BMR Urapunga 4 Interpretive Summary

Upper Velkerri – Corcoran Interval

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PETROLEUM GEOCHEMISTRY

INTRODUCTORY NOTE

A geochemical investigation has been conducted to assess hydrocarbon prospectivity of the Upper, Middle and Lower Velkerri, and Corcoran Formations in the BMR Urapunga 4 well located in the McArthur Basin, Northern Territories, Australia. Thirty (30) core chip samples from this well were analyzed by a variety of geochemical techniques, including total organic carbon (TOC, LECO®) and programmed pyrolysis (SRA). In addition, client supplied published geochemical data for 111 samples were also incorporated into the interpretive evaluation. The complete results of these analyses are documented in this report along with an integrated geochemical interpretation that is summarized in the following table.

Well Name	Formation		Main Product	Thermal Maturity	Source Rock Richness	Organic Matter Type	Shale Oil Risk
BMR Urapunga 4	Upper Velkerri	***Estimated Original*** ⟶			*Good (1.33% TOC)*	*Oil-prone Type II*	**Moderate**
		Measured Currently ⟶	Oil	Peak Oil Window	Good (1.00% TOC)	Gas-prone Type III	
BMR Urapunga 4	Middle Velkerri	***Estimated Original*** ⟶			*Excellent (4.39% TOC)*	*Oil-prone Type II*	**Low**
		Measured Currently ⟶	Oil	Peak Oil Window	Very Good (3.07% TOC)	Oil-prone Type II	
BMR Urapunga 4	Lower Velkerri	***Estimated Original*** ⟶			*Fair (0.55% TOC)*	*Oil-prone Type II*	**High**
		Measured Currently ⟶	Minor Oil	Late Oil Window	Poor (0.32% TOC)	Gas-prone Type III	
BMR Urapunga 4	Corcoran	***Estimated Original*** ⟶			*Fair (0.61% TOC)*	*Oil-prone Type II*	**High**
		Measured Currently ⟶	Minor Oil	Late Oil Window	Poor (0.23% TOC)	Inert Type IV	

Current TOC averages represent all data available; Original TOC averages are only high graded samples that have PPy data

Table 1. Geochemical Summary

UPPER VELKERRI FORMATION

Fifteen samples (15) from the Upper Velkerri Formation were analyzed for LECO TOC content and programmed pyrolysis, with the remaining data set (10 samples) composed of client supplied public data (Fig. 1). TOC contents ranged from 0.21 to 6.58 wt.% and averaged 1.00 wt.% (good). Six (6) of these samples have TOC contents above the minimum requirement of 1 wt.% for *effective* petroleum source rocks, while two (2) samples have TOC content above the minimum requirement of 2 wt.% for *economic* petroleum source rocks. Highest TOC content is near the base of the designated Upper Velkerri interval (130.02 m depth) and increases dramatically at the contact with the underlying Middle Velkerri Formation (Fig. 1).

The S1 values of the Upper Velkerri source rock samples average 0.50 mg HC/g rock (11 bbl oil/acre-ft) and S2 values average 3.09 mg HC/g rock (68 bbl oil/acre-ft). The S1 and S2 values imply fair in-situ hydrocarbon saturation and fair remaining generative potential (Fig. 1). The normalized oil content (NOC) in the Upper Velkerri samples, (S1/TOC) x 100, averages 44 (Fig. 1). NOC values of 20 to 50 are

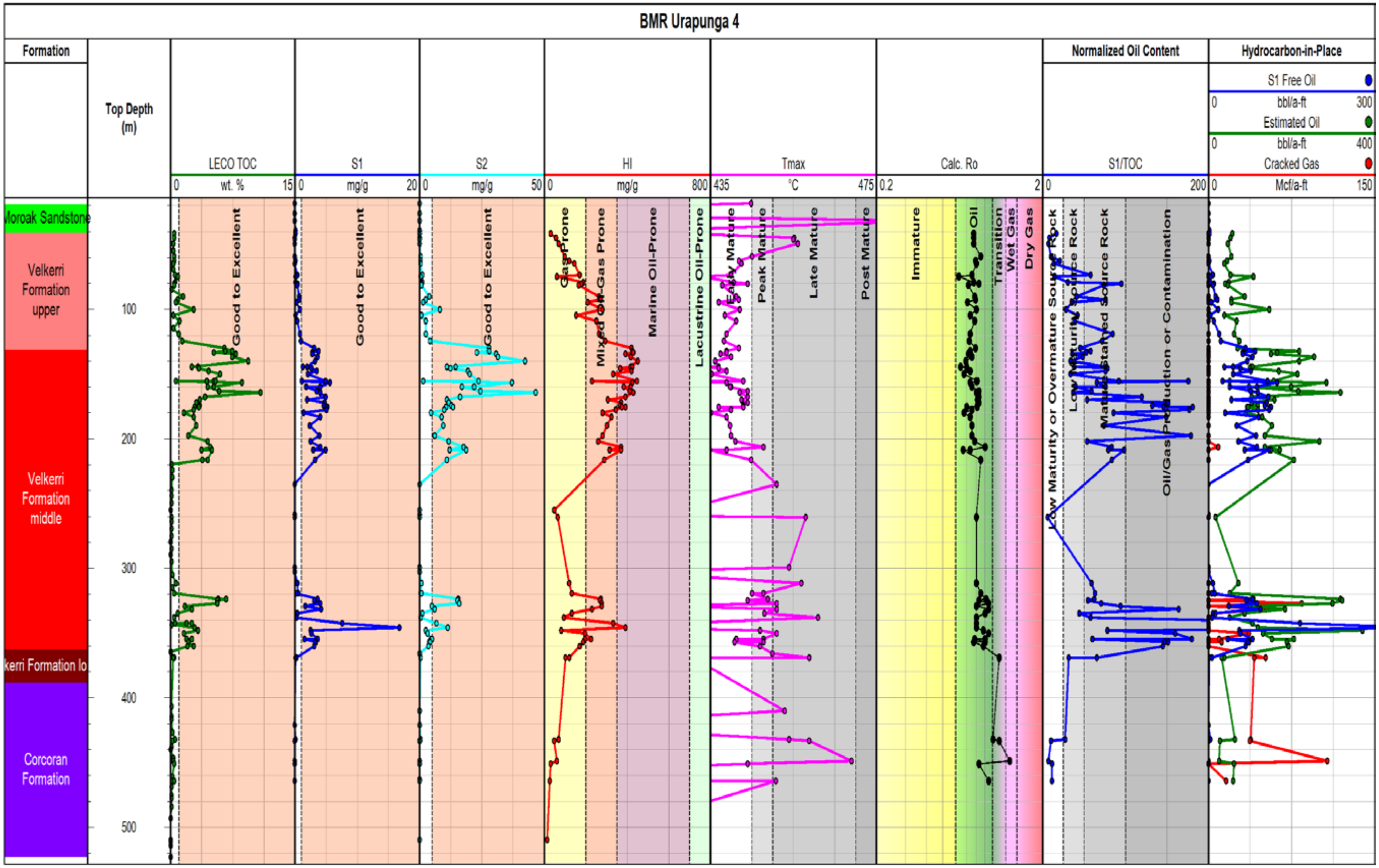

Figure 1. Geochemical depth plots for the BMR Urapunga 4 well.

typical of low maturity source rocks, whereas values of 50 to 100 indicate possible oil staining or shows in thermally mature, tight petroleum source rocks. NOC > 100 are often associated with conventional oil reservoirs and indicate good prospectivity in unconventional shale oil plays. Jarvie (2012) has utilized a depth comparison of TOC versus programmed pyrolysis S1 yields as a potential indicator of producible hydrocarbon saturation in unconventional source rocks. When the S1 yields (reported as mg HC/g rock) exceed or "cross-over" the measured TOC content (reported as wt.%), this would be interpreted to represent zones with good potential for containing producible hydrocarbon saturation (or zones of possible contamination). In the present study, there are no samples within the Upper Velkerri Formation where S1 crosses over TOC (Fig. 1).

