Tarlee S3 Interpretive Summary

Upper Velkerri – Middle Velkerri Interval

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Submitted to:
Daniel Revie
Northern Territory Geological Survey
Department of Mines and Energy
38 Farrell Crescent
Winnellie, NT 0820 Australia

Prepared By:
Weatherford Laboratories
Study Project No. AB-74329

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Report Contributors:

Tim Ruble (Petroleum Geochemistry)

Elizabeth Roberts (Compiler)

Brian Hankins & Jennifer Yee (Isologica Data Processing)

Elvira Barcelona (Organic Petrology)

Weatherford
LABORATORIES

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PETROLEUM GEOCHEMISTRY

INTRODUCTORY NOTE

A geochemical investigation has been conducted to assess hydrocarbon prospectivity of the Upper and Middle Velkerri Formations in the Tarlee S3 well located in the Beetaloo Sub-Basin, Northern Territories, Australia. Nine (9) core chip samples from this well were analyzed by a variety of geochemical techniques, including total organic carbon (TOC, LECO®), programmed pyrolysis (SRA) and organic petrology with measured maceral reflectance (R_o). In addition, client supplied published geochemical data for 363 samples was 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 Gas Risk
Tarlee S3	Upper Velkerri	**Estimated Original** →		Good (1.98% TOC)	Oil-prone Type II	Moderate
Measured Currently →		Dry Gas	Dry Gas Window	Good (1.46% TOC)	Inert Type IV	
Tarlee S3	Middle Velkerri	**Estimated Original** →		Excellent (5.42% TOC)	Oil-prone Type II	Low
Measured Currently →		Dry Gas	Dry Gas Window	Excellent (4.11% 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

One (1) sample from the Upper Velkerri Formation was analyzed for LECO TOC content and programmed pyrolysis (Fig. 1), thus the interpretative results reported in this study should be used with caution since they may not be representative of the entire interval. TOC content in this sample from 1207.55 m depth is 1.46 wt.% (good). This is above the minimum requirement of 1 wt.% for *effective* petroleum source rocks, but below the minimum requirement of 2 wt.% for *economic* petroleum source rocks.

The S1 value of the Upper Velkerri source rock sample is 0.11 mg HC/g rock (2 bbl oil/acre-ft) and the S2 value is 0.15 mg HC/g rock (3 bbl oil/acre-ft). The S1 and S2 values imply low in-situ hydrocarbon saturation and poor remaining generative potential (Fig. 1). The normalized oil content (NOC) in the Upper Velkerri sample, (S1/TOC) x 100, is 8 (Fig. 1). NOC values of 20 to 50 are 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. Very low NOC values < 20 are most likely related to post-mature source rocks that have likely generated and expelled most of their in-situ hydrocarbon saturation. 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 is no S1 cross over TOC in any of the samples analyzed (Fig. 1).

