
PetraGas Ltd

C/- 169 Fullarton Rd, Dulwich 5065, South Australia

**ANNUAL TECHNICAL REPORT
KEMPTON PROJECT
EL3/2013**

For the period 16th January 2014 to 15th January 2015

**P.W. REID & M. MESSEILLER
10 JANUARY 2015**

ABSTRACT

The licence area covers a portion of the southern extent of the onshore Tasmania Basin. Historical work undertaken by exploration companies, government departments and universities have determined the folded lower Palaeozoic succession, the Wurawina Supergroup and the Carboniferous to Triassic succession, the Lower Permian Supergroup have hydrocarbon source rocks (e.g. Bacon et. al. 2000). Exploration work aims to test un-conventional shale oil/gas potential. Initial work involves an investigation of potential source rock material for its suitability.

Work completed during the period included:

- Compilation and review of previous exploration
- Compilation and review of open-file regional geophysical datasets; initial target area generation
- Land access discussions with land holders
- Inspection and sampling of drill core
- Reconnaissance road side field visit of tenement area and prospective source rock outcrops
- TOC and SRA analysis of source rock

An independent review of the data acquired by McKirdy Geoscience indicates that source rock intervals analyzed share geochemical similarities with the Upper Paleozoic Woodford and Barnett Shale's, which host major shale oil and gas reserves in the southern Midcontinent USA. Evidence of gas migration may also indicate conventional gas traps may be a viable exploration target.

Further source rock analysis needs to be undertaken to better characterize the potential of the basin. In addition year 2 work needs to focus on geophysical methods to better characterize basin morphology and depth utilizing gravity and or magneto-telluric studies.

CONTENTS

ABSTRACT.....	ii
1. INTRODUCTION	1
1.1 Authority history	1
1.2 Exploration rationale.....	2
2. PREVIOUS INVESTIGATIONS.....	5
3. EXPLORATION COMPLETED DURING THE REPORTING PERIOD CONCLUSIONS	5
3.1 Data compilation and review	5
3.2 Target source rocks	6
3.3 Exploration activities.....	7
4. RESULTS	8
5. CONCLUSIONS.....	10
6. ENVIRONMENT	10
7. EXPENDITURE.....	11
REFERENCES.....	12

FIGURES

Figure 1: Figure 1: Kempton Project location plan	2
Figure 2: Interpreted Tasmania Basin sediment thickness	6
Figure 3: Woody Island Formation thickness map.....	7

TABLES

Table 1: Kempton Project tenement particulars	1
Table 2: Total Organic Carbon (TOC) results from core and outcrop.....	9
Table 3: Source Rock Analysis results	9
Table 4: Year 1 Expenditure	11

APPENDICES

Appendix 1: TOC Geochemistry (digital file only)	
Appendix 2: SRA Data (digital file only)	
Appendix 3: SRA Pyrograms (digital file only)	
Appendix 4: Organic Richness and Thermal Maturity of Potential Source Rocks, Review Report	

1. INTRODUCTION

In February 2013, Petratherm, through its wholly owned subsidiary PetraGas Limited, applied for an oil and gas exploration licence north of Hobart (EL3/2013), exploring for both conventional and unconventional oil and gas. As part of the licence application process, PetraGas responded to 22 written submissions from potentially affected landowners and this resulted in some areas being excised from the licence application. EL3/2013 (Kempton) was formally granted on the 16th January 2014.

The licence area covers a portion of the southern extent of the onshore Tasmania Basin. Historical work undertaken by exploration companies, government departments and universities has determined the folded lower Palaeozoic succession, the Wurawina Supergroup and the Carboniferous to Triassic succession of the Lower Parmeener Supergroup have hydrocarbon source rocks (Bacon et. al. 2000).

Exploration work aims to test un-conventional shale oil/gas potential and initially plans to investigate source rock material for its suitability. All maps and locational data provided in the report uses the GDA 94 reference datum.

1.1 Authority history

The Kempton Project tenure comprises one granted Exploration Licence covering an area of 3840 km² (Figure 1). Exploration Licence EL3/2013 is held by PetraGas Ltd a 100% owned subsidiary of ASX listed geothermal exploration and development company, Petratherm Limited. The tenement has been granted for a period of five years. Tenement details are provided in Table 1.

TENEMENT	SIZE (km ²)	GRANT DATE	MINIMUM EXPENDITURE FIRST 2 YEARS
EL 3/2013	3840	16/01/2014	300,000

Table 1: Kempton Project tenement particulars

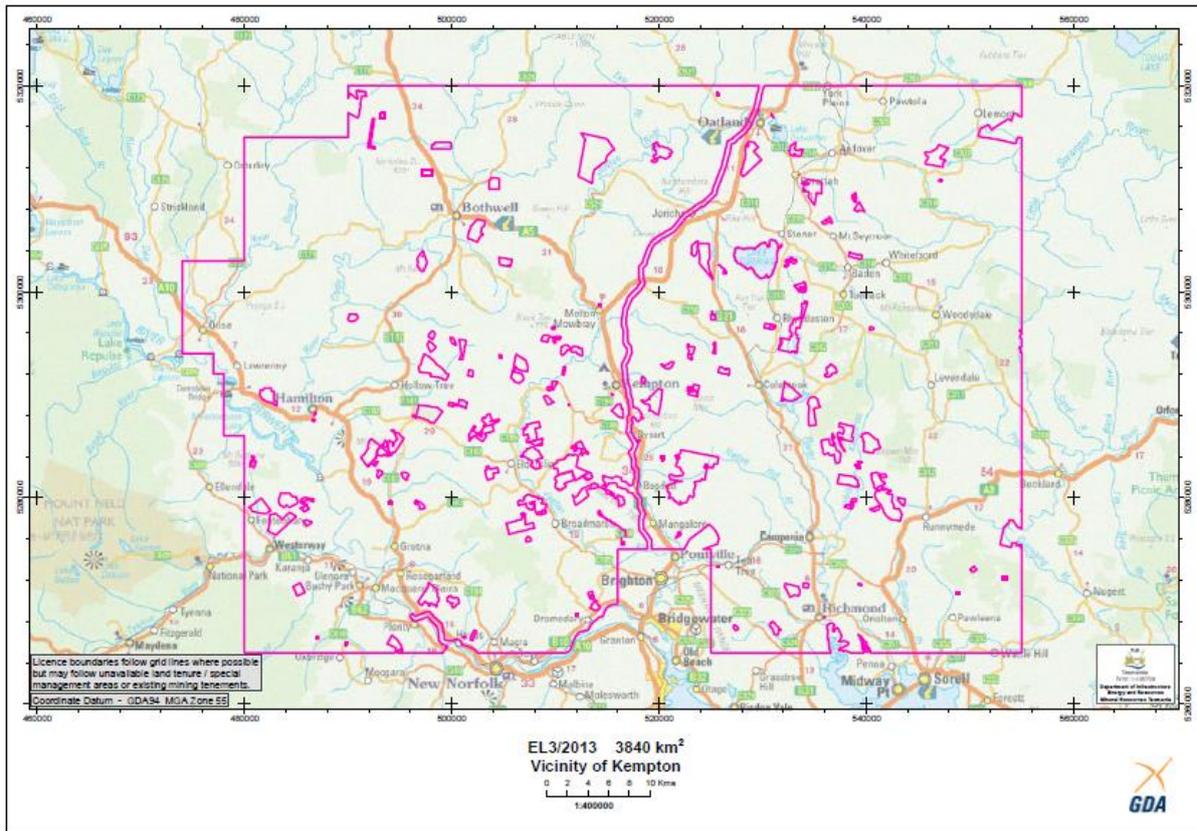


Figure 1: Kempton Project location plan

1.2 Exploration rationale

The licence area covers a portion of the southern extent of the onshore Tasmania Basin. Notably the area is traversed by the Tasmanian Gas Pipeline which may provide a connection point to market. Historical work has determined the folded lower Palaeozoic succession, the Wurawina Supergroup and the Carboniferous to Triassic succession, the Lower Parmeener Supergroup, have hydrocarbon source rocks (e.g. Bacon et al, 2000).

One key target sequence is the organic siltstone of the Woody Island Formation, which reaches its thickest developments in excess of 200 metres in a region north of Hobart which is under the licence area. Vitrinite reflectance analyses indicate in this region that the formation is in the oil generation with entry into the gas window (Reid et al, 2004). Similarly the older Ordovician sequences which underlie the Tasmania Basin strata will also be targeted as these have been shown to be organically rich and demonstrate the right thermal maturity to generate oil and gas.

As the exploration model is targeting un-conventional shale oil/gas, the play is less concerned about locating potential reservoirs and trap sites but rather large thicknesses of source rock material that

may be amenable to fracture stimulation methods such that commercial rates of oil/gas could potentially be extracted.