Measured Hydrogen Index (HI) values in the Upper Velkerri average 187 mg HC/g TOC, indicating gas-prone Type III kerogen quality in these source rocks at present day. Original HI_o of these samples are estimated to average 450 mg HC/g rock, which indicate oil-prone Type II kerogen. Transformation Ratios (TR) based upon HI average 68%, which is consistent with a peak oil window thermal maturity. T_{max} values in the Upper Velkerri samples average 440°C. T_{max} between 435 and 445°C typically indicate peak oil window, while values between 445 and 450°C indicate late oil window (Type II kerogen). On the basis of these guidelines, the average Upper Velkerri T_{max} values in this well would be interpreted to be in the peak oil window. Using the formula published by Jarvie et al. (2007) for Type II kerogen (Calculated R_o = (0.0180)(T_{max}) – 7.16), the average measured T_{max} value of 440°C is equivalent to a Calc. %R_o value of 0.77%. It is important to note that T_{max} is only a crude measure of thermal maturation (Peters, 1986) and it can be compromised by a variety of pyrolysis artifacts and caveats.

Production Index (PI) values in these Upper Velkerri samples average 0.18. These elevated PI values are consistent with source rocks in the peak oil window, which typically have PI values between ~0.15 to 0.25.

The thermal maturity of the Upper Velkerri was also evaluated by measured Kübler Index values from XRD, which are based upon illite crystallinity. These values can be used as maturity indicator when samples contain sufficient high quality clays (Abad, 2008). A single sample (42 m) from the Upper Velkerri interval (avg. 56% clays) has a measured Kübler Index of 0.149, which is equivalent to a measured vitrinite reflectance of > 4% (late stage metagenesis). This interpretation is inconsistent with other geochemical maturity ratios evaluated in this study and suggests the Kübler Index should be used with caution to evaluate thermal maturity in Mesoproterozoic aged source rocks.

MIDDLE VELKERRI FORMATION

Fourteen samples (14) from the Middle Velkerri Formation were analyzed for LECO TOC content and programmed pyrolysis, with the remaining data set (68 samples) composed of client supplied public data (Fig. 1). The Middle Velkerri Formation in the BMR Urapunga 4 well exhibits very good generative potential for petroleum source rocks based on TOC content values (Fig. 1). TOC content ranges from 0.08 to 10.90 wt.% and averages 3.07 wt.% (very good). Fifty (50) of these samples analyzed exceed the minimum value of 2.0 wt.% for *economic* petroleum source rocks (Lewan, 1987). There are three distinct cycles of TOC within this interval with maxima occurring at depths of 165, 210 and 325 m (Fig. 1). These three organic rich intervals have been previously recognized within the Middle Velkerri (Lanigan et al, 1994) and could be associated with the base of transgressive systems tracts (TST) in a series of platform/ramp parasequences (Bohacs et al., 2013). These stepwise changes in TOC and corresponding minimal change in Hydrogen Index values (HI) suggests that production was the major control on organic richness along with auto-dilution by pelagic carbonate (Bohacs et al., 2013).

The S1 values in the Middle Velkerri average 3.42 mg HC/g rock (75 bbl oil/acre-ft), indicating very good in-situ hydrocarbon saturation (Fig. 1) and are consistent with a thermal maturity in the peak oil window. These values should be considered a minimum for in-situ oil saturation since they do not account for potential loss of volatile components during sample collection and analysis. NOC values in the Middle Velkerri interval are higher in comparison to the overlying strata and average 89. Oil cross over (NOC > 100) was observed for many samples in the upper and basal sections of this unit, but not within the middle interval where TOC values are relatively low (Fig. 1). This suggests possible producible hydrocarbons are present in the upper and lower portions of this source interval. The S2 values in this interval average 13.50 mg HC/g rock (296 bbl oil/acre-ft), which indicates very good remaining generative potential and this observation is generally more consistent with an early oil window thermal maturity.

Measured HI values in these samples average 309 mg HC/g TOC, which indicate oil-prone Type II kerogen quality in these source rocks at present day. Estimated original HI_o values in these samples average 467 mg HC/g TOC, which indicate oil-prone Type I/II kerogen quality. Transformation Ratios (TR) based upon HI average only 48%, which is more consistent with an early oil window thermal maturity.

The organic-matter in the Middle Velkerri interval in the BMR Urapunga 4 well is thermally mature and is interpreted to be in the peak oil window. Programmed pyrolysis T_{max} values average 442°C (Fig. 1). Using the formula published by Jarvie et al. (2007) for Type II kerogen (Calculated $R_o = (0.0180)(T_{max}) – 7.16$), the average measured T_{max} value of 442°C is equivalent to a Calc. %R_o value of 0.80%. It is important to note that T_{max} is only a crude measure of thermal maturation (Peters, 1986) and it can be compromised by a variety of pyrolysis artifacts and caveats.

Production Index (PI) values in these Middle Velkerri samples average 0.25. These elevated PI values are consistent with source rocks in the peak oil window. The PI values tend to increase toward the base of the Middle Velkerri interval and are generally elevated in the same zone where NOC values are also highest. This suggests possible producible in-situ oil saturation within this horizon.

LOWER VELKERRI FORMATION

Two (2) samples from the Lower Velkerri Formation were analyzed for LECO TOC content and programmed pyrolysis, with the remaining data set (2 samples) composed of client supplied public data (Fig. 1). TOC contents ranged from 0.12 to 0.47 wt.% and averaged 0.32 wt.% (poor). None of these samples have TOC contents above the minimum requirement of 1 wt.% for *effective* petroleum source rocks. The measured TOC data is too sparse to properly evaluate depth trends within the Lower Velkerri interval (Fig. 1).

The S1 values in the Lower Velkerri source rock samples average only 0.22 mg HC/g rock (5 bbl oil/acre-ft) and S2 values are also very low with an average 0.48 mg HC/g rock (11 bbl oil/acre-ft). The S1 and S2 values imply generally poor in-situ hydrocarbon saturation and generative potential (Fig. 1). The normalized oil content (NOC) in the Lower Velkerri samples average 51 (Fig. 1) and there is no oil "cross-over" observed in any of these samples.

Measured Hydrogen Index (HI) values in the Lower Velkerri average 113 mg HC/g TOC, indicating gas-prone Type III kerogen quality in these source rocks at present day (Fig. 1). Original HI_o of these samples are estimated to average 450 mg HC/g rock, which indicate oil-prone Type II kerogen. Transformation Ratios (TR) based upon HI average 83%, which is consistent with a wet gas/condensate window thermal maturity.

The organic-matter in the Lower Velkerri interval in the BMR Urapunga 4 well is thermally mature and is interpreted to be in the late oil window. T_{max} values in the Lower Velkerri samples are generally considered to be unreliable for maturity assessment due to low S2 yields. Using select data deemed valid gives an average 459°C. T_{max} between 450 and 470°C typically indicate condensate/wet gas window, while values > 470°C are considered post-mature dry gas window (Type II kerogen). On the basis of these guidelines, the average Lower Velkerri T_{max} values in this well would be interpreted to be in the early condensate/wet gas window. Using the formula published by Jarvie et al. (2007) for Type II kerogen (Calculated $R_o = (0.0180)(T_{max}) – 7.16$), the average measured T_{max} value of 458°C is equivalent to a Calc. %R_o value of 1.10%. It is important to note that T_{max} is only a crude measure of thermal maturation (Peters, 1986) and it can be compromised by a variety of pyrolysis artifacts and caveats.