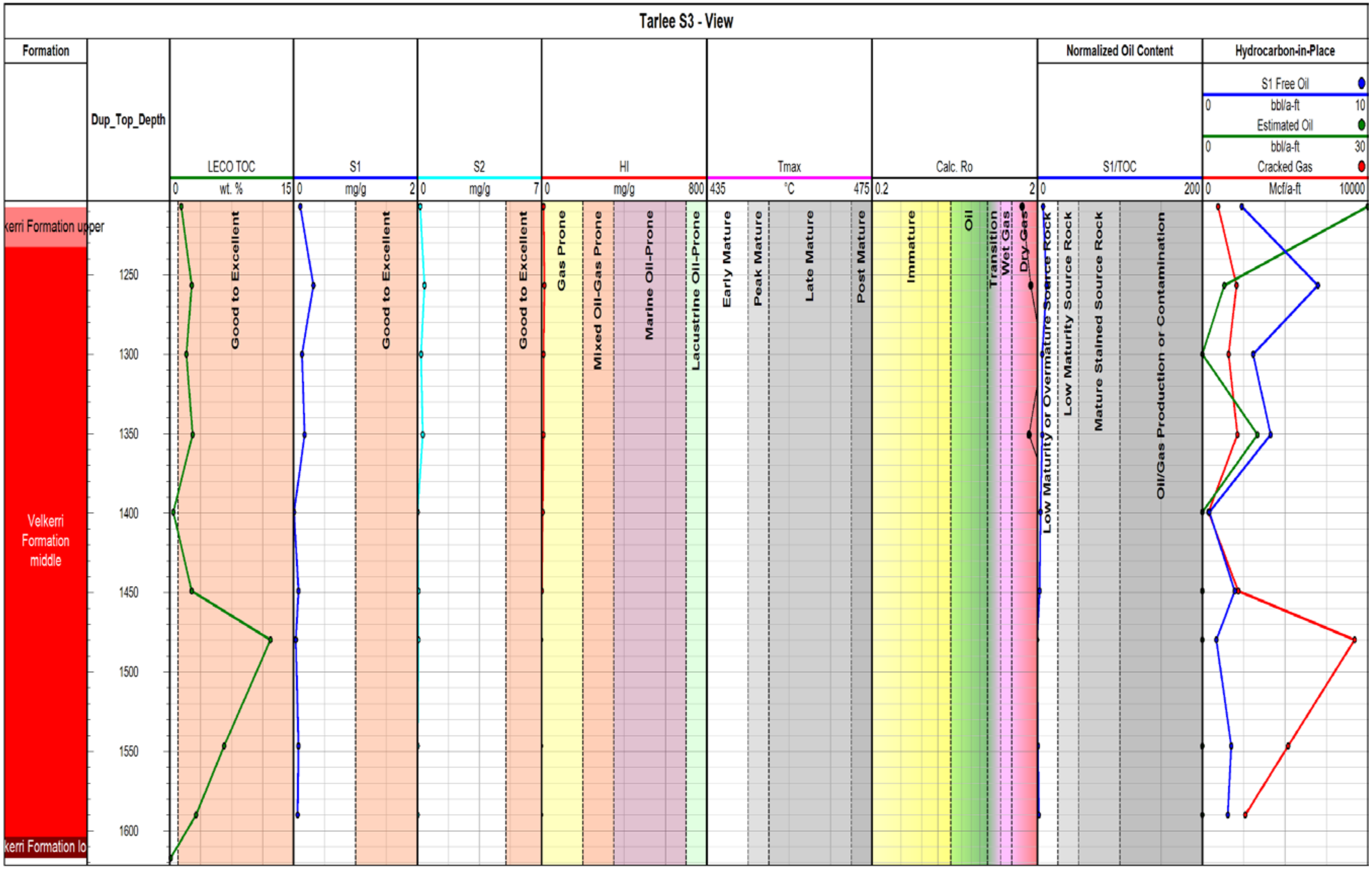

Figure 1. Geochemical depth plots for the Tarlee S3 well. Note Tmax values plot off scale on depth plot beyond post-mature field.

The measured Hydrogen Index (HI) value in the Upper Velkerri is 10 mg HC/g TOC, indicating inert Type IV 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 are 99%, which is consistent with a post-mature dry gas window thermal maturity. The T_{max} value in the Upper Velkerri sample is 488°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 Upper Velkerri T_{max} value in this well would be interpreted to be post-mature and likely in the late condensate/wet gas to early dry gas widow. Using the formula published by Jarvie et al. (2007) for Type II kerogen (Calculated $R_o = (0.0180)(T_{max}) - 7.16$), the measured T_{max} value of 488°C is equivalent to a Calc. %R_o value of 1.63%. 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, especially post-mature samples where S2 yields are very low.

The Production Index (PI) value in this Upper Velkerri sample is 0.42. This elevated PI value is consistent with source rocks in the late condensate/wet gas window, which typically have PI values in the range of 0.25 to 0.40. Samples in the dry gas window tend to have very low PI values due to low S1 yields, but this is more problematic since low S2 yields can cause this ratio to be erratic and inaccurate.

MIDDLE VELKERRI FORMATION

Eight samples (8) from the Middle Velkerri Formation were analyzed for LECO TOC content and programmed pyrolysis (Fig. 1). The Middle Velkerri Formation in the Tarlee S3 well exhibits excellent generative potential for petroleum source rocks based on TOC content values (Fig. 1). TOC content ranges from 0.46 to 12.20 wt.% and averages 4.11 wt.% (excellent). Seven (7) of the eight samples analyzed exceed the minimum value of 2.0 wt.% for *economic* petroleum source rocks (Lewan, 1987). Maximum TOC content occurs in the lower portion of the sampled interval at a depth of 1480.52 m (Fig. 1), but there is insufficient sample density to assess whether the three distinct organic rich intervals previously recognized within the Middle Velkerri (Lanigan et al, 1994) are also present in this well.