2.0 PREVIOUS INVESTIGATIONS

Onshore exploration for hydrocarbons has occurred on a small scale for approximately 100 years spurred on largely by reported presence of oil and gas seeps. Very few however of the over 100 historical seeps reported have found to be later valid. These reports along with the occurrence of the Tasmanites oil shale contained within the late Carboniferous, Woody Island Formation has motivated some 13 companies to actively explore for oil in the last 75 years. Exploration however has been crude and almost no modern systematic exploration tools have been used to locate and test potential hydrocarbon trap accumulation sites.

Small deposits of Late Carboniferous oil shale have been investigated on several occasions as a potential source of hydrocarbons or road bitumen. During the 1930's a number of experimental reports which trialed to produce a variety of hydrocarbons but were never successful in being commercialised. A detailed historical summary of the Tasmania Basins seeps, bitumen's and gas shows can be found in Bulletin 71 produced by Mineral Resources Tasmania, compiled by Bacon *et al* in 2000.

Some 38 shallow wells have been drilled in onshore Tasmania, for the purpose of exploring for oil or gas, without any detailed knowledge of structure or stratigraphy. Most wells are drilled to depths of 350 metres or less and most bottomed in Jurassic dolerite. A peak of activity occurred in the 1920s, driven by a Commonwealth Government reward of £10,000 for the discovery of payable oil anywhere in Australia. Most activity occurred in the region between Devonport and Launceston, northern Tasmania. Gas was reported from 335m in the Iles well at Port Sorell in 1923, drilled by The Adelaide Oil and Exploration Company Ltd. The source of the gas, contained in a tertiary sand, has been postulated to be the result of decomposing vegetable matter (peat, lignite) producing a methane gas (Bacon *et al*,2000).

Another phase of activity occurred from 1967-1974, when 7 wells were drilled west and north- west of Launceston. The wells ranged in depths from 50-831 meters and all bottomed in the Jurassic dolerite. In 1981 Victor Petroleum and Resources Ltd in partnership with the Northwest Bay Co. Pty Ltd, held exploration licences covering a large part of the Midlands for coal and oil. A preliminary

report on the potential onshore Tasmania Basin was made and some rock samples maturity analyses showed that the sequence had at one time been through the oil producing window. One sample of Woody Island Siltstone returned 1.2% Carbon.

From 1984, various licenses were taken out over the central and southern Tasmania Basin by Great South Land Minerals (GSLM) and its predecessor companies, Condor Oil Pty Ltd and Conga Oil Pty Ltd. Geochemical analyses using current technologies was carried out on source rocks, seeps, tars and bitumen's. In addition a large amount of infill gravity and magnetic data was captured to try and model the first-order structure of the Tasmania Basin. Work was initially concentrated on the possibility of oil generation from the Gordon Group Limestone but more recent exploration has been premised on sources within the Tasmania Basin, particularly the tasmanite.

Short lines of seismic were acquired in the waters around and on Bruny Island. In the 1990's routine geochemical analyses were carried out on new sample material. In 1994, Condor Oil Pty Ltd commenced drilling 2 stratigraphic wells (Shittim- I, and Gilgal-1). Shittim-I was completed to a depth of 1751m in 1996/7 and encountered around 600m of Permian glaciogene sediments intruded by two dolerite sills, and reached metamorphic basement. In 1997, the stratigraphic well campaign was continued by GSLM with the completion of Jericho-1 (640m) on Bruny Island, followed by Lonnavale-1(557m), Hunterston-1 (336m), Bridgewater-1 252m, and Pelham-1 503m. All wells have been suspended in the Permian sequence or in the Jurassic dolerite.

Gas shows have been recorded in wells, Shittim-1, Jericho-1 and Lonnavale-1, with methane and C2-C6 hydrocarbons detected in cuttings gas and trip gas. The gas from Shittim-1 has been analyzed and shown to be a highly mature thermal gas with the presence of methane, carbon dioxide, nitrogen, hydrogen and helium. The latter two gases indicate a source from deep in the basement. Since well locations have not been located on structural features constrained by seismic data, it is not surprising that there are few reports of hydrocarbons.

In 2000, Mineral Resources Tasmania published a detailed review of the petroleum potential of onshore Tasmania (Bacon et al, 2000), which critically looked at potential source rocks, thermal history, potential reservoirs, seals and traps. The study included some source rock analysis to determine hydrocarbon potential across the basin. Most recently the School of Earth Sciences, University of Tasmania under took Petroleum System Modelling research for the on-shore Tasmania

Basin (Reid, 2002; Reid and Burrett, 2004). This work highlights source rocks and the potential for both oil and gas prone sequences within portions of the basin.

3.0 EXPLORATION COMPLETED DURING THE REPORTING PERIOD

Exploration undertaken during the period has included:

- Compilation and review of previous exploration
- Compilation and review of open-file regional geophysical datasets; initial target area generation
- Land access discussions with land holders
- Inspection and sampling of drill core
- Reconnaissance road side field visit of tenement area and prospective source rock outcrops
- Total Organic Carbon (TOC) and Source Rock Analysis (SRA) of potential source rocks

3.1 Data compilation and review

Government databases were interrogated to identify work undertaken by previous explorers, government officers, and researchers. Digital compilation of historical geochemical, geological and geophysical data into ArcGIS format was undertaken. Particular focus was given to historical drilling and identifying of potential source rock material for analysis from core or outcrop. One of the exploration risks identified is that much of the potential source rock material occurs at relatively shallow depths (<800m). Regional geophysical surveys were compiled to identify general basin architecture to try and locate thick source rock accumulations and deeper portions of the basin that would be far more amenable for un-conventional oil/gas exploitation.

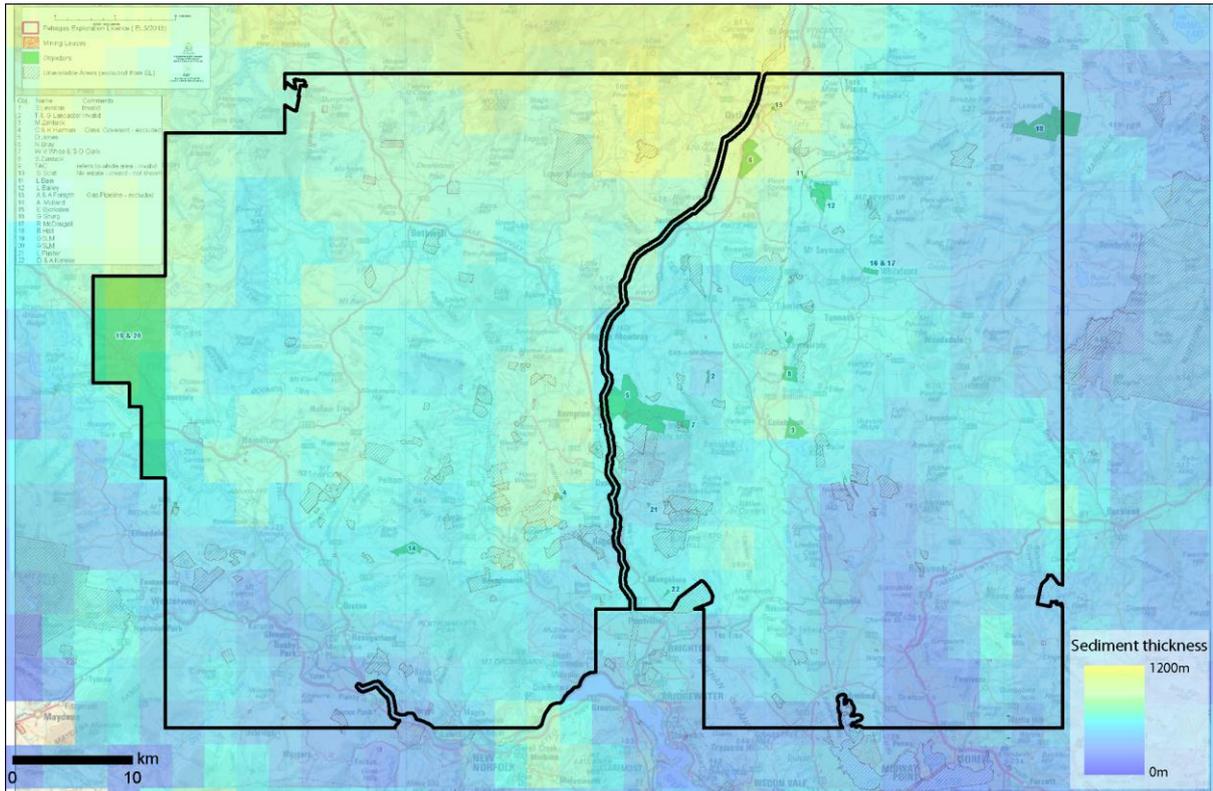


Figure 2: Interpreted Tasmania Basin sediment thickness based on modelling of geophysical data and drill hole information.