Production Index (PI) values in the Lower Velkerri samples average 0.29. These elevated PI values are consistent with source rocks in the late oil window, which typically have PI values between ~0.25 and 0.35.

CORCORAN FORMATION

Four (4) samples sample from the Corcoran Formation were analyzed for LECO TOC content and programmed pyrolysis, with the remaining data set (21 samples) composed of client supplied public data (Fig. 1). TOC contents ranged from 0.07 to 0.62 wt.% and averaged 0.23 wt.% (poor). None of these samples exceeds the minimum requirement of 1 wt.% for *effective* petroleum source rocks. Highest TOC was found in the middle of the sampled interval at a depth of 432.7m (Fig. 1).

The S1 values in the Corcoran source rock samples average only 0.07 mg HC/g rock (2 bbl oil/acre-ft) and S2 values are very low with an average 0.23 mg HC/g rock (5 bbl oil/acre-ft). The S1 and S2 values imply poor in-situ hydrocarbon saturation and poor remaining generative potential (Fig. 1). The normalized oil content (NOC) in the Corcoran samples average 15 (Fig. 1) and there no samples exhibiting oil “cross-over”.

Measured Hydrogen Index (HI) values in the Corcoran Formation average only 49 mg HC/g TOC, indicating inert Type IV kerogen quality in these source rocks at present day (Fig. 1). Original HI_o of these samples are estimated to average 450 mg HC/g rock, which indicate oil-prone Type II kerogen. Transformation Ratios (TR) based upon HI average 93%, which is consistent with dry gas window thermal maturity.

The organic-matter in the Corcoran interval in the BMR Urapunga 4 well is thermally mature and is interpreted to be in the late oil window. Programmed pyrolysis T_{max} values average 455°C (Fig. 1). Using the formula published by Jarvie et al. (2007) for Type II kerogen (Calculated $R_o = (0.0180)(T_{max}) - 7.16$), the average measured T_{max} value of 455°C is equivalent to a Calc. $\%R_o$ value of 1.04%. It is important to note that T_{max} is only a crude measure of thermal maturation (Peters, 1986) and it can be compromised by a variety of pyrolysis artifacts and caveats.

Production Index (PI) values in the Corcoran samples average 0.22. These elevated PI values are more consistent with source rocks in the peak oil window, which typically have PI values between ~0.15 and 0.25.

ORIGINAL GENERATIVE POTENTIAL AND HYDROCARBON YIELD CALCULATIONS

Petroleum generative capacity depends on the original quantity of organic matter (TOC_o) and the original type of organic matter (HI_o) (Peters et al., 2005, p. 97). The petroleum generation process has likely decreased the remaining generative potential as measured by TOC_{pd} and HI_{pd} in the Velkerri and Corcoran source rocks examined in this study. We can estimate the extent of the petroleum generation process, the volume of expelled oil and the expulsion efficiency by making some reasonable assumptions based on the core geochemical data and published regional information (Jarvie et al., 2007; Peters et al., 2005).

HI_o values can be computed from visual kerogen assessments and assigned kerogen-type HI_o average values using the following equation (Jarvie et al., 2007):

$$HI_o = \left(\frac{\%\text{Type I}}{100} \times 750\right) + \left(\frac{\%\text{Type II}}{100} \times 450\right) + \left(\frac{\%\text{ Type III}}{100} \times 125\right) + \left(\frac{\%\text{Type IV}}{100} \times 50\right) \quad (1)$$

This equation requires the input of maceral percentages from visual kerogen assessment of a source rock. For the present study, only limited kerogen data were available. Where available, these kerogen data sets were used. In the absence of other measured kerogen data original kerogen type were interpreted in the context of measured present day TOC, HI and OI values to arrive at an appropriate kerogen mix for each sample examined in this investigation. All samples were modeled using appropriate kerogen mix to maintain an appropriate transformation ratio consistent with the interpreted thermal maturity. The average maceral percentage in the various formations evaluated in the current study are shown in Table 2, along with the resultant average original HI_o values calculated using equation (1) above. The kerogen estimations used in this study are generally in agreement with other published values that suggest Type II to a mixed Type I/II kerogen assemblage (Law et al., 2010; Crick et al., 1988; Taylor et al., 1994).

Formation	%Type I 750 HI_o	%Type II 450 HI_o	%Type III 125 HI_o	%Type IV 50 HI_o	HI_o
Upper Velkerri	0	100	0	0	450
Middle Velkerri	6	94	0	0	467
Lower Velkerri	0	100	0	0	450
Corcoran	0	100	0	0	450

Table 2. Average Kerogen Estimations for BMR Urapunga 4 well.

The extent of the petroleum-generation process, or transformation ratio (TR) which is also called fractional conversion, is calculated as follows (Jarvie et al., 2007, p. 497):

$$TR_{HI} = 1 - \frac{HI_{pd}\left[1200 - HI_o\left(1 - PI_o\right)\right]}{HI_o\left[1200 - HI_{pd}\left(1 - PI_{pd}\right)\right]} \quad (2)$$

HI_{pd} and PI_{pd} are the measured HI and PI values for the various source rock samples in this well. The average HI_{pd} and PI_{pd} for the formations evaluated in the current study are shown in Table 3. HI_o and PI_o are the original HI and PI values for immature organic matter in the rocks. For this calculation using the assumptions described previously results in average HI_o values of between 450 to 467 mg HC/g TOC (Table 2). We assume a PI_o of 0.02 (see Peters et al., 2005). Using these values in equation 2, the extent of fractional conversion of HI_o to petroleum is 0.48 to 0.93 (Table 3), i.e., on average an estimated 48 to 93% of the petroleum generation process has been completed.

The original TOC_o in the source rocks before burial and thermal maturation is constrained by mass balance considerations as follows (corrected from Jarvie et al., 2007):

$$TOC_o = \frac{HI_{pd}\left(\frac{TOC_{pd}}{1+k}\right)(83.33)}{\left[HI_o\left(1 - TR_{HI}\right)\left(83.33 - \left(\frac{TOC_{pd}}{1+k}\right)\right)\right] + \left[HI_{pd}\left(\frac{TOC_{pd}}{1+k}\right)\right]} \quad (3)$$

In this equation k is a correction factor based on residual organic carbon being enriched in carbon over original values at high maturity (Jarvie et al., 2007, p. 497). For Type II kerogen the increase in residual carbon C_R at high maturity is assigned a value of 15% (whereas for Type I, it is 50%, and for Type III, it is 0%) and the correction factor k is then $TR_{HI} \times C_R$. The kerogen mix for each individual sample was used in this calculation.

Using equation 3, the average estimated original TOC_o for the source rock samples in this well before petroleum generation varies from 0.55 to 4.39 wt.% (Table 3).

The original generation potential $S2_o$ can be calculated using the following equation:

$$S2_o = \left(\frac{HI_o \times TOC_o}{100}\right) \quad (4)$$

For the source rocks examined in the BMR Urapunga 4 well, the average $S2_o$ values vary from 2.5 to 21.0 mg HC/g rock or approximately 54 to 459 bbl/acre-ft (multiply $S2_o$ by 21.89 to calculate barrels/acre-ft, Jarvie and Tobey, 1999) (Table 3).

Knowing the measured remaining generation potential S2 from programmed pyrolysis and using the calculated original generation potential $S2_o$ enables a determination of the amounts of hydrocarbons generated. A VR_o algorithm can then be applied to estimate fractional oil cracking thereby converting yields to estimated oil and cracked gas (reported as Mcf/acre-ft or thousand cubic feet/acre-ft).

$$\text{Original } (S2_o) - \text{Remaining } (S2) = \text{Generated HCs} \quad (5)$$

Using this methodology for the Upper Velkerri samples analyzed in the current study, the generated oil yields average 66 bbl/acre-ft. For the Middle Velkerri samples analyzed in the current study, the generated oil yields average 162 bbl/acre-ft along with 5 Mcf/acre-ft of secondary cracked gas. The generated oil yields from the underlying Lower Velkerri were much lower with 36 bbl/acre-ft and 47 Mcf/acre-ft of secondary cracked gas. The Corcoran Formation generated 49 bbl/acre-ft of oil and an estimated 40 Mcf/acre-ft of cracked gas (Table 3).