The S1 values in the Middle Velkerri average 0.12 mg HC/g rock (3 bbl oil/acre-ft), indicating generally poor in-situ hydrocarbon saturation (Fig. 1). NOC values in the Middle Velkerri interval are overall slightly lower in comparison to the overlying strata and average 3. Oil cross over (NOC > 100) was not observed in this unit. The S2 values in this interval average just 0.15 mg HC/g rock (2 bbl oil/acre-ft), which indicates poor remaining generative potential.

Measured HI values in the Middle Velkerri samples average 6 mg HC/g TOC, which indicate inert Type IV kerogen quality in these source rocks at present day. Estimated original HI_o values in these samples average 450 mg HC/g TOC, which indicate oil-prone Type II kerogen quality. Transformation Ratios (TR) based upon HI average 99%, which suggest post-mature dry gas window thermal maturity.

The organic-matter in the Middle Velkerri interval in the Tarlee S3 well is thermally post-mature and is interpreted to be in the dry gas window. Programmed pyrolysis T_{max} values average 530°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 530°C is equivalent to a Calc. %R_o value of 2.37%. 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, especially post-mature samples where S2 yields are very low.

Production Index (PI) values in these Middle Velkerri samples average 0.50. These elevated PI values are consistent with source rocks in the late condensate/wet gas window, which typically have PI values in the range of 0.25 to 0.40. Samples in the dry gas window tend to have very low PI values due to low S1 yields, but this is more problematic since low S2 yields can cause this ratio to be erratic and inaccurate.

Organic petrology was performed on one sample from the Middle Velkerri interval (1480.52−1480.54 m). The results from this analysis show a distribution that consists exclusively of macerals identified as high reflectance solid bitumens (Fig. 2). These organic macerals are thought to possibly represent fine grained migrabitumen, although they could also represent preserved original cyanobacterial kerogen that has subsequently undergone thermal conversion to form a dispersed solid bitumen network within these Velkerri Formation source rocks. The mean measured reflectance value for these solid organic macerals is 2.28% R_o (a value very close to the T_{max} Calc. %R_o value of 2.37%). Published solid bitumen conversions were applied to these reflectance values. The conversion formula published by Landis and Castaño (1995) for bitumen in lenses/layers (Eq. R_o = (Bitumen R_o +0.41)/1.09) resulted in a 2.47% Eq. R_o, while the conversion formula published by Jacob (1985) equation (Eq. R_o = (Bitumen $R_o \times$ 0.618) + 0.4) for 'angular-like' pyrobitumen trapped in mineral pore spaces resulted in a 1.81% Eq. R_o. The Landis and Castaño (1995) conversion would suggest an elevated late dry gas window thermal maturity, which is somewhat higher than predicted based on other parameters. However, the Jacob (1985) conversion appears to provide a possible correction back to a more suitable thermal maturity. Comparison with other samples examined in the current study suggest that the high reflectance solid bitumen reflectance readings can be corrected using the Jacob (1985) formula and often these “corrected” values compare favorably to “uncorrected” readings from the population of low reflectance solid bitumen within the same sample. Thus, the calculated 1.81% Eq. R_o value would suggest the Middle Velkerri samples in this well are within the early dry gas window.

The high thermal maturity of the Middle Velkerri source rocks is also supported 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). Five (5) samples from the Middle Velkerri (avg. 38% clays) have an average measured Kübler Index of 0.220, 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.

