

# **PETROLEUM SYSTEM MODELLING ONSHORE TASMANIA**

## **Possible source potential of the Upper Permian Cygnet Coal Measures**

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## INTRODUCTION

Bitumen was found during developmental work at the Comstock mine near Zeehan in 2001 and at the time Ordovician Gordon Limestone was considered to be the source. Figure 1 shows there are faults along which bitumen could flow between Gordon Limestone and the Comstock area.

Fresh samples of bitumen were collected in 2003 and petrographic and geochemical analysis was conducted in an effort to determine the source of the bitumen. Maturity of the Comstock bitumen was determined by reflection measurements and found to average  $R_v$  0.75% which is within the oil window. Reflection measurements on bitumen derived from Gordon Limestone averaged  $R_v$  2.70% which is within the dry gas range. Rock Eval  $T_{max}$  temperatures and biomarker maturity indexes also indicating gas range support these measurements. As well as major differences in maturity there are differences in the organic source matter with Gordon Limestone derived bitumen having marine algal affinities and Comstock bitumen with plant affinities as determined by organic geochemical analysis. Figure 2 shows derivation of algal affinities for Gordon Limestone sample.

A comparison of the GC-MS traces from analysis of Comstock and Gordon Limestone samples is shown in Figure 3. It can be seen that each sample has different chemical characteristics implying they are derived from separate source rocks.

These results indicated that the Comstock bitumen was not sourced from Gordon Limestone and low maturity suggested the source was most likely younger. Investigations were made of Permian outcrops to the south of Zeehan along the Badger River and bitumen saturated coarse-grained quartz sandstone was located. Oil inclusions some containing gas bubbles were found in samples from these outcrops as shown in photomicrograph, Figure 4. The sandstone outcrops formed the upper parts of

Cygnets Coal Measures and lower in the sequence thin coal beds and thick, black beds of siltstone were located. Rock Eval pyrolysis of samples from these suspected source beds indicated that the siltstone had the potential to generate oil and gas. A chart, Figure 5, and Table 1 comparing Rock Eval results from both siltstones and coals of the Cygnets Coal Measures shows that coals have distinctly higher  $T_{max}$  values than the siltstones and also lower HI values indicating that the coals had low source potential.

Finding possible source beds for oil and gas within the Cygnets Coal Measures from which hydrocarbon generation and migration had obviously occurred led to investigation of outcrops of this sequence in other parts of Tasmania to see if any other areas had potential. The wide distribution of this sequence across the Tasmania Basin is shown in Figure 6 and sites where sampling was undertaken to determine source potential are indicated by vitrinite reflection values on this figure.

## COAL AS A POTENTIAL OIL SOURCE ROCK

Coal is recognised as a potential source rock for gas but is not generally considered as a source for oil however Permian Gondwanan coals are an exception as is demonstrated within the Cooper Basin where coal is a source for oil (Curry et al., 1994; Powell and Boreham, 1991; Vincent et al., 1985). The palaeoenvironment of deposition for the Cygnets Coals Measures in Tasmania was essentially the same as that for Permian coals within the Cooper Basin with both having alluvial and delta plain environments at high latitudes (Lang et al., 2000; Martini and Banks, 1989; McLoughlin, 1993). If Permian coals in the Cooper Basin can generate oil it may also be the case in Tasmania hence the current investigation.