3.2 Target Source Rocks

Source Rocks focused on during the period are contained in the Late Carboniferous to Triassic Tasmania Basin. Here thick basal marine sequences occur, some with relatively high organic content. The Woody Island Shale is up to 250 metres thick in the vicinity of Hobart (Figure 3) and reported Total Organic Carbon ranges between 0.5-2% but includes in places thin Tasmanite Oil Shale at its base, which consists of a number of thin organic-rich bands (typically 30cm) with a recorded TOC ranging between 8 – 30%. Intervening Woody Island shale's between the Tasmanite bands have also been reported to have elevated TOCs ranging between 1-2%. This lower section is a potential target.

The basin is mature through the central and southern portions of the Tasmania Basin over the Licence area. Thermal maturation studies have shown the Woody Island Formation contains gas-prone and oil-prone source rocks in the licence area. In addition late stage dolerites may have provided locally elevated maturation where these intrusives occur. Very little exploration has been carried out – the true potential of the basin is still to be discovered.

the results were submitted to McKirdy Geoscience to generate an independent professional opinion on the data, and his report is presented as Appendix 4 of this report.

4.0 RESULTS

Results from analyses averaged 0.89% TOC for the Woody Island Formation. The quarry samples range between 0.6 and 0.9% and these measurements are likely to take into account the free hydrocarbons responsible for the strong petroliferous smell as only a very small portion may have been lost when crushing the rock. Further characterization is needed to investigate the free hydrocarbons and their implication for shale gas. The Liffey Group shows much higher TOCs (average of 1.5%). This is explained by the carbonaceous rich horizons and presence of coal. The Bundella mudstone sample records the highest value of 4.4% for one sample, a highly carbonaceous shale (Table 2).

The SRA analyses showed (Table 3) that the Hydrogen Indexes (HI) are not high for any of the samples where a remaining hydrocarbon generative potential (S2) was observed. Volatile hydrocarbon (S1- free HC) are also relatively low with the Tunbridge and Woody Island quarry samples showing the highest responses. A number of the samples from the Ross and Granton Wells showed no discernible S2 peak and low S1 – these are likely to have passed through the oil and wet gas windows. There is some potential shown in the shallowest of the Ross Well samples which suggests this section hasn't reached full maturity (Ro calc 0.85).

The data from the Tunbridge samples indicates this has passed into the wet-gas window (most reliable value was Ro calc 1.24) and the Hunterston & Woody Island Quarry samples are at the top of the oil window (Ro calc ~0.9).

There are some interesting features in the pyrograms too (refer to Appendix 4), with a bimodal distribution observed which is commonly associated with migration of Hydrocarbons. This may indicate there may have been generation and mobilization of oil within these sections, though there is no way of quantifying this from these samples.

Sample	X	Y	Depth (m)	Formation	Lithology	Weathering	TOC	RockEval	XRD	Comments	Sample type	Total carbon (%)	Inorganic Carbon (%)	TOC (%)
WI01	465652	5262024	0	Woody Island Fm	Dark siltstone	fresh				strong petroliferous odour, bottom of stratigraphy in the quarry	Quarry			
WI02	465633	5262024	0	Woody Island Fm	Dark siltstone	fresh	1	1		moderate petroliferous odour, middle of stratigraphy in the quarry	Quarry	1.19	0.23	0.96
WI03	465651	5262023	0	Woody Island Fm	Dark siltstone	fresh	1	1		very strong petroliferous odour, bottom of stratigraphy in the quarry	Quarry	1.14	0.24	0.90
WI04	465636	5262002	0	Woody Island Fm	Dark siltstone	fresh				moderate petroliferous odour, top of stratigraphy in the quarry	Quarry			
WI05	465722	5261963	0	Woody Island Fm	Dark siltstone	fresh	1	1		strong petroliferous odour, top of stratigraphy in the quarry	Quarry	0.81	0.12	0.69
WI06	467661	5259169	0	Wynyard tillite	Tillite	moderate				Highly weathered, close to contact with overlying Woody Island Fm	Road side			
WI07	468604	5259549	0	Woody Island Fm	Siltstone	moderate				petroliferous odour	Road side			
WI08	472877	5259719	0	Woody Island Fm	Siltstone	very strong				No sample, top of Woody Island, petroliferous odour	Road side			
WI09	475043	5391865	0	Woody Island Fm	Siltstone	strong				Quamby Mudstone, no carbonaceous trace, no odour	Road side			
Hun1 Hunterston 01	495614	5326590	932.95	Woody Island Fm	Siltstone	fresh	1	1		dark grey mudstone, with rare clasts, gradational transition to sandstone from 950m	Half core	3.23	2.47	0.76
Tunbridge BH2 01	524516	5335035	350.6	Liffey Group	Shale	Fresh	1	1		dark grey, finely laminated, carbonaceous	Half core	0.85	0.05	0.80
Tunbridge BH2 02	524516	5335035	361.4	Liffey Group	Shale	Fresh	1	1		dark grey, finely laminated, carbonaceous	Half core	2.23	0.02	2.21
Tunbridge BH2 03	524516	5335035	390.15	Bundella	Shale	Fresh	1	1		finely laminated, dark grey	Half core	4.37	0.03	4.34
Tunbridge BH2 04	524516	5335035	639.85	Woody Island Fm	Siltstone	Fresh	1	1	1	fine grained, dark grey siltstone	Half core	1.49	0.14	1.35
Tunbridge BH2 05	524516	5335035	679.0	Woody Island Fm	Siltstone	Fresh	1	1	1	fine grained, dark grey siltstone	Half core	0.47	0.13	0.34
GR-DOM1 Granton 01	515727	5266676	132.7	Liffey Group	Shale	Fresh	1	1		carbonaceous shale, finely laminated, with thin sandstone intervals	Half core	1.14	0.03	1.11
GR-DOM1 Granton 02	515727	5266676	157.8	Liffey Group	Shale	Fresh	1	1		carbonaceous shale, finely laminated, with thin sandstone intervals	Half core	2.53	0.05	2.48
ROSS-R1 01	554791	5331369	98.6	Woody Island Fm	Siltstone	fresh	1	1		mudstone, getting gradationally darker with depth	Half core	0.86	0.03	0.83
ROSS-R1 02	554791	5331369	109.9	Woody Island Fm	Siltstone	fresh	1	1		mudstone, getting gradationally darker with depth	Half core	1.05	0.04	1.01
ROSS-R1 03	554791	5331369	120.55	Woody Island Fm	Siltstone	fresh	1	1		mudstone, getting gradationally darker with depth	Half core	1.19	0.04	1.15
ROSS-R1 04	554791	5331369	127.75	Woody Island Fm	Siltstone	fresh	1	1		mudstone, getting gradationally darker with depth	Half core	0.81	0.08	0.73
ROSS-RG 146 01	536395	5347351	133.8	Liffey Group	Siltstone	fresh	1	1		Altered pebbly mudstone, calcareous, carbonate clasts	Half core	1.25	0.50	0.75
ROSS-RG 146 02	536395	5347351	366.45	Woody Island Fm	Siltstone	fresh	1	1		massive mudstone, dark grey with rare debris	Half core	0.94	0.05	0.89
ROSS-RG 146 03	536395	5347351	393.5	Woody Island Fm	Siltstone	fresh	1	1	1	massive mudstone, dark grey with rare debris	Half core	1.37	0.27	1.10
ROSS-RG 146 04	536395	5347351	412.6	Woody Island Fm	Siltstone	fresh	1	1	1	massive mudstone, dark grey with rare debris	Half core	1.26	0.07	1.19
ROSS-RG 146 05	536395	5347351	419.75	Woody Island Fm	Siltstone	fresh	1	1	1	massive mudstone, dark grey with rare debris	Half core	0.61	0.04	0.57