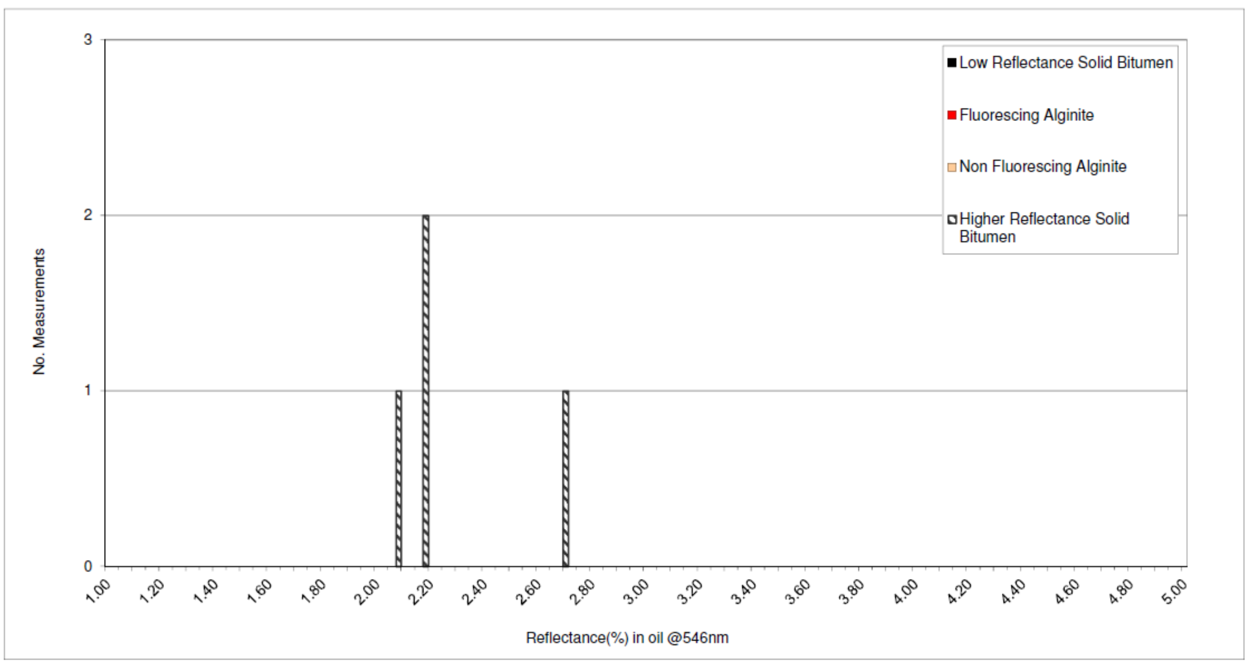

Figure 2. Organic petrology of the Middle Velkerri (1480.52 m) in the Tarlee S3 well. Mean maceral reflectance of high reflecting solid bitumen is 2.28% R_o, while calculated Eq. R_o is 1.81% R_o using the conversion of Jacob (1985).

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 source rock samples 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):

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

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	0	100	0	0	450

Table 2. Average Kerogen Estimations for Tarlee S3 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):

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

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 an average HI_o values of 450 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 0.99 (Table 3), i.e., on average an estimated 99% 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):

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

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 1.98 to 5.42 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 Velkerri source rocks examined in the Tarlee S3 well, the average $S2_o$ values vary from 8.9 to 24.4 mg HC/g rock or approximately 195 to 534 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 cracked gas yields average 973 Mcf/acre-ft along with 30 bbl/acre-ft of residual oil. The generated cracked gas yield from underlying Middle Velkerri was higher with 3174 Mcf/acre-ft along with 2 bbl/acre-ft of residual oil (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	1.46	10	3	450	0.99	1.98	195	2	30	973
Middle Velkerri	4.11	6	3	450	0.99	5.42	534	3	2	3174

Table 3. Hydrocarbon Yields average data for Tarlee S3 well.

The Upper and Middle Velkerri source rock interval in the Tarlee S3 well are interpreted to be in the dry gas window and hydrocarbon yield calculations suggest moderate to significant amounts of generation have occurred (predominantly dry gas with minor residual oil/condensate). 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 4). 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 Middle Velkerri original generation potential ($S2_o$) averages 534 bbl oil/acre-ft, this is comparable to many of the other formations on the list of unconventional US Shale plays shown below.

For the Upper Velkerri, original generation potential is much lower at only 195 bbl oil/acre-ft and this unit does not 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	0.99	1.98	8.93	3	195	0.84	2	30	973
Middle Velkerri	450	0.99	5.42	24.38	3	534	1.00	3	2	3174