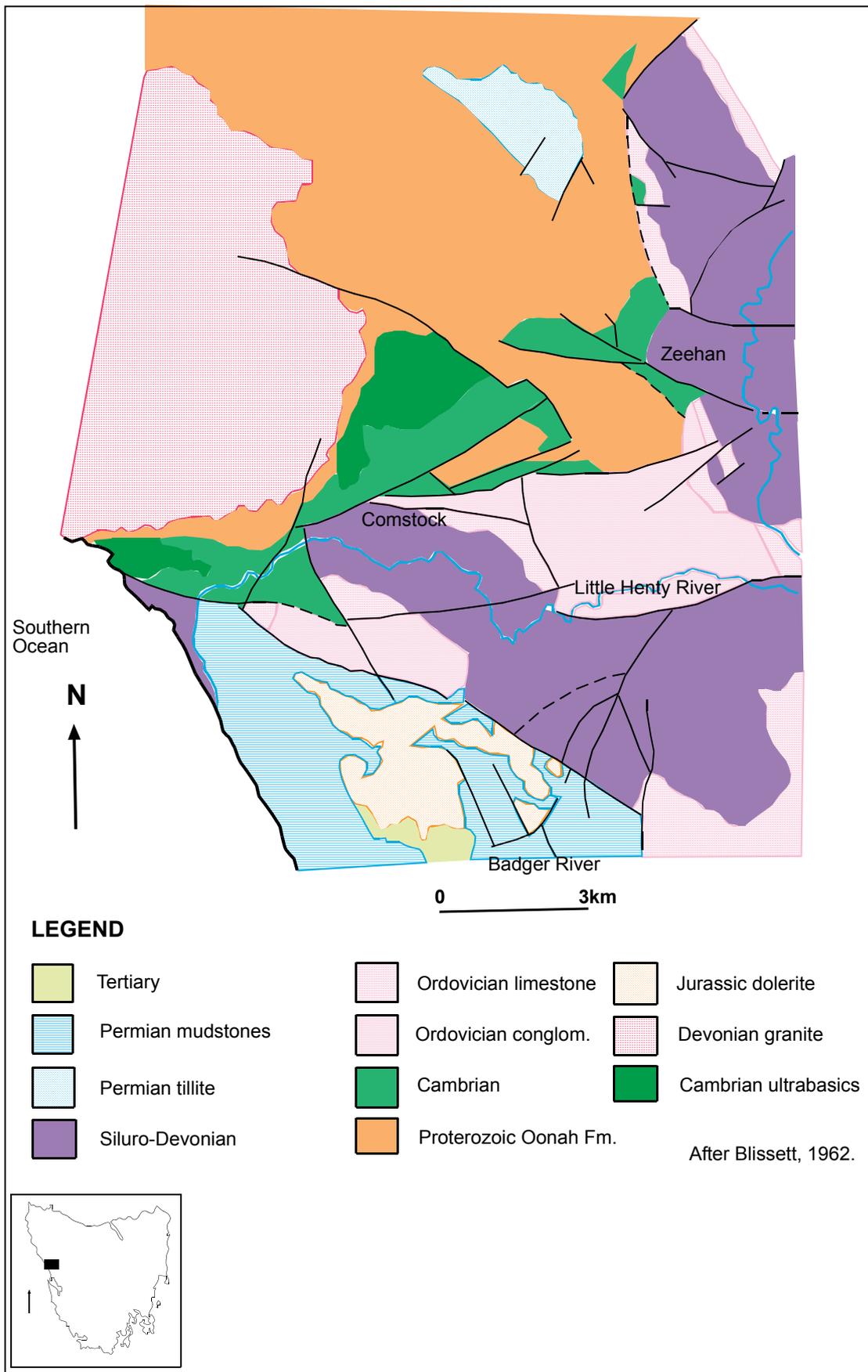


Figure 1. Locations mentioned in text and surface geology of the area near Zeehan where bitumen has been found.

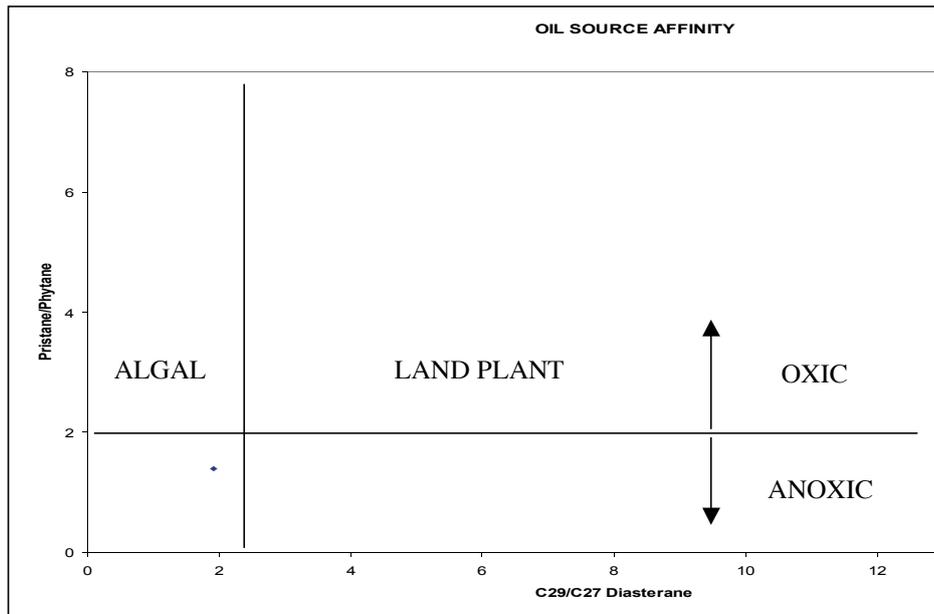
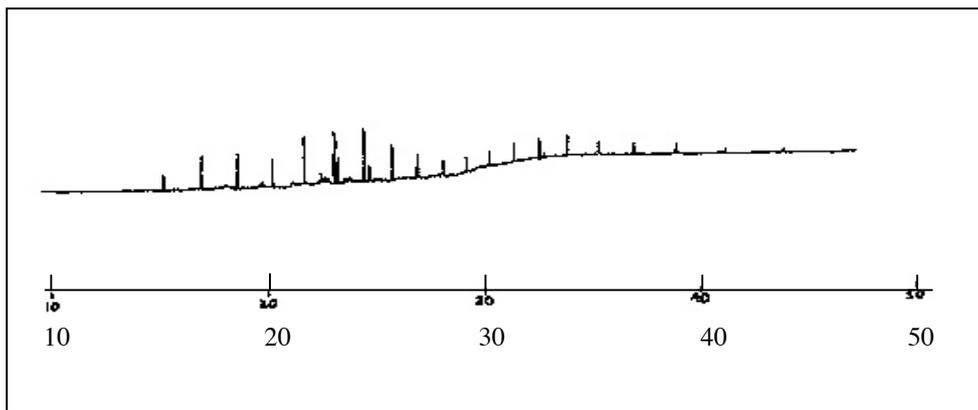
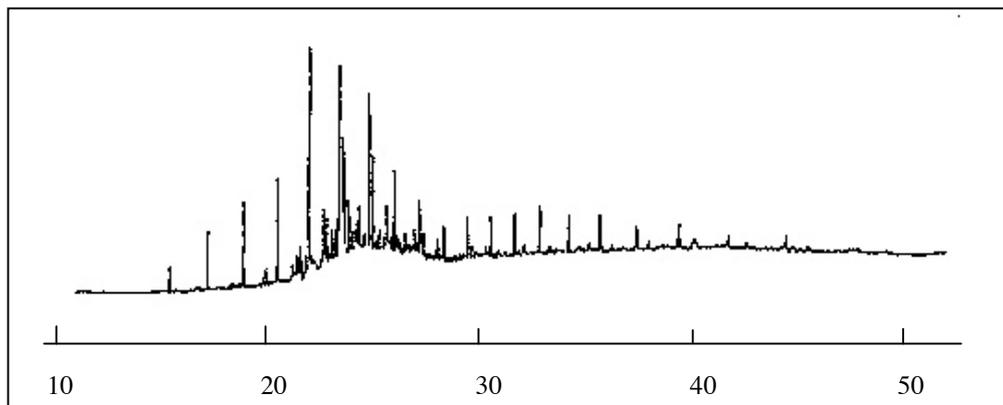