Table 2: Total Organic Carbon (TOC) results from core and outcrop

Client ID	Top Depth (m)	Sample Type	Sample Prep	* SRA TOC	S1	S2	S3	Tmax (°C)	** Calc. % Ro	HI	OI	S2/S3	S1/TOC *100	PI	Notes	Lab ID
ROSS-RG 146 05	419.75	Siltstone	Woody Island Fm	0.57	0.03				1.00				5	1.00		SRA STD
ROSS-RG 146 04	412.6	Siltstone	Woody Island Fm	1.19	0.10				1.00				8	1.00		SRA STD
ROSS-RG 146 03	393.5	Siltstone	Woody Island Fm	1.10	0.10				1.00				9	1.00		SRA STD
ROSS-RG 146 02	366.45	Siltstone	Woody Island Fm	0.89	0.16				1.00				18	1.00		SRA STD
ROSS-RG 146 01	133.8	Siltstone	Liffey Group	0.75	0.03	0.43		445	0.85	57			4	0.07		SRA STD
ROSS-R1 04	127.75	Siltstone	Woody Island Fm	0.73	0.02				1.00				3	1.00		SRA STD
ROSS-R1 03	120.55	Siltstone	Woody Island Fm	1.15	0.05				1.00				4	1.00		SRA STD
ROSS-R1 02	109.9	Siltstone	Woody Island Fm	1.01	0.05				1.00				5	1.00		SRA STD
ROSS-R1 01	98.6	Siltstone	Woody Island Fm	0.83	0.05				1.00				6	1.00		SRA STD
GR-DOM1 Granton 02	157.8	Shale	Liffey Group	2.48	0.04				1.00				2	1.00		SRA STD
GR-DOM1 Granton 01	132.7	Shale	Liffey Group	1.11	0.02				1.00				2	1.00		SRA STD
Tunbridge BH2 05	679	Siltstone	Woody Island Fm	0.34	0.08	0.06		458	x	1.09	18		24	0.57		SRA STD
Tunbridge BH2 04	639.85	Siltstone	Woody Island Fm	1.35	0.54	0.31		440	x	0.76	23		40	0.64		SRA STD
Tunbridge BH2 03	390.15	Shale	Bundella	4.34	0.53	2.55		468	x	1.27	59		12	0.17		SRA STD
Tunbridge BH2 02	361.4	Shale	Liffey Group	2.21	0.12	0.34		436	x	0.69	15		5	0.26		SRA STD
Tunbridge BH2 01	350.6	Shale	Liffey Group	0.80	0.09	0.10		467	x	1.24	12		11	0.47		SRA STD
Hun1 Hunterston 01	932.95	Siltstone	Woody Island Fm	0.76	0.28	0.48		450	0.94	63			37	0.37		SRA STD
WI05		Dark siltstone	Woody Island Fm	0.69	0.37	0.45		447	0.89	65			53	0.45		SRA STD
WI03		Dark siltstone	Woody Island Fm	0.90	0.59	0.61		449	0.93	68			65	0.49		SRA STD
WI02		Dark siltstone	Woody Island Fm	0.96	0.42	0.37		432	x	0.62	39		44	0.53		SRA STD

Notes:
 "--" - not measured or invalid value for Tmax
 TOC - Total Organic Carbon, wt. %
 S1 - volatile hydrocarbon (HC) content, mg HC/ g rock
 S2 - remaining HC generative potential, mg HC/ g rock
 S3 - carbon dioxide content, mg CO₂/ g rock
 * - comments regarding contamination
 ** - low S2, Tmax is unreliable
 Meas. %Ro - measured vitrinite reflectance
 HI - Hydrogen index = S2 x 100 / TOC, mg HC/ g TOC
 OI - Oxygen Index = S3 x 100 / TOC, mg CO₂/ g TOC
 PI - Production Index = S1 / (S1+S2)
 Pyrogram:
 f - flat S2 peak
 n - normal
 hS2sh - low temperature S2 shoulder
 hS2p - low temperature S2 peak
 htS2p - high temperature S2 peak
 Calculated%VRo = 0.0180 x Tmax - 7.16 (Jarvie et al., 2001)
 LECO - TOC on Leco Instrument
 RE - Programmed pyrolysis or
 TOC on Rock-Eval instrument
 EXT - Extracted Rock
 NPRE - Normal Preparation

Table 3: Source Rock Analysis Results

5.0 CONCLUSIONS

In summary, the first analysis of potential source rock TOC indicate the Woody Island Formation is a marginal source rock. Recent studies however working on the relationship between TOC and productivity on the north American shale gas play have shown that lower TOCs (between 1 and 2%) have a better productivity than some higher TOC shale's, so some potential may still exist for the Lower Woody Island Formation where the Tasmanites may be present.

The independent review of data by McKirdy Geoscience, indicates that all three source rock intervals analyzed share geochemical similarities with the Upper Paleozoic Woodford and Barnett Shale's, which host major shale oil and gas reserves in the southern Midcontinent USA. Evidence of gas migration may also indicate conventional gas traps may be a viable exploration target.

Further source rock analysis needs to be undertaken to better characterize the potential of the basin. In addition year 2 work needs to focus on geophysical methods to better characterize basin morphology and depth utilizing gravity and or magneto-telluric studies.

6.0 ENVIRONMENT

No ground disturbing activities were undertaken in the first year of licence tenure. During the licence application process there was a moderate level of concern raised from stake holders regarding petroleum exploration processes and potential later developments in the region. The number one concern relates to use of precious ground water and or potential contamination of these water sources which could jeopardise land holders farming viability and the green image marketed to consumers. The Company is in the early stages of evaluating the prospectivity of the licence area and prior to any ground activities extensive stakeholder consultation and an agreed program of works will be required to address these issues appropriately.

7.0 EXPENDITURE

Total expenditure for activities on EL 3/2013 are provided in Table 2 below.

EL3/2013

Item	Total
Geoscientific Costs	\$64,868
Land and Access	\$1,294
Other	\$16,985
Administration	\$9,196
Total	\$92,343

Table 4: Summary of exploration expenditure, Year 1, Kempton Project.

REFERENCES

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APPENDICES

Appendix 1: TOC Geochemistry (digital file only)

Appendix 2: SRA Data (digital file only)

Appendix 3: SRA Pyrograms (digital file only)

Appendix 4: Organic Richness and Thermal Maturity of Potential Source Rocks, Review Report

APPENDIX 4

Organic Richness and Thermal Maturity of Potential Source Rocks, Review Report

**ORGANIC RICHNESS AND THERMAL MATURITY OF
POTENTIAL HYDROCARBON SOURCE ROCKS,
LOWER PARMEENER SUPERGROUP,
TASMANIA BASIN**

A professional opinion prepared by

David M. McKirdy

McKirdy Geoscience

for



November 2013

Executive summary

The organic richness and thermal maturity of the Permian Woody Island Formation in the central Tasmania Basin qualify it as a potential source for unconventional gas resources. Its total organic carbon content is at the low end of the range for marine shales known to be sources of commercial accumulations of petroleum hydrocarbons, while its kerogen ranges from oil-prone Type I/II to dry gas-prone Type IV.

The volumetrically less significant shales and siltstones of the overlying Bundella Formation and Liffey Group are two to three times more organic-rich, although their kerogen is of poorer quality (Types III & IV).

Regional maturation levels decrease southward, from the peak-oil generation zone of catagenesis in the north of the basin to the dry gas zone of metagenesis along the Styx Valley. Dolerite intrusions have locally increased the thermal maturity of the Woody Island Formation in the vicinity of Ross and the Liffey Group at Granton.

The highest yields of free hydrocarbons (residual oil and gas) are found within the Woody Island Formation at Tunbridge and in the Styx Valley, making these localities the most prospective sites so far identified within the area encompassed by PetraGas's permit application EL3/2013.

Significantly, all three units exhibit many geochemical similarities with the Upper Palaeozoic Woodford and Barnett Shales, which host major shale oil and gas reserves in the southern midcontinent USA.

Introduction

This brief report was prepared in response to a request from Peter Reid (Exploration Manager) for a review of the available total organic carbon (TOC), Rock-Eval and programmed pyrolysis data on the Woody Island Formation (non-*Tasmanites* facies), Bundella Formation and Liffey Group. These units are potential targets for unconventional shale oil and gas in subsidiary PetraGas's proposed exploration of the onshore Tasmania Basin (application EL3/2013: Figure 1).

Newly acquired analytical data on 20 samples (17 drill hole, 3 outcrop) were compared with archival data on the same units collated by the Tasmanian Geological Survey (Bacon *et al.*, 2000) and more recent data from DDH Hunterston-1 (Reid *et al.*, 2003). Sample locations are shown in Figure 2.

The report addresses the following questions:

1. What is the organic richness of the aforementioned units and how does it vary across the study area?
2. What is the kerogen type and present thermal maturity of these units?
3. How do they compare with two Devonian-Carboniferous marine formations that host major shale oil and gas plays in the southern mid-continent USA?

Analytical data

The assembled organic geochemical data are presented in Tables 1–4 and Figures 3–6.

Organic richness

The TOC contents of the three units sampled in the study area (Figure 1) are summarised in Tables 1–3. In terms of conventional source rock richness, these values range from fair to very good. Their mean TOC contents range from 0.90% in the Woody Island Formation (n = 34), through 1.92% in the Liffey Group (n = 9), to 2.97% in the Bundella Formation (n = 2). The highest values recorded in each unit are 1.35%, 3.10% and 4.34%, respectively, all from the Tunbridge and Hunterston drill holes located in the central Tasmania Basin (Figure 2). The results for the Woody Island Formation compare favourably with those previously reported from Ross-1 (78-128 m depth, mean 1.1% TOC) and Bicheno-10 (mean 1.2%, maximum 1.7%: Bacon *et al.*, 2000).