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

UNCONVENTIONAL OIL & GAS RISK ASSESSMENT

The Mesoproterozoic Velkerri Formation source rocks in the Tarlee S3 well have been evaluated for unconventional oil and gas potential. These source rock samples are presented in a modified geochemical risk assessment diagram (Fig. 3) based upon published results from the Barnett Shale in the Fort Worth Basin. The data illustrated in the star plot represents average values for all four diagnostic ratios where 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 Upper Velkerri source rock interval in the Tarlee S3 well is tentatively interpreted to represent a moderate geochemical risk for in-situ shale gas production, on the basis of one sample analysis. The measured TOC content of 1.46 wt.% is above the generally accepted minimum value of 1% TOC to be considered an *effective* source rock for hydrocarbon generation/expulsion (Fig. 3). However, it is below 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 Upper Velkerri source interval in early dry gas window. The average Tmax value of 488°C is well above the recommended minimum value of 455°C for shale gas (Fig. 3). This amount of conversion would likely be sufficient to generate/expel moderate amounts of hydrocarbons from this oil prone source facies. Transformation Ratios (TR), the least constrained risk parameter, average 99% and fall well above the recommended minimum of 80% for shale gasl systems (Fig. 3). On the basis of all of these measured geochemical risk parameters, the Upper Velkerri source interval would be considered a moderate risk for shale gas since the organic richness falls below the recommended minimum threshold (Fig. 3).

The other formation examined in the current study is considered to represent low risk for in-situ shale gas production. The Middle Velkerri samples have an average TOC of 4.11 wt.% and are well above the recommended minimum threshold of 2 wt. % TOC for shale gas. Thermal maturity indicators suggest early dry gas window maturity. On the risk assessment diagram, average Tmax value of 530°C is above the recommended minimum value of 455°C for shale gas (Fig. 3). The Transformation Ratio of 99% is also above the recommended minimum of 80% for shale gas (Fig. 3). Measured maceral reflectance values give a calculated Eq. R_o of 1.81% R_o, which is above the recommended minimum of 1.0% for shale gas (Fig. 3).