Formation	TOC_{pd}	HI_{pd}	$S2_{pd}$ bbl/a-ft	HI_o	TR	TOC_o	$S2_o$ bbl/a-ft	S1 Free Oil bbl/a-ft	Est. Oil bbl/a-ft	Cracked Gas Mcf/a-ft
Upper Velkerri	1.13	187	68	450	0.68	1.33	131	11	63	0
Middle Velkerri	3.83	309	296	467	0.48	4.39	459	75	162	5
Lower Velkerri	0.42	113	11	450	0.83	0.55	54	5	36	47
Corcoran	0.46	49	5	450	0.93	0.61	61	2	49	40

Table 3. Hydrocarbon Yields average data for BMR Urapunga 4 well.

The amount of hydrocarbons (oil + gas) expelled from the rocks can be estimated as the difference between the amount of residual oil measured via programmed pyrolysis (S1) and the amount of estimated generated hydrocarbon yields determined above (equation 5). The expulsion efficiency (ExEf) can then be calculated as a direct proportion of the measured retained oil saturations and the average generated hydrocarbon yields. Thus, the resulting expulsion efficiency for the Velkerri intervals varies from 83% in the Upper unit, 54% in the Middle and 89% in the Lower interval, while the Corcoran is estimated to have 97% expulsion. This is likely to be a consequence of increased thermal maturity resulting in more volatile in-situ oil compositions and higher gas/oil ratios in the Lower Velkerri and Corcoran intervals, both of which would tend to enhance expulsion in the deeper source rock intervals.

The Upper and Middle Velkerri source rock intervals in the BMR Urapunga 4 well are interpreted to be in peak oil window, while the Lower Velkerri and Corcoran intervals are in the late oil window. Hydrocarbon yield calculations suggest minor to significant amounts of generation have occurred (predominantly oil with minor associated and secondary cracked gas). From an exploration risk perspective, this is generally favorable. However, it is useful to relate these hydrocarbon yields to other productive unconventional US Shale plays (Table 5). In doing so, the potential critical value is not necessarily the generated oil and gas yields, but also the original ($S2_o$) generation potential of the source rocks. These values related to the ultimate volumes of hydrocarbon that could be generated at depth in the basin. For the Upper Velkerri original generation potential ($S2_o$) averages only 131 bbl oil/acre-ft, this is below all of the other formations on the list of unconventional US Shale plays shown below. Likewise, the 54 bbl oil/acre-ft for the Lower Velkerri and 61 bbl oil/acre-ft for the Corcoran are also well below US Shale plays (Table 5). For the Middle Velkerri interval, original generation potential is higher at 459 bbl oil/acre-ft and this unit does compare favorably with other unconventional US Shale plays.

Sample Database Averages TOC >1%	HI° mg/g TOC	TR	TOC° wt%	S2° mg/g Rock	Remaining Potential bbl/a-ft	Original Potential bbl/a-ft	Oil Cracked %	S1 Free Oil bbl/a-ft	Estimated Oil bbl/a-ft	Cracked Gas Mcf/a-ft
Barnett Shale Ft. Worth Basin	435	0.84	5.38	23.40	94	513	0.40	33	251	1005
Barnett Shale Delaware Basin	435	0.91	5.25	22.84	52	500	0.80	32	90	2149
Woodford Shale Delaware Basin	480	0.89	6.41	30.79	139	674	0.89	46	60	2854
Haynesville Shale E. Texas Basin	400	0.98	3.93	15.73	7	344	1.00	3	0	2022
Fayetteville Shale Arkoma Basin	435	0.95	3.34	14.53	15	318	1.00	10	0	1820
Woodford Shale Arkoma Basin	520	0.87	5.15	26.80	12	587	0.70	87	170	2431
Eagle Ford Shale Gulf Coast Basin	520	0.85	3.19	16.61	61	364	0.47	22	161	848
Marcellus Shale Appalachian Basin	600	0.97	6.44	38.66	34	847	1.00	24	0	4875
Utica Shale Appalachian Basin	450	0.98	2.74	12.32	6	270	1.00	12	0	1585
Barnett Shale Oil	450	0.47	5.47	24.64	326	540	0.00	79	213	0
Barnett Shale Gas	450	0.96	5.58	25.13	23	550	0.87	7	68	2751
Upper Velkerri	450	0.68	1.33	5.97	68	131	0.00	11	63	0
Middle Velkerri	467	0.48	4.39	20.95	296	459	0.00	75	162	5
Lower Velkerri	450	0.83	0.55	2.48	11	54	0.18	5	36	47
Corcoran	450	0.93	0.61	2.76	5	61	0.14	2	49	40

Table 4. Geochemical Properties and Generation Potential for US Shale plays and current study.

UNCONVENTIONAL OIL & GAS RISK ASSESSMENT

The Mesoproterozoic Velkerri and Corcoran Formation source rocks in the BMR Urapunga 4 well have been evaluated for unconventional oil and gas potential. These source rock samples are presented in a modified geochemical risk assessment diagram (Fig. 2) based upon published results from the Barnett Shale in the Fort Worth Basin. The data illustrated in the star plot represents average values for three of the four diagnostic ratios (no measured R_o data available). Also shown are the recommended areas for unconventional oil (in green) and gas (in red). Data that lies above the minimum threshold and within the shaded areas indicates samples with low geochemical risk for either thermogenic oil or gas production. Data that lie below the minimum threshold and fall in the immature region (in gray) indicate a high risk for commercial shale oil or gas production. Transformation ratios (TR) were calculated based upon HI_o estimates using measured and interpreted fractional composition of kerogen macerals.

The Middle Velkerri source rock interval in the BMR Urapunga 4 well is interpreted to represent a low geochemical risk for in-situ shale oil production. The average TOC content of 3.07 wt.% is above the generally accepted minimum value of 1% TOC to be considered an *effective* source rock for hydrocarbon generation/expulsion (Fig. 2). It is also above the minimum requirements of 2 wt.% for *economic* petroleum source rocks, which is also the minimum threshold for prospective shale gas. Original organic matter type is interpreted to be predominantly oil-prone Type II marine algal kerogen. Thermal maturity parameters from programmed pyrolysis place the Middle Velkerri source interval in peak oil window. The average Tmax value of 442°C is above the recommended minimum value of 435°C for shale oil, but below the minimum of 455°C for shale gas (Fig. 2). This amount of conversion would likely be sufficient to generate/expel significant amounts of hydrocarbons from this organic-rich, oil prone source facies. Transformation Ratios (TR), the least constrained risk parameter, average 48% and fall just below the recommended minimum of 50% for shale oil systems (Fig. 2). On the basis of all of these measured geochemical risk parameters, the Middle Velkerri source interval would be considered a low risk for shale oil and a high risk for shale gas since all of the thermal maturity risk parameters do fall well below recommended minimum thermogenic shale gas thresholds (Fig. 2).