The corresponding mean normalised free hydrocarbon yields (in mg HC/g TOC) range from 11 in the Liffey Group, through 21 in the Bundella Formation, to 38 in the Woody Island Formation, with the highest values being 25, 29 and 95, respectively. The highest yields (commonly >50 mg/g TOC) were obtained from the Woody Island Formation in the Tunbridge drill hole and the Styx Valley (Figure 2).

Kerogen type and thermal maturity

The hydrocarbon generative potential of a source rock depends on its kerogen type and thermal maturity, the assignment of which in this instance is based on the hydrogen index, Tmax and calculated vitrinite reflectance data summarised in Table 4.

Given the Permian age, carbonaceous pyritic shale/mudstone/siltstone lithofacies and suboxic marine depositional setting of the Woody Island and Bundella Formations (Bacon *et al.*, 2000), it is reasonable to assume that their original dispersed organic matter was mostly of algal origin, giving rise to oil and gas-prone Type II kerogen. The paralic depocentre of the Liffey Group shale would have received a greater input of allochthonous higher plant detritus, and so its protokerogen is likely to have been gas-prone Type III in composition.

The regional variation of both the thermal maturity and kerogen type of the Woody Island Formation (non-tasmanite facies) is illustrated in Figure 3. There is a clear trend of increasing thermal maturity from peak oil-generative Type I/II kerogen at Bicheno, Golden Valley and other northern localities, to late mature (light oil and wet gas-generating) and overmature (dry gas-generating) Type II and III kerogens at Tunbridge and in the Styx Valley. This interpretation is supported by methylphenanthrene index (MPI)-derived calculated vitrinite reflectance values of 1.35% for the Woody Island Formation (or its correlative) at Tunbridge-1 and Ross-2 (Bacon *et al.*, 2000, table 5). The apparent shift from Type II to Type III kerogen in the late oil window may in part reflect the micritisation of bituminite and other oil-prone liptinite macerals (e.g. alginite) following their catagenic release of liquid hydrocarbons.

Low free hydrocarbon yields from the Woody Island Formation at Ross-1 (3-6 mg/g TOC: Table 3) may be partly attributable to local heating by igneous intrusions (Bacon *et al.*, 2000). Here the base of the formation is 85 m above a 470+ m-thick dolerite sill. At Ross-2, where the base of the formation lies 63 m above a 21 m-thick dolerite intersection there is a steady decline in hydrocarbon yield, from 18 mg/g TOC at 366 m to 5 mg/g TOC at 420 m depth.

Likewise, the very low hydrocarbon yields from shale of the Liffey Group at Granton (2 mg/g TOC: Table 1), and the lack of an S2 peak in its pyrogram (Figure 4) suggests overmaturity due to baking by a dolerite intrusion. The pyrograms shown in Figure 4 illustrate three stages in the thermal progression of this source rock from late oil window to overmature (i.e. totally spent).

All marine shales undergo significant loss of organic carbon during the oil and gas-generation phases of thermal maturation (Raiswell and Berner, 1987). According to Hunt (1996), the maximum theoretical loss of TOC from a source rock during the generation and expulsion of hydrocarbons (oil and gas) is 48% for Type II kerogen, compared with 25% for Type III kerogen. The above estimates may be somewhat conservative. According to Behar and Vandenbroucke (1987), Type II kerogens lose ~60% of their original organic carbon during the oil generation phase of maturation (0.5–1.2% vitrinite reflectance).

Fate of generated hydrocarbons

Regardless of their kerogen type and initial hydrogen index, expulsion efficiencies for rocks containing less than 1–2% TOC are likely to be low (Peters *et al.*, 2005). Accordingly, in his petrographic study of the Devonian Woodford Shale, Lewin (1987) concluded that rocks with TOC values <2.5% contained insufficient dispersed organic matter to establish a continuous bitumen network, necessary for primary oil migration and expulsion to occur. In other words, the generated oil is retained in the source rock for subsequent cracking to gas. It is of interest that this formation was subsequently identified as a major source of unconventional oil and gas (Jarvie, 2008: see below).

Comparison with known shale oil and gas plays

In terms of their present organic richness, normalised hydrocarbon yield, hydrogen index and thermal maturity, three potential source rocks in the central and southern Tasmania Basin compare favourably with the aforementioned Woodford Shale and another formation, the Mississippian Barnett Shale (Jarvie *et al.*, 2005, 2007; Kinley *et al.*, 2008), which together host major shale oil and gas plays throughout Texas, Oklahoma, New Mexico and Kansas (Table 5).

Conclusions

The three units sampled display fair to good source rock potential for oil and gas, both conventional and unconventional. Although they are the least organic-rich, siltstones of the Woody Island Formation are

volumetrically more significant than the more carbonaceous shales of the overlying Bundella Formation and Liffey Group.

The highest normalised free hydrocarbon yields were measured in samples of the Woody Island Formation from the Tunbridge and Styx Valley localities, where it exceeds 200 m in thickness. This finding confirms the shale gas prospectivity of the western half of PetraGas's permit application.

Geochemically, these Tasmanian shales and siltstones appear remarkably similar to the Woodford and Barnett Shales which host major unconventional oil and gas resources in the southern USA.

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Table 1: TOC and programmed pyrolysis data on shale and siltstone from the Liffey Group

Location	Depth m	TOC	Tmax	S1	S2	S3	PI	HI	OI	S1/TOC
<i>Ross</i>										
RG-146*	133.8	0.75	445	0.03	0.43	nd	0.07	57	nd	4
<i>Tunbridge</i>										
BH-2*	350.6	0.80	[467]	0.09	0.10	nd	0.47	11	nd	11
	361.4	2.21	[436]	0.12	0.34	nd	0.26	5	nd	5
<i>Hunterston</i>										
Hun-1**	850.2	3.10	459	0.54	1.90	nd	0.22	61	nd	17
	856.5	2.35	464	0.38	1.84	nd	0.17	78	nd	16
	859.2	2.24	458	0.41	1.49	nd	0.22	67	nd	17
	869.5	2.20	464	0.55	1.51	nd	0.27	71	nd	25
<i>Granton</i>										
DOM-1*	132.7	1.11	nd	0.02	nd	nd	nd	nd	nd	2
	157.8	2.48	nd	0.48	nd	nd	nd	nd	nd	2

* Analyses performed by P.A. Hall (Sprigg Geobiology Centre, University of Adelaide)

** Based on archival TOC and Rock-Eval data (Reid *et al.*, 2003)

RG-146 = Ross-2 in Figure 2

Key

nd = not determined

[] = unreliable because of low S2

TOC = total organic carbon (wt %)

Tmax = temperature at which S2 peak reaches its maximum (°C)

HI = hydrogen index (mg hydrocarbons/g TOC)

S1 = free hydrocarbons (mg hydrocarbons/g rock) = residual oil

S2 = hydrocarbons released from kerogen (mg hydrocarbons/g rock)

S3 = CO₂ released from kerogen (mg CO₂/g rock)

PI = S1 / (S1 + S2)

HI = hydrogen index (mg S2/g TOC)

OI = oxygen index (mg S3/g TOC)

S1/TOC = mg free hydrocarbons/g TOC

Table 2: TOC and programmed pyrolysis data on shale and siltstone from the Bundella Formation

Location	Depth m	TOC	Tmax	S1	S2	S3	PI	HI	OI	S1/TOC
<i>Tunbridge</i>										
BH-2*	390.1	4.34	468	0.53	2.55	nd	0.17	59	nd	12
<i>Hunterston</i>										
Hun-1**	874.4	1.26	447	0.36	1.01	nd	0.26	80	nd	29

* Analysis performed by P.A. Hall (Sprigg Geobiology Centre, University of Adelaide)

** Based on archival TOC and Rock-Eval data (Reid *et al.*, 2003)

Key as in Table 1

Table 3: TOC and programmed pyrolysis data on siltstone and mudstone from the Woody Island Formation

Location	Depth m	TOC	Tmax	S1	S2	S3	PI	HI	OI	S1/TOC
<i>Ross</i>										
R-1*	98.6	0.83	nd	0.03	nd	nd	nd	nd	nd	6
	109.9	1.01	nd	0.05	nd	nd	nd	nd	nd	5
	120.5	1.15	nd	0.05	nd	nd	nd	nd	nd	4
	127.7	0.73	nd	0.02	nd	nd	nd	nd	nd	3
RG-146*	366.4	0.89	nd	0.16	nd	nd	nd	nd	nd	18
	393.5	1.10	nd	0.10	nd	nd	nd	nd	nd	9
	412.6	1.19	nd	0.10	nd	nd	nd	nd	nd	8
	419.7	0.57	nd	0.03	nd	nd	nd	nd	nd	5
<i>Tunbridge</i>										
BH-2*	639.8	1.35	[440]	0.54	0.31	nd	0.64	23	nd	40
	679.0	0.34	[458]	0.08	0.06	nd	0.57	18	nd	24
<i>Hunterston</i>										
Hun-1*	932.9	0.76	450	0.28	0.48	nd	0.37	63	nd	37
Mean **	n = 12	0.89	444	0.44	0.41	0.02	0.52	45	2	49
<i>Styx Valley Outcrop</i>										
W102*		0.96	432	0.42	0.37	nd	0.53	39	nd	44
W103*		0.90	449	0.59	0.61	nd	0.49	68	nd	65
W105*		0.69	447	0.37	0.45	nd	0.45	65	nd	53
Mean **	n = 8	0.80	454	0.44	0.57	0.05	0.44	65	7	55