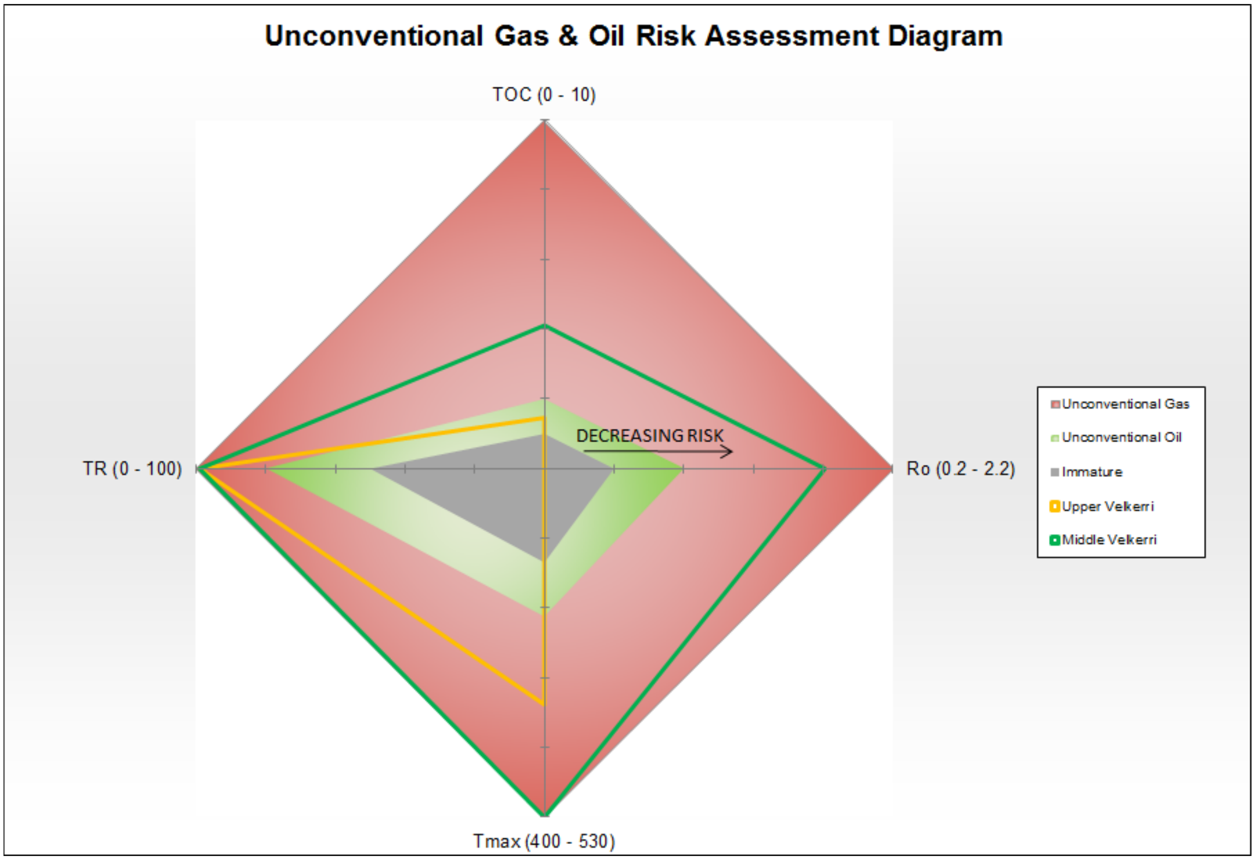

Figure 3. Geochemical Risk Assessment diagram for Mesoproterozoic Velkerri Formation source rocks in the Tarlee S3 well.

In the Upper Velkerri source interval, measured in-situ oil saturation determined by programmed pyrolysis S1 yields is poor (2 bbl oil/acre-ft), which is consistent with the interpreted thermal maturity level of this interval (Fig. 4). Hydrocarbon yield calculations on the as-received sample shows estimates of average generated oil from the Upper Velkerri at 30 bbl oil/acre-ft. and oil cracking is estimated to have been 84%, resulting in a cracked gas yield of 973 Mcf/acre-ft (Fig. 4). As a comparison, a representative example from the core area of Barnett Shale gas production in the Fort Worth Basin has an estimated cracked gas yield of 2751 Mcf/acre-ft, with 68 bbl/acre-ft of residual oil/condensate and a measured in-situ oil saturation of 7 bbl/a-ft. These values are higher compared to the Upper Velkerri and are primarily due to differences in organic richness (Barnett Shale gas example has average of 4.21 wt. % TOC).

In the Middle Velkerri source interval measured in-situ oil saturation from S1 yields is generally poor (avg.3 bbl oil/acre-ft). Estimated generated oil yields are also low (avg. 2 bbl oil/acre-ft), but there is significant amounts of secondary cracked gas (avg. 3174 Mcf/acre-ft) due to the elevated thermal maturity and estimated ~100% oil cracking (Fig. 4). These values are considered a low risk for shale gas development and the estimated cracked gas yields are actually slightly higher than the Barnett Shale gas production in the Fort Worth Basin.

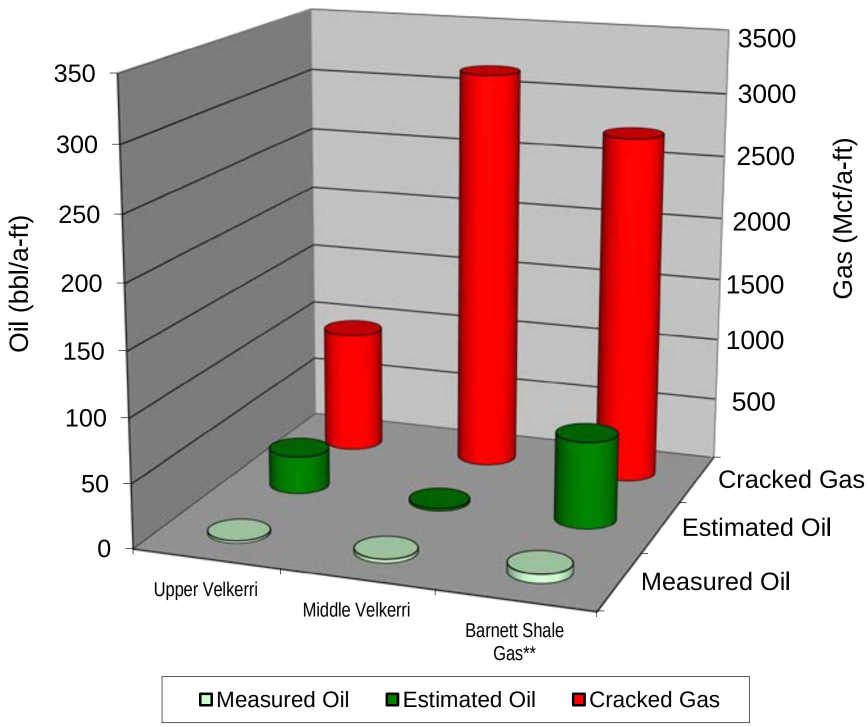

Figure 4. Hydrocarbon yield estimates for the Mesoproterozoic source rocks in the Tarlee S3 well compared to Barnett Shale in the gas window.