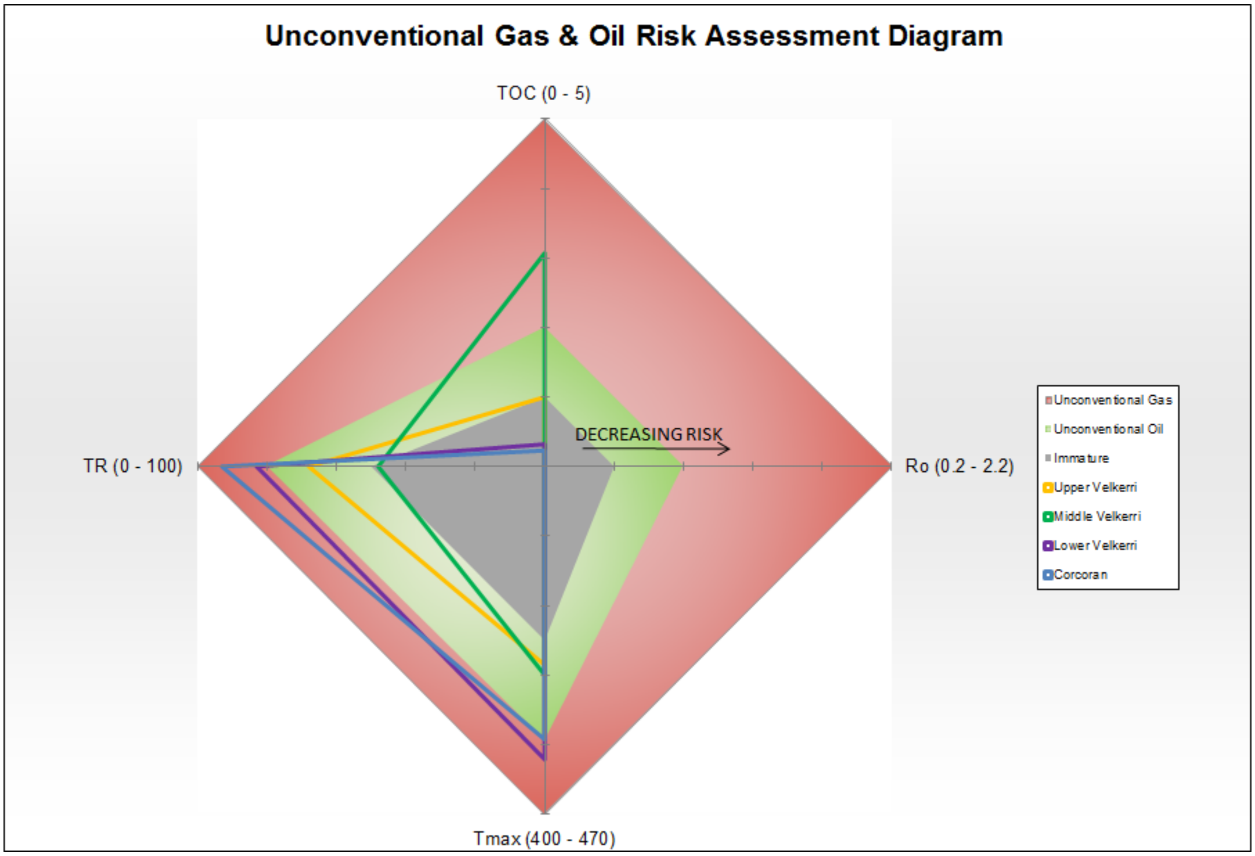

Figure 2. Geochemical Risk Assessment diagram for Mesoproterozoic Velkerri and Corcoran Formation source rocks in the BMR Urapunga 4 well.

The other formations examined in the current study are considered to represent low to moderate risk for in-situ shale oil production. This is primarily related to organic richness, although additional factors also need to be considered. The Upper Velkerri samples have an average TOC of 1.00 wt.% and thermal maturity indicators suggest peak window maturity. On the risk assessment diagram, average Tmax value of 440°C is above the recommended minimum value of 435°C for shale oil and the Transformation Ratio of 68% is also above the minimum threshold (Fig. 2). Although the average TOC content just meets the minimum threshold for shale oil (Fig.2), the Upper Velkerri interval is considered to be moderate risk for commercial shale oil development due to low measured in-situ oil saturations. Given its proximity to the underlying Middle Velkerri, it would be logical to conclude that any contribution to the overall resource potential from this horizon would simply be included within the evaluation of the Middle Velkerri, since fracture stimulation would likely connect both horizons, especially when considering the most prospective zone with elevated NOC values is the basal section of the Upper Velkerri.

The Lower Velkerri and Corcoran Formation have average TOC values of only 0.32 and 0.23 wt.%. This is far below the recommended minimum for *effective* source rocks and plot on the risk assessment diagram in unfavorable location for shale oil. Furthermore, measured in-situ oil saturation in both of these source rock intervals are very low (avg. 5 and 2 bbl oil/acre-ft) which suggest that any generated oil has either been cracked to gas or expelled from the source rock. Thermal maturity parameters suggest both of these intervals have a relatively high maturity within the late oil window. On the risk assessment diagram the Tmax values of 459 and 455°C and Transformation Ratios of 83 and 93% are all well above the minimum thresholds for prospective shale gas. However, the low TOC content of this interval preclude any significant hydrocarbon generation and thus this interval is considered a high risk for both unconventional oil and unconventional gas development.

In the Middle Velkerri source interval, measured in-situ oil saturation determined by programmed pyrolysis S1 yields is very good (avg. 75 bbl oil/acre-ft), suggesting low risk for shale oil development (Fig. 3). Hydrocarbon yield calculations on as-received samples show estimates of average generated oil from the Middle Velkerri at 162 bbl oil/acre-ft, along with 5 Mcf/acre-ft of secondary cracked gas. As a comparison, a representative example from the core area of Barnett Shale oil production in the Fort Worth Basin has an estimated generated oil yield of 213 bbl/a-ft with a measured in-situ oil saturation of 79 bbl/a-ft. These values are somewhat higher compard to the Middle Velkerri and primarily reflect differences in organic richness (Barnett Shale oil example has 4.70 wt.%).

In the Upper Velkerri source interval measured in-situ oil saturation from S1 yields is generally poor (avg. 11 bbl oil/acre-ft), but estimated generated oil yields are moderate (avg. 63 bbl oil/acre-ft) due to lower organic richness (Fig. 3). The Lower Velkerri and Corcoran Formations have much lower measured in-situ oil saturation (2 and 5 bbl oil/acre-ft), but this could be a partial consequence of elevated thermal maturity and loss of volatile oil saturation. Estimated generated oil yields are low (36 and 49 bbl oil/acre-ft) along with some minor amounts of secondary cracked gas (47 and 40 Mcf/acre-ft). These low values suggest a high risk for shale oil and shale gas within the Lower Velkerri and Corcoran intervals.

It is important to note that the quantity of oil generated from a potential source rock is only one geochemical factor to consider in regard to risk assessment. Equally important is the quality of the oil generated, since this factor can be a critical element in assessing the movability and ultimate recovery. The interpreted thermal maturity of the Upper and Middle Velkerri source intervals in this well is in the peak oil window and hydrocarbon saturation is likely to be fairly light and mobile. The Lower Velkerri and Corcoran intervals are in the late oil window and also would be expected to have minor volatile oil with a high gas/oil ratio. The presence of heavy oil and/or bitumen could also indicate a source interval with restricted microporosity. Such microporosity is considered necessary for recovery of in-situ oil saturation and can be better assessed using scanning electron microscopy (SEM). Source rock extract fingerprints and bulk fractional compositional analyses from select Velkerri samples would also aid in the determination of the quality of the in-situ hydrocarbon saturation and provide a better assessment of their movability and ultimate recovery potential.