* Analyses performed by P.A. Hall (Sprigg Geobiology Centre, University of Adelaide)

** Based on archival TOC and Rock-Eval data (Bacon *et al.*, 2000)

RG-146 = Ross-2 in Figure 3

Key as in Table 1

Table 4: Thermal maturity and kerogen type

Location	Depth m	Unit	Calc VR * %	Maturity **	Kerogen type **
<i>Ross</i>					
RG-146	133.8	LG	0.85	Late oil window	III
<i>Tunbridge</i>					
BH-2	350.6	LG	1.24	Overmature	III
	390.1	BF	1.27	Overmature	II
	639.8	WIF	0.76	Early oil window	IV
	679.0	WIF	1.09	Overmature	III
<i>Hunterston</i>					
Hun-1	874.4†	BF	0.89	Late oil window	III
	932.9	WIF	0.94	Late oil window	III
<i>Styx Valley Outcrop</i>					
W102		WIF	0.62	Initially mature	III-IV
W103		WIF	0.93	Late oil window	III
W105		WIF	0.89	Late oil window	III
S3#		WIF	1.01	Overmature	II
S6#		WIF	1.14	Overmature	II
S10#		WIF	0.98	Late oil window	II
S11#		WIF	0.69	Early oil window	II

* Calculated vitrinite reflectance, VR (%) = 0.018 x Tmax - 7.16 (Jarvie *et al.*, 2007)

** Based on comparison of HI and Tmax values in Tables 1–3 with Figure 3

† Based on data from Reid *et al.* (2003)

Based on data from Bacon *et al.* (2000)

LG = Liffey Group BF = Bundella Formation WIF = Windy Island Formation

Table 5: Geochemical comparison of potential Upper Palaeozoic shale oil and gas plays in Tasmania and the southern midcontinent USA

Unit	Thermal maturity window	Calc VR %	TOC %	HI	S1/TOC	n
<i>Tasmania Basin</i>						
Liffey Group	Late oil–early gas	1.08–1.19	1.92*	40	14	7
Bundella Formation	Late oil–early gas	0.89–1.27	2.97	70	21	2
Woody Island Formation	Early oil–early gas	0.62–0.94	0.85	56	38	21
<i>Midcontinent USA**</i>						
Woodford Shale	Late oil–early gas	0.92	2.04	73	17	40
	Late oil–early gas	1.02	3.93	87	70	32
Barnett Shale	Late oil–dry gas	0.86–2.10	4.04	67	33	858
	Dry gas	1.72	4.45	45	19	90

Key as for Tables 1–4

Values listed for each parameter are mean values, except where ranges are specified for certain calculated VR populations

* Includes two additional overmature samples from Granton-1

** Data from Jarvie (2008)

Figure 1: Location of PetraGas Limited exploration licence application EL3/2013 in Tasmania Basin (Petratherm, 2013)

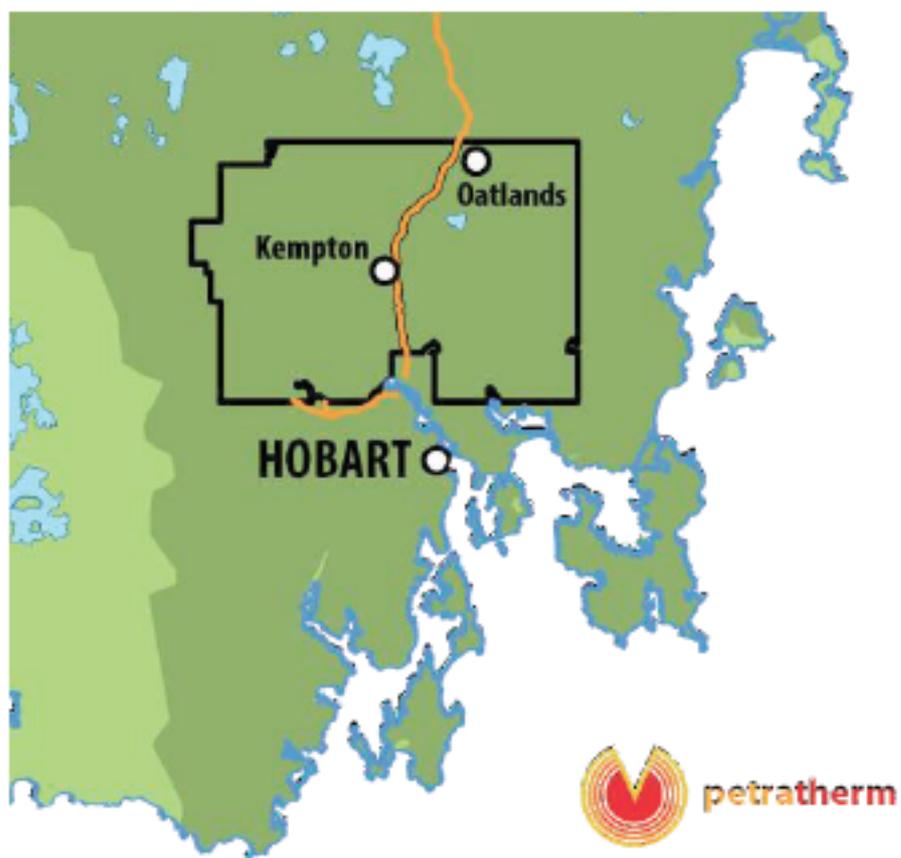


Figure 2: Palaeogeography of Lower Freshwater Sequence showing location of major drill holes (modified after Bacon *et al.*, 2000). Sites sampled for this study are highlighted in red.