GEOCHEMICAL SUMMARY

The Middle Velkerri source interval in the Tarlee S3 well is interpreted to represent low geochemical risk for unconventional shale gas development. It clearly has elevated organic richness (avg. 4.11 wt.% TOC) and is considered an excellent source rock with dominantly oil-prone Type II kerogen. Thermal maturity parameters indicate that the source interval is in the early dry gas window, 2.37% Calc. R_o & 1.81% Eq. R_o from solid bitumen reflectance. All key risk ratios are above recommended minimum thresholds for shale gas systems. The Upper Velkerri has likely generated significant amounts of secondary cracked gas (avg. 3174 Mcf/acre-ft) and these values are actually higher in comparison to other systems such as the Barnett Shale in the gas window.

The Upper Velkerri source rock interval evaluated in the Tarlee S3 well (single samples) is tentatively considered a moderate risk for unconventional shale gas development. This horizon has good organic richness, with a measured 1.46 wt% TOC. However, this is below the recommended minimum threshold of 2 wt. % for shale gas systems. Thermal maturity parameters are all above minimum thresholds and indicate early dry gas window. This unit has likely generated a fair amount of secondary cracked gas (973 Mcf/acre-ft) and given the close proximity to the more prospective Middle Velkerri interval which lies beneath it, the Middle Velkerri could be expected to contribute to completion of that unit via fracture stimulation.

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Appendix I

Hydrocarbon Yield Calculation
Beetaloo Sub-Basin Group
Tarlee S3

McArthur Basin Integrated Petroleum Geochemistry, 2016

Northern Territory Geological Survey - Australia

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Tarlee S3

Hydrocarbon Yield Calculation

																S2 (meas)	S2 (orig)				
Sample	**Top Depth**	**TOC***	**HI***	**S1***	**S2***	**Calc.Ro**	**PI***	**%Type IV 50 HIº**	**% Type III 125 HIº**	**%Type II 450 HIº**	**%Type I 750 HIº**	**HIº**	**TR**	**TOCº**	**S2º**	**Remaining Potential**	**Original Potential**	**Oil Cracked**	**S1 Free Oil**	**Estimated Oil**	**Cracked Gas**
Tarlee S3	**(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**
LH14DJR045	1208	1.46	10	0.11	0.15	**1.63**	0.42	0	0	100	0	450	0.99	1.98	8.93	3	195	0.84	2	30	973
Upper Velkerri (Avg)		**1.46**	**10**	**0.11**	**0.15**	**1.63**	**0.42**	**0**	**0**	**100**	**0**	**450**	**0.99**	**1.98**	**8.93**	**3**	**195**	**0.84**	**2**	**30**	**973**
LH14DJR046	1257	2.70	16	0.32	0.43	**1.84**	0.43	0	0	100	0	450	0.98	3.64	16.36	9	358	0.99	7	4	2071
LH14DJR047	1301	2.03	11	0.14	0.22	**2.16**	0.39	0	0	100	0	450	0.98	2.75	12.36	5	271	1.00	3	0	1596
LH14DJR048	1351	2.81	11	0.19	0.31	**1.80**	0.38	0	0	100	0	450	0.98	3.79	17.03	7	373	0.97	4	10	2139
LH14DJR049	1400	0.46	6	0.02	0.03	**2.59**	0.40	0	0	100	0	450	0.99	0.63	2.86	1	63	1.00	0	0	371
LH14DJR050	1450	2.75	2	0.09	0.06	2.37	0.60	0	0	100	0	450	1.00	3.72	16.73	1	366	1.00	2	0	2190
LH14DJR051	1481	12.20	0	0.04	0.05	2.37	0.44	0	0	100	0	450	1.00	15.62	70.27	1	1539	1.00	1	0	9227
LH14DJR052	1547	6.68	1	0.08	0.04	**2.75**	0.67	0	0	100	0	450	1.00	8.83	39.72	1	870	1.00	2	0	5213
LH14DJR053	1590	3.25	1	0.07	0.03	**3.11**	0.70	0	0	100	0	450	1.00	4.38	19.72	1	432	1.00	2	0	2587
Middle Velkerri (Avg)		**4.11**	**6**	**0.12**	**0.15**	**2.37**	**0.50**	**0**	**0**	**100**	**0**	**450**	**0.99**	**5.42**	**24.38**	**3**	**534**	**1.00**	**3**	**2**	**3174**
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)