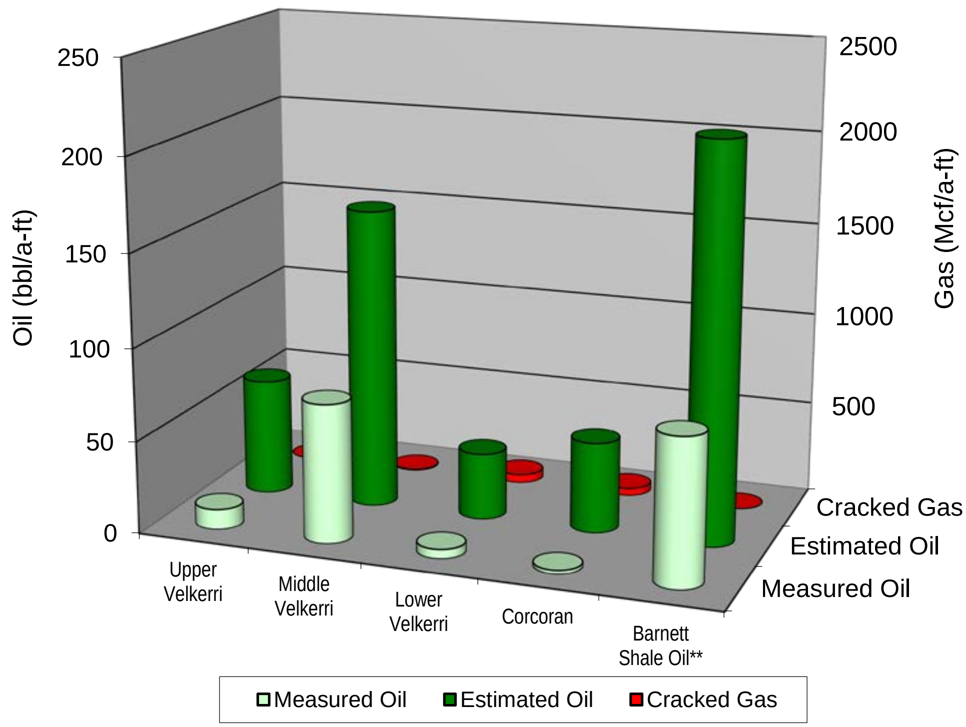

Figure 3. Hydrocarbon yield estimates for the Mesoproterozoic source rocks in the BMR Urapunga 4 well compared to Barnett Shale in the oil window.

GEOCHEMICAL SUMMARY

The Middle Velkerri source interval in the BMR Urapunga 4 well is interpreted to represent low geochemical risk for unconventional shale oil development. It clearly has elevated organic richness (avg. 3.07 wt.% TOC) and is considered a very good source rock with dominantly oil-prone Type II kerogen. Thermal maturity parameters indicate that the source interval is in the peak oil window, 0.80% Calc. R_o, and most key risk ratios are above recommended minimum thresholds for shale oil systems. The Middle Velkerri has likely generated significant amounts of oil (avg. 162 bbl oil/acre-ft) and comparison to other systems such as the Barnett Shale show in-situ oil saturations are generally comparable for the Middle Velkerri. Risk criteria like the S1 versus TOC show oil cross-over for many samples in the upper and basal sections of this unit. Further evaluation of in-situ oil characteristics would be required to fully evaluate potential oil mobility and recovery risk.

The other source rock intervals evaluated in the BMR Urapunga 4 well generally have higher risk in comparison to the Middle Velkerri. The Upper Velkerri has marginal organic richness with an average 1.00 wt.% TOC, but is considered a moderate risk for shale gas primarily due to low measured in-situ oil saturation. The Lower Velkerri and Corcoran intervals have much lower organic richness (< 0.32 wt% TOC) and are well below minimum threshold for shale oil, consequently both of these intervals are considered high risk for shale oil and gas development..

REFERENCES CITED

Abad, I., 2008, Physical meaning and applications of the illite Kübler index: measuring reaction progress in low-grade metamorphism, in F. Neito and J-M. Millan, eds., Diagenesis and low-temperature metamorphism: Theory, methods, and regional aspects: Seminarios de la Sociedad Española de Mineralogía, Unpaginated.

Crick I. H., Boreham, C. J., Cook, A. C. and Powell, T.G., 1988,Petroleum geology and geochemistry of Upper Proterozoic McArthur Basin, Northern Territory II: Assessment of source rock potential. American Association of Petroleum Geologists, Bulletin 72(12), 1495–1514.

Jarvie, D. M., 2012, Shale resource systems for oil and gas: Part 2 – shale-oil resource systems, *in* Breyer, J.A., ed., Shale reservoirs—giant resources for the 21st century: AAPG Memoir 97, CD-ROM Material, p. 89-119.

Jarvie, D. M., Hill, R.J., Ruble, T.E., and Pollastro, R.M., 2007, Unconventional shale gas systems: the Mississippian Barnett Shale of north-central Texas as one model for thermogenic shale-gas assessment, American Association of Petroleum Geologists Bulletin, v. 91, p. 475-499.

Jarvie, D. M. and Tobey, M H., 1999, TOC, Rock-Eval, or SR Analyzer Interpretive Guidelines: Application Note 99-4: Weatherford Laboratories, 16 p.

Lanigan, K., Hibbird, S., Menpes, S. and Torkington, J., 1994. Petroleum exploration in the Proterozoic Beetaloo Sub‑basin, Northern Territory. APEA Journal 34, 674 –691.

Lewan, M. D.,1987, Petrographic study of primary petroleum migration in the Woodford Shale and related rock units, *in* B. Doligez, ed., Migration of hydrocarbons in sedimentary basins, 2nd Edition, IFP Exploration Research Conference, Carcans, France, June 15-19, 1987, p. 113-130.

Peters, K. E., 1986, Guidelines for evaluating petroleum source rocks using programmed pyrolysis, AAPG Bulletin, v 70, p. 318-329.

Peters, K. E., C. C. Walters, and M. Moldowan, 2005, The biomarker guide, 2nd Edition, Volumes 1 and 2, Cambridge University Press, 1155 p.

Taylor, D. P., Kontorovich, A. E., Larichev, A. I. and Glikson, M., 1994. Petroleum source rocks in the Roper Group of the McArthur Basin: Source characterisation and maturity determinations using physical and chemical methods. APEA Journal 34, 279 –296.