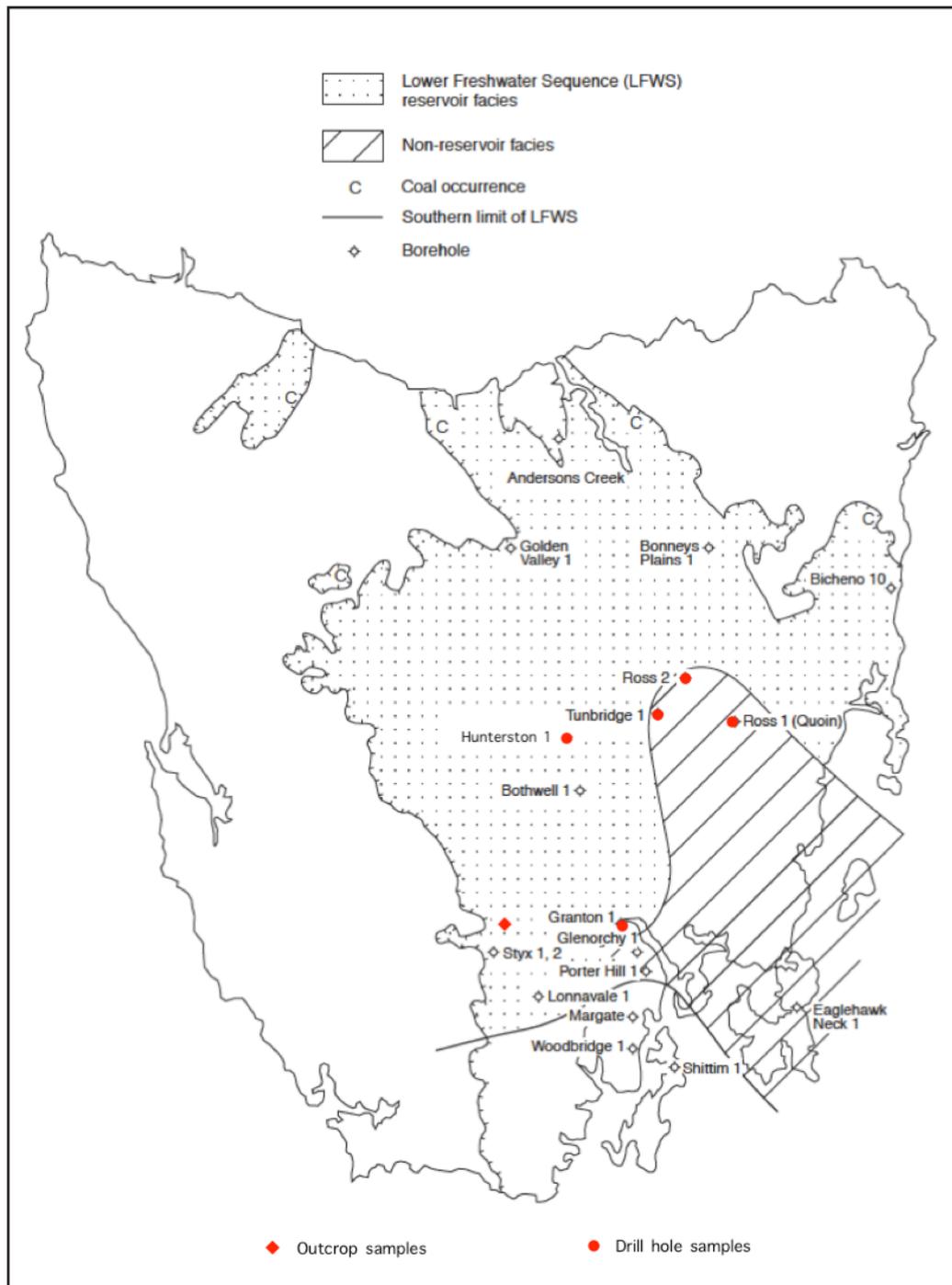


Figure 3: Kerogen type and maturity for Woody Island Siltstone and its correlative Quamby Mudstone (modified after Bacon *et al.*, 2000). Samples from the Tunbridge and Styx River localities are highlighted in red.

