grove#1	Kockatea	0.85
Depot Hill#1	Kockatea	052	Wittecarra#1	Kockatea	1.54
Central Yardarino#1	Kockatea	0.71	Condor#1	Kockatea	0.62

Table 3. Thermal maturity values of Kockatea and Carynginia formations.