Appendix I

Hydrocarbon Yield Calculation
Shelf Group
BMR Urapunga 4

McArthur Basin Integrated Petroleum Geochemistry, 2016

Northern Territory Geological Survey - Australia

Weatherford®
LABORATORIES

BMR Urapunga 4

Hydrocarbon Yield Calculation

																S2 (meas)	S2 (orig)				
Sample	**Top Depth**	**TOC***	**HI***	**S1***	**S2***	**Calc.Ro**	**PI***	**%Type IV 50 HI°**	**% Type III 125 HI°**	**%Type II 450 HI°**	**%Type I 750 HI°**	**HI°**	**TR**	**TOC°**	**S2°**	**Remaining Potential**	**Original Potential**	**Oil Cracked**	**S1 Free Oil**	**Estimated Oil**	**Cracked Gas**
BMR Urapunga 4	**(m)**	**wt%**	**mg/g TOC**	**mg/g Rock**	**mg/g Rock**	**%**						**mg/g TOC**		**wt%**	**mg/g Rock**	**bbl/a-ft**	**bbl/a-ft**	**%**	**bbl/a-ft**	**bbl/a-ft**	**Mcf/a-ft**
UR14DJR047	42	0.46	32	0.08	0.15	0.77	0.35	0	0	100	0	450	0.95	0.63	2.82	3	62	0.00	2	58	0
UR14DJR048	45	0.46	59	0.04	0.27	0.77	0.13	0	0	100	0	450	0.91	0.61	2.74	6	60	0.00	1	54	0
UR14DJR049	50	0.41	71	0.03	0.29	0.77	0.09	0	0	100	0	450	0.89	0.54	2.42	6	53	0.00	1	47	0
UR14DJR051	60	0.54	101	0.06	0.54	***0.85***	0.10	0	0	100	0	450	0.85	0.69	3.12	12	68	0.00	1	56	0
1312272	63	0.46	122	0.10	0.56	***0.80***	0.15	0	0	100	0	450	0.81	0.59	2.66	12	58	0.00	2	46	0
UR14DJR052	65	0.42	147	0.06	0.62	***0.81***	0.09	0	0	100	0	450	0.77	0.53	2.39	14	52	0.00	1	39	0
1312187	74	0.62	171	0.36	1.06	***0.76***	0.25	0	0	100	0	450	0.73	0.79	3.54	23	78	0.00	8	54	0
UR14DJR054	75	0.93	61	0.14	0.57	***0.63***	0.20	0	0	100	0	450	0.91	1.24	5.56	12	122	0.00	3	109	0
UR14DJR055	80	0.61	189	0.19	1.16	***0.77***	0.14	0	0	100	0	450	0.69	0.76	3.41	25	75	0.00	4	49	0
1312186	81	0.48	179	0.46	0.86	***0.83***	0.35	0	0	100	0	450	0.72	0.62	2.78	19	61	0.00	10	42	0
1312210	82	0.54	169	0.40	0.91	***0.72***	0.31	0	0	100	0	450	0.74	0.69	3.11	20	68	0.00	9	48	0
UR14DJR057	90	1.54	268	0.64	4.12	***0.78***	0.13	0	0	100	0	450	0.53	1.81	8.15	90	178	0.00	14	88	0
1312301	93	0.95	276	0.73	2.62	***0.80***	0.22	0	0	100	0	450	0.53	1.14	5.12	57	112	0.00	16	55	0
UR14DJR058	95	0.75	213	0.27	1.59	***0.71***	0.15	0	0	100	0	450	0.65	0.91	4.10	35	90	0.00	6	55	0
UR14DJR059	100	2.87	284	0.83	8.14	***0.80***	0.09	0	0	100	0	450	0.49	3.29	14.82	178	325	0.00	18	146	0
UR14DJR060	105	0.43	157	0.18	0.67	***0.73***	0.21	0	0	100	0	450	0.75	0.54	2.45	15	54	0.00	4	39	0
UR14DJR061	110	1.10	252	0.43	2.77	***0.79***	0.13	0	0	100	0	450	0.57	1.31	5.88	61	129	0.00	9	68	0
UR14DJR064	120	1.01	266	0.86	2.69	***0.74***	0.24	0	0	100	0	450	0.55	1.22	5.50	59	121	0.00	19	62	0
UR14DJR065	125	1.45	294	1.05	4.26	***0.73***	0.20	0	0	100	0	450	0.49	1.71	7.69	93	168	0.00	23	75	0
UR14DJR066	130	6.58	424	3.04	27.91	***0.79***	0.10	0	0	100	0	450	0.12	6.92	31.12	611	682	0.00	67	70	0
Upper Velkerri (Avg)		**1.13**	**187**	**0.50**	**3.09**	**0.77**	**0.18**	**0**	**0**	**100**	**0**	**450**	**0.68**	**1.33**	**5.97**	**68**	**131**	**0.00**	**11**	**63**	**0**
1312185	133	6.61	426	3.85	28.18	**0.74**	0.12	0	0	75	25	525	0.33	7.28	38.19	617	836	0.00	84	219	0
1312302	134	5.31	433	2.83	22.97	**0.74**	0.11	0	0	75	25	525	0.31	5.82	30.55	503	669	0.00	62	166	0
UR14DJR067	135	7.88	391	2.88	30.84	**0.72**	0.09	0	0	100	0	450	0.22	8.38	37.73	675	826	0.00	63	151	0
1312184	138	7.51	420	3.69	31.57	**0.76**	0.10	0	0	75	25	525	0.33	8.22	43.17	691	945	0.00	81	254	0
UR14DJR068	140	9.40	450	3.20	42.34	**0.69**	0.07	0	0	75	25	525	0.25	9.97	52.34	927	1146	0.00	70	219	0
1312303	145	2.64	418	2.04	11.03	**0.71**	0.16	0	0	75	25	525	0.36	2.99	15.69	242	344	0.00	45	102	0
UR14DJR069	145	3.40	428	1.31	14.56	**0.65**	0.08	0	0	75	25	525	0.31	3.71	19.46	319	426	0.00	29	107	0
1312183	146	3.41	369	2.67	12.59	**0.71**	0.17	0	0	100	0	450	0.30	3.82	17.19	276	376	0.00	58	101	0
1312304	148	4.61	422	3.54	19.45	**0.74**	0.15	0	0	75	25	525	0.35	5.18	27.18	426	595	0.00	78	169	0
UR14DJR070	151	6.05	335	2.07	20.27	**0.68**	0.09	0	0	100	0	450	0.37	6.68	30.08	444	659	0.00	45	215	0
1312811	156	5.28	449	4.88	23.73	**0.81**	0.17	0	0	75	25	525	0.29	5.89	30.91	520	677	0.00	107	157	0
1312810	156	0.67	230	1.18	1.54	0.80	0.43	0	0	100	0	450	0.64	0.86	3.87	34	85	0.00	26	51	0
1312306	157	8.68	428	5.70	37.16	**0.74**	0.13	0	0	75	25	525	0.33	9.55	50.13	814	1098	0.00	125	284	0
1312305	160	5.27	417	4.04	21.95	**0.76**	0.16	0	0	75	25	525	0.36	5.93	31.12	481	681	0.00	88	201	0
UR14DJR071	160	4.48	385	1.80	17.25	**0.76**	0.09	0	0	100	0	450	0.24	4.82	21.70	378	475	0.00	39	97	0
1312182	164	5.87	415	3.51	24.37	**0.83**	0.13	0	0	75	25	525	0.35	6.52	34.23	534	750	0.00	77	216	0
UR14DJR072	165	10.90	430	4.12	46.85	**0.80**	0.08	0	0	75	25	525	0.30	11.69	61.38	1026	1344	0.00	90	318	0
1312314	168	4.15	393	4.96	16.31	**0.83**	0.23	0	0	100	0	450	0.26	4.69	21.09	357	462	0.00	109	105	0
UR14DJR073	170	3.52	310	1.91	10.91	**0.81**	0.15	0	0	100	0	450	0.44	4.03	18.16	239	398	0.00	42	159	0
1312313	173	3.15	371	4.78	11.70	**0.83**	0.29	0	0	100	0	450	0.33	3.67	16.52	256	362	0.00	105	106	0
1312312	175	3.54	366	4.69	12.97	**0.81**	0.27	0	0	100	0	450	0.34	4.10	18.43	284	404	0.00	103	120	0
1312311	176	3.49	393	5.11	13.71	**0.81**	0.27	0	0	100	0	450	0.27	4.00	18.01	300	394	0.00	112	94	0
1312208	176	2.88	378	5.21	10.88	**0.71**	0.32	0	0	100	0	450	0.33	3.39	15.25	238	334	0.00	114	96	0
1312209	179	2.86	346	5.06	9.90	**0.76**	0.34	0	0	100	0	450	0.40	3.42	15.40	217	337	0.00	111	120	0
UR14DJR074	180	1.62	283	1.40	4.58	**0.67**	0.23	0	0	100	0	450	0.52	1.94	8.72	100	191	0.00	31	91	0
1312199	184	2.77	323	4.13	8.96	**0.74**	0.32	0	0	100	0	450	0.44	3.32	14.94	196	327	0.00	90	131	0
UR14DJR075	190	3.19	304	2.37	9.70	**0.76**	0.20	0	0	100	0	450	0.46	3.72	16.74	212	367	0.00	52	154	0
1312198	199	2.22	281	3.98	6.23	**0.76**	0.39	0	0	100	0	450	0.54	2.76	12.42	136	272	0.00	87	136	0
UR14DJR077	203	4.55	261	2.48	11.89	**0.78**	0.17	0	0	100	0	450	0.55	5.37	24.15	260	529	0.00	54	268	0
1312310	207	4.81	373	4.05	17.93	**0.90**	0.18	0	0	100	0	450	0.30	5.38	24.21	393	530	0.01	89	136	9
1312309	209	3.82	316	3.03	12.06	**0.74**	0.20	0	0	100	0	450	0.44	4.43	19.93	264	436	0.00	66	172	0
1312197	210	5.09	372	5.00	18.94	**0.67**	0.21	0	0	100	0	450	0.31	5.74	25.84	415	566	0.00	110	151	0
1312308	217	3.88	290	3.26	11.25	**0.85**	0.22	0	0	100	0	450	0.50	4.58	20.62	246	452	0.00	71	205	0
1312196	261	0.16	69	0.01	0.11	0.80	0.08	0	0	100	0	450	0.90	0.21	0.95	2	21	0.00	0	18	0
1312245	312	0.70	120	0.42	0.84	0.80	0.33	0	0	100	0	450	0.82	0.92	4.12	18	90	0.00	9	72	0
UR14DJR094	320	0.52	135	0.33	0.70	**0.85**	0.32	0	0	100	0	450	0.79	0.68	3.04	15	67	0.00	7	51	0
1312317	325	5.81	272	3.65	15.83	**0.92**	0.19	0	0	100	0	450	0.53	6.81	30.65	347	671	0.02	80	318	41
1312204	325	5.72	269	3.15	15.37	**0.83**	0.17	0	0	100	0	450	0.54	6.69	30.12	337	660	0.00	69	323	0
1312316	327	5.71	278	4.05	15.88	**0.96**	0.20	0	0	100	0	450	0.52	6.70	30.17	348	661	0.04	89	299	84