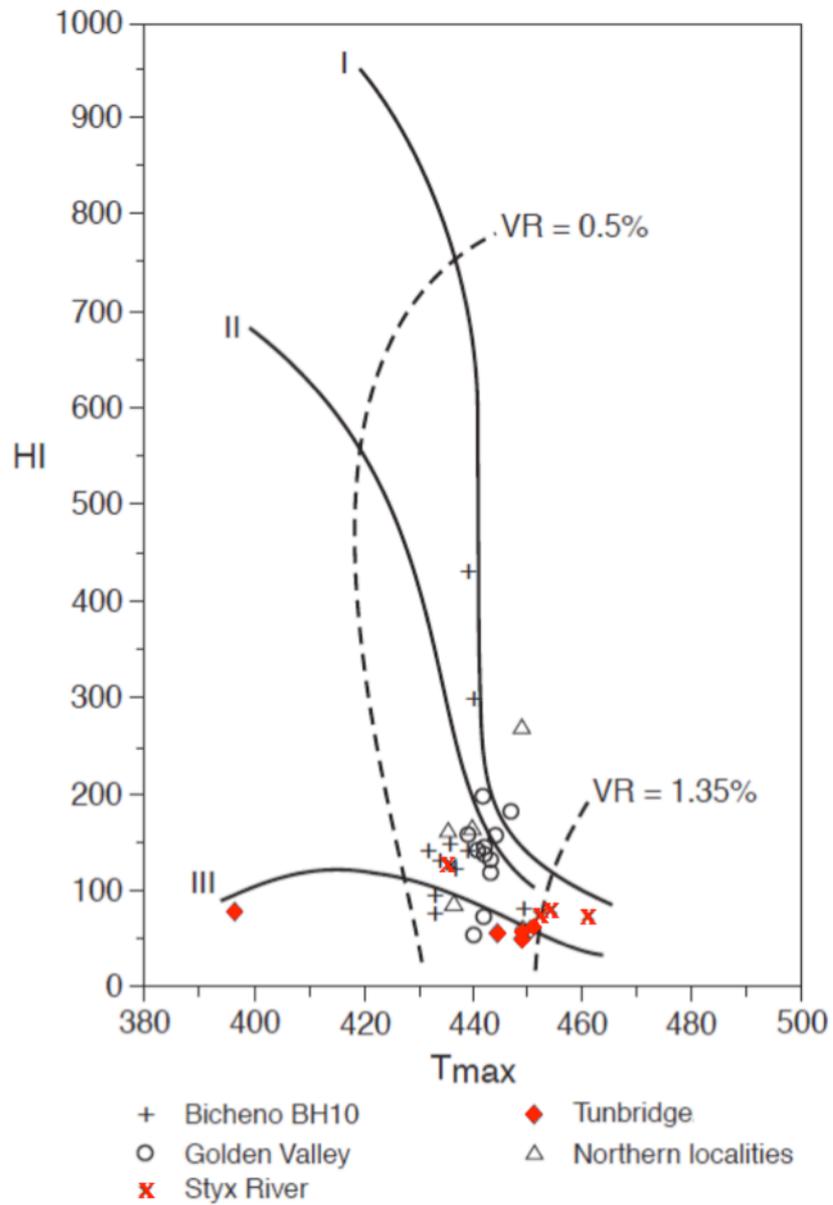


Figure 4: SRA pyrograms of Liffey Group

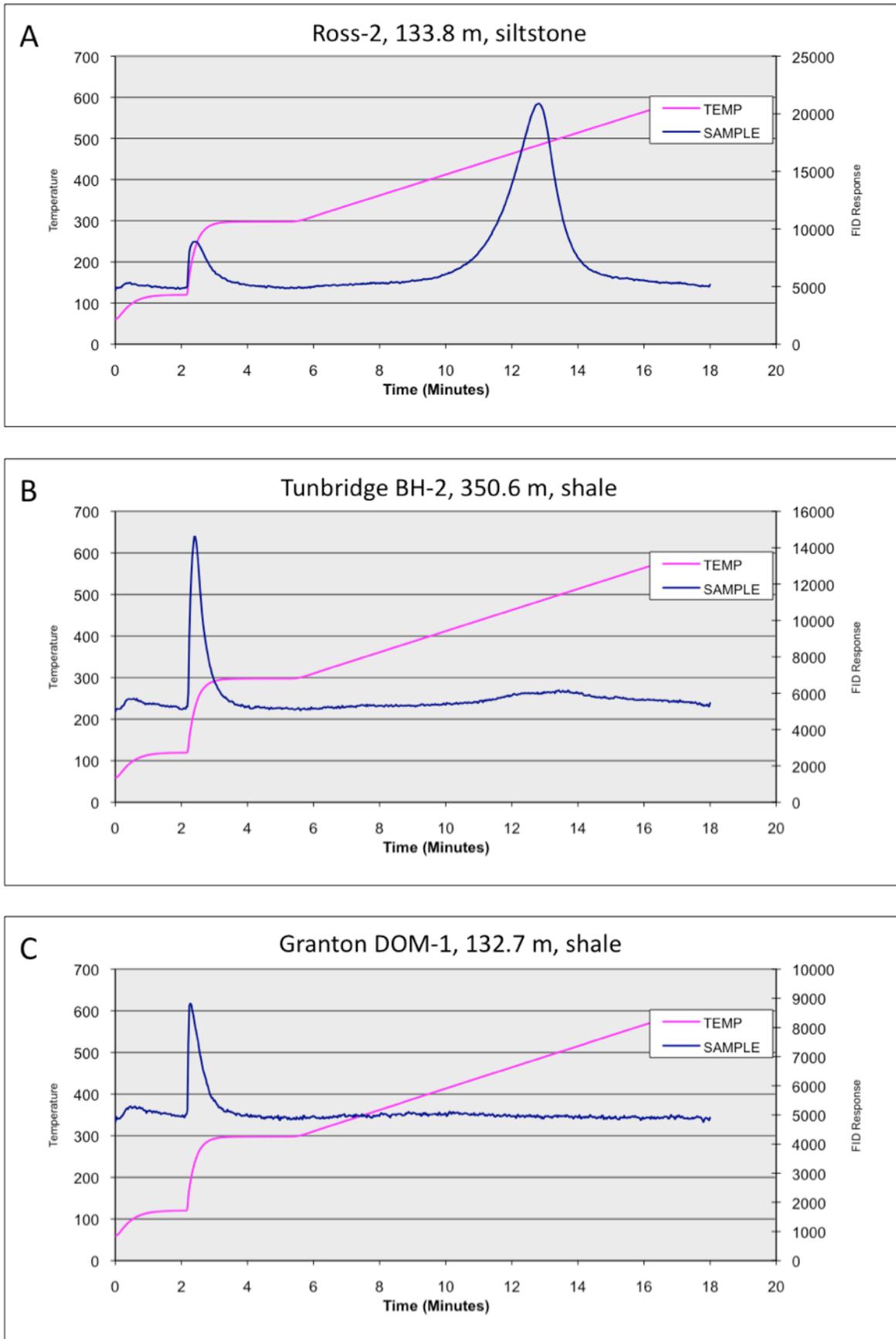


Figure 5: SRA pyrogram of Bundella Formation

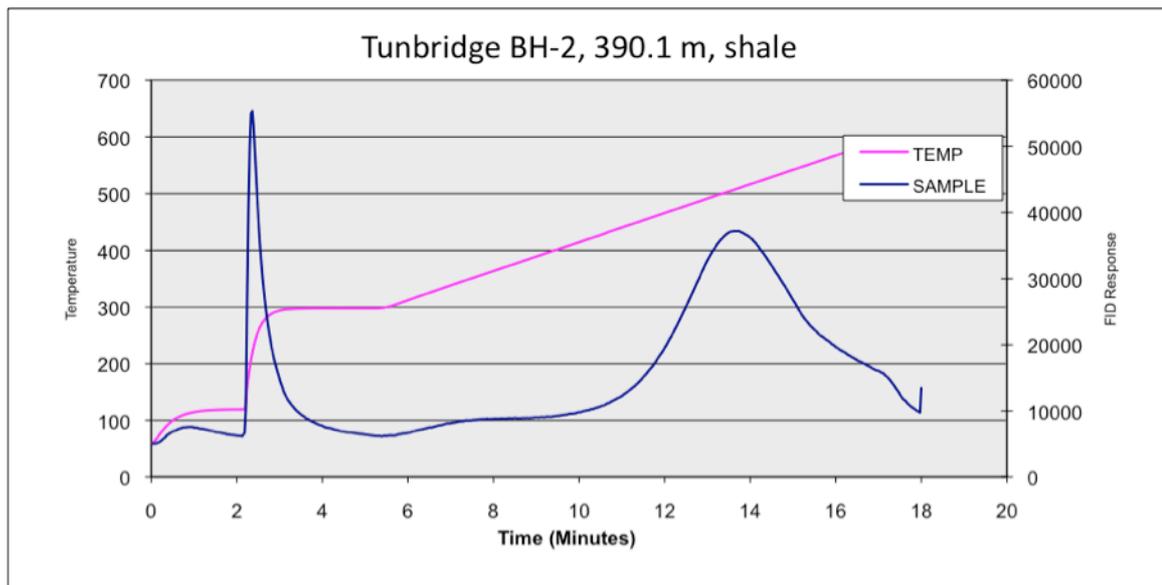
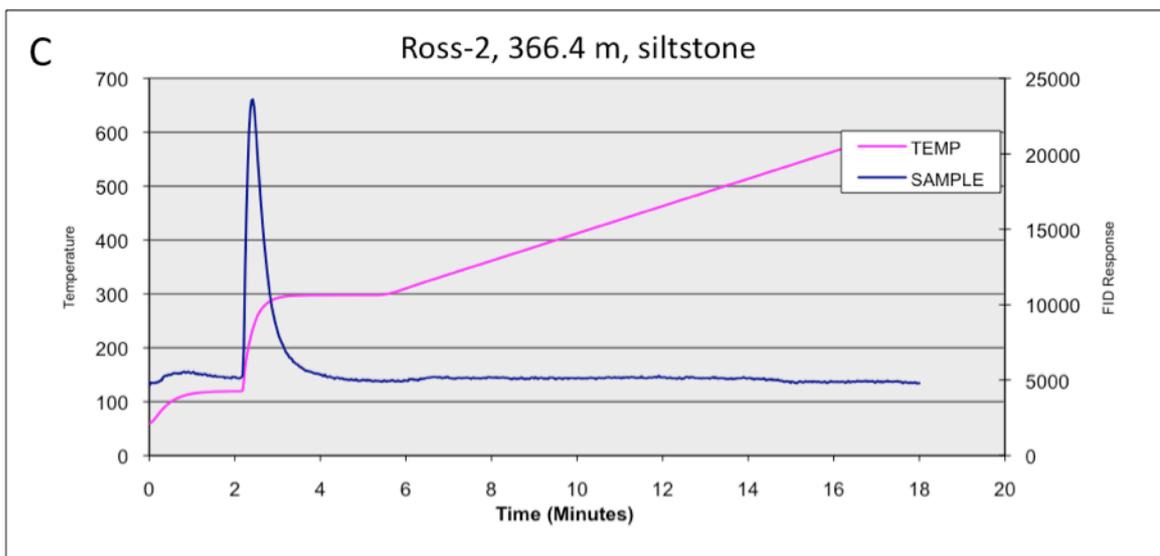
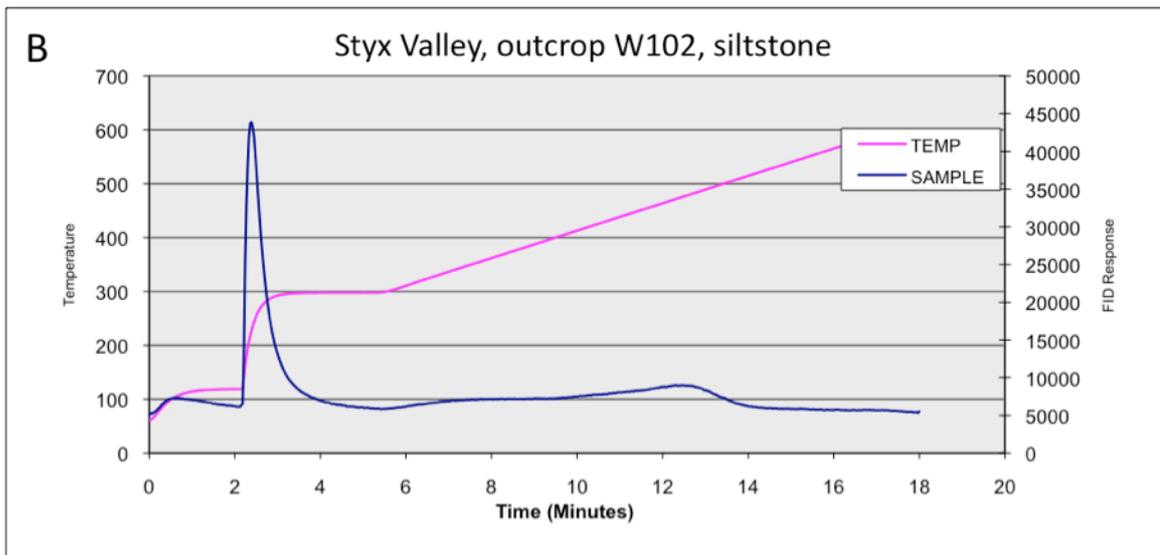
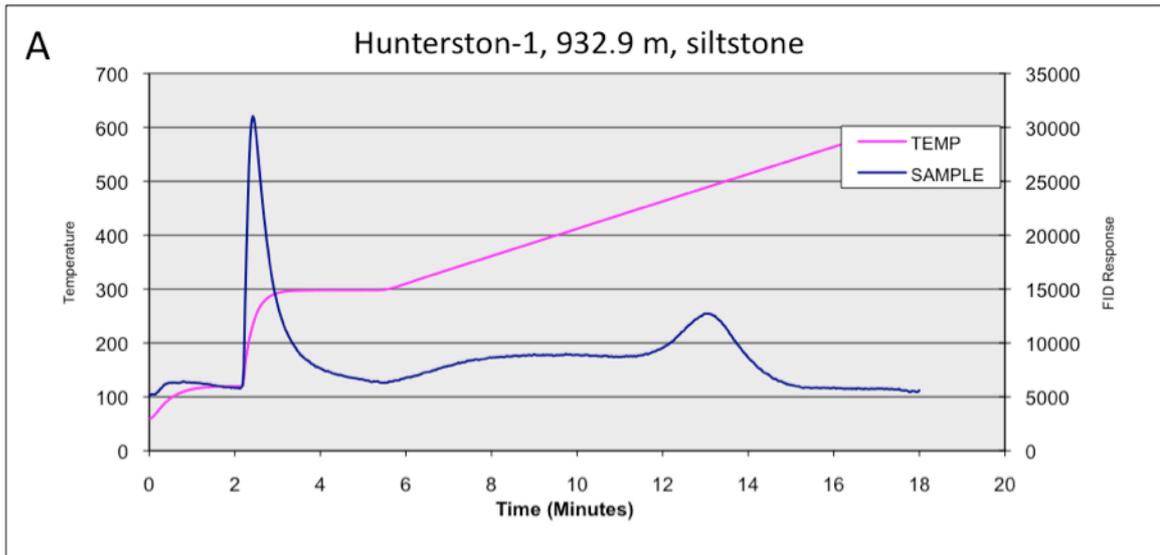


Figure 6: SRA pyrograms of Woody Island Siltstone



For further information please contact

McKirdy Geoscience ABN 33 558 021 809

David M. McKirdy BSc (Hons), MSc, PhD, DipT
Principal Consultant

11 Dover Street
Malvern SA, 5061
Australia

Phone +61 8 8272 0520

E-mail david.mckirdy@adelaide.edu.au