BMR Urapunga 4

Hydrocarbon Yield Calculation

Sample	Top Depth	TOC*	HI*	S1*	S2*	Calc.Ro	PI*	%Type IV 50 HI°	% Type III 125 HI°	%Type II 450 HI°	%Type I 750 HI°	HI°	TR	TOC°	S2°	S2 (meas) Remaining Potential	S2 (orig) Original Potential	Oil Cracked	S1 Free Oil	Estimated Oil	Cracked Gas
BMR Urapunga 4	(m)	wt%	mg/g TOC	mg/g Rock	mg/g Rock	%						mg/g TOC		wt%	mg/g Rock	bbl/a-ft	bbl/a-ft	%	bbl/a-ft	bbl/a-ft	Mcf/a-ft
UR14DJR095	330	1.76	280	1.67	4.92	0.80	0.25	0	0	100	0	450	0.52	2.12	9.53	108	209	0.00	37	101	0
1312315	331	2.62	232	4.30	6.07	**0.96**	0.41	0	0	100	0	450	0.63	3.32	14.93	133	327	0.04	94	185	52
UR14DJR096	335	0.91	135	0.41	1.23	**0.91**	0.25	0	0	100	0	450	0.79	1.17	5.26	27	115	0.01	9	87	7
1317201	339	0.48	98	0.28	0.47	0.80	0.37	0	0	100	0	450	0.85	0.64	2.86	10	63	0.00	6	52	0
1312175	343	2.01	332	7.60	6.68	0.80	0.53	0	0	100	0	450	0.46	2.56	11.54	146	253	0.00	166	106	0
1312809	346	2.91	392	16.79	11.41	0.80	0.60	0	0	100	0	450	0.36	3.74	16.83	250	369	0.00	368	119	0
1312174	348	3.31	82	2.60	2.72	**0.89**	0.49	0	0	100	0	450	0.88	4.38	19.71	60	432	0.00	57	372	0
1312173	351	1.64	199	2.63	3.26	**0.96**	0.45	0	0	100	0	450	0.69	2.12	9.53	71	209	0.04	58	131	37
1312244	355	2.02	227	3.65	4.59	**0.90**	0.44	0	0	100	0	450	0.64	2.58	11.62	101	254	0.01	80	152	10
UR14DJR099	355	2.63	199	1.59	5.24	**0.79**	0.23	0	0	100	0	450	0.68	3.26	14.66	115	321	0.00	35	206	0
1312243	357	2.23	188	3.39	4.19	**0.90**	0.45	0	0	100	0	450	0.71	2.88	12.96	92	284	0.01	74	190	12
1312207	357	2.24	192	3.31	4.29	**0.78**	0.44	0	0	100	0	450	0.70	2.88	12.98	94	284	0.00	72	190	0
1312242	360	2.13	171	3.09	3.64	**0.89**	0.46	0	0	100	0	450	0.74	2.77	12.46	80	273	0.00	68	193	0
Middle Velkerri (Avg)		**3.83**	**309**	**3.42**	**13.50**	**0.80**	**0.25**	**0**	**0**	**94**	**6**	**467**	**0.48**	**4.39**	**20.95**	**296**	**459**	**0.00**	**75**	**162**	**5**
1312241	370	0.47	121	0.31	0.57	**1.10**	0.35	0	0	100	0	450	0.82	0.62	2.78	12	61	0.18	7	40	52
1312205	370	0.37	105	0.12	0.39	1.10	0.24	0	0	100	0	450	0.84	0.48	2.18	9	48	0.18	3	32	41
Lower Velkerri (Avg)		**0.42**	**113**	**0.22**	**0.48**	**1.10**	**0.29**	**0**	**0**	**100**	**0**	**450**	**0.83**	**0.55**	**2.48**	**11**	**54**	**0.18**	**5**	**36**	**47**
1312203	433	0.62	71	0.17	0.44	**1.01**	0.28	0	0	100	0	450	0.90	0.82	3.71	10	81	0.09	4	65	38
1312239	433	0.29	52	0.03	0.15	**1.10**	0.17	0	0	100	0	450	0.92	0.39	1.74	3	38	0.18	1	29	37
1312202	449	0.38	61	0.03	0.23	**1.28**	0.12	0	0	100	0	450	0.91	0.50	2.27	5	50	0.40	1	27	108
1312740	451	0.50	32	0.06	0.16	**0.83**	0.27	0	0	100	0	450	0.95	0.68	3.04	4	67	0.00	1	63	0
UR14DJR103	465	0.50	30	0.06	0.15	**0.95**	0.29	0	0	100	0	450	0.96	0.68	3.05	3	67	0.04	1	61	16
Corcoran (Avg)		**0.46**	**49**	**0.07**	**0.23**	**1.04**	**0.22**	**0**	**0**	**100**	**0**	**450**	**0.93**	**0.61**	**2.76**	**5**	**61**	**0.14**	**2**	**49**	**40**
Barnett Shale Oil**		4.70	300	3.60	14.90	0.86	0.20	0	0	100	0	450	0.47	5.47	24.64	326	540	0.00	79	213	0
Barnett Shale**		4.21	26	0.33	1.07	1.66	0.24	0	0	100	0	450	0.96	5.58	25.13	23	550	0.87	7	68	2751

Notes: Calc.Ro values in **bold** are calculated from measured Tmax. Calc.Ro values in red font are intrepreted from other geochemical maturity data because Tmax was considered unreliable. All other Calc.Ro values are formation specific averages because Tmax was considered unreliable.

Kerogen Type in **bold** have visual kerogen data for estimates TR = Transformation Ratio (fractional conversion) (Original Potential - Remaining Potential) = (Estimated Oil + Cracked Gas)

Estimated Oil and Cracked Gas yield data assume complete conversion and no expulsion of hydrocarbon products and the proportion between each is based on empirical Ro calculated % cracking.

Yields do not represent recoverable products and are intended primarily for comparison purposes, yield calculations based on carbon mass balance are likely to be overestimations. **Estimated parameters for productive Barnett Shale in the Ft. Worth Basin

Hydrocarbon yield calculations and formulas are fully documented in the appendix section of Jarvie et al. (2007)