Figure 2. Oil source affinity for Gordon Group sample derived from plot of pristane/phytane against C29/C27 diasterane showing algal affinity deposited in an anoxic environment. Analysis by AMDEL.



GC-MS trace of saturates from sample of Badger River bitumen. Analysis by AMDEL.



GC-MS trace of saturates from sample of Gordon Limestone, Florentine Valley. Analysis by AMDEL.

Figure 3. GC-MS traces of bitumen samples from Permian Cygnet Coal Measures from the Badger River and of Gordon Limestone from Florentine Valley. Plots illustrate the different chemical compositions of each sample implying derivation from separate sources.

## DISTRIBUTION OF THE CYGNET COAL MEASURES IN TASMANIA

Cygnnet Coal Measures, part of the Permian Upper Fresh Water Sequence, are distributed widely across Tasmania as shown in Figure 6. The sequence consists of cross-bedded, quartzose sandstones and siltstones up to 100 m in thickness and thin discontinuous coal seams have been reported in many areas (Forsyth, 1989). These sediments conformably overlie the Ferntree Group and are in turn covered by Triassic fluvialite sediments in places unconformably.

Coal seams have only been mined in the Mount Cygnnet area and further south near Leprena, as coal seams to the north are generally too thin to be economic (Bacon, 1991). Maximum seam thickness of 900 mm occurs at Mount Cygnnet. The seams also appear to be discontinuous and erosion may have removed parts of the sequence in some areas as in places conglomerate unconformities mark the base of the Triassic sedimentation (Barbour, 1980). Drilling by Marathon Petroleum during exploration for coal in the Tasmania Basin found that the Cygnnet Coal Measures are almost devoid of coal and that seams lensed rapidly to coaly stringers within one metre. High organic content siltstone similar to the source rocks south of Zeehan may possibly be more widespread than coal seams.

## RESULTS OF INVESTIGATIONS ON CYGNET COAL MEASURES FROM THE BADGER RIVER AREA

Samples of bitumen saturated sandstone and siltstone, assumed to be source material, were sent to Dr. Alan Cook for assessment of maturity. Reflectance measurements established the maturity as  $R_v$  0.75% or mid oil window. Dr. Cook confirmed this by observations using fluorescence mode and strong fluorescence was noted with bright yellow oil droplets also detected as can be seen in Figure 4. Larger oil inclusions also contained gas bubbles showing that generation of both oil and gas had occurred.

Rock Eval pyrolysis of both coal and siltstone samples was used to determine the likely source rock. Selected information from these analyses is shown in the tables below.

### ASSESSMENT PARAMETERS FOR TABLES 1 AND 2

TOC above 2% is considered to have very good potential as a source rock.

$T_{max}$  is an indication of maturity with 435°-470°C the oil range. Higher values indicate gas range. Vitrinite reflectance is

Table 1. Rock Eval results from analysis of coal and siltstone samples.

Sample	Site	T max	VR equi	HI	TOC	S2	S2/S3
BR7	Badger	437	0.7	45	47.8	21.82	1.51
MQ2	Mallana	456	1.0	85	3.4	2.9	5.00
MQ3	Mallana	457	1.0	102	3.25	3.33	10.09
5949	Badger	450	0.9	34	2.65	0.90	0.51
LC1	Leprena	497	1.7	6	32.9	2.29	0.69
CCM2	S. Cape	539	2.3	4	14.3	0.69	Na
MQC1	Mallana	465	1.3	55	4.75	2.65	1.51
MQC2	Mallana	496	1.7	23	6.15	1.43	1.06
Note: First four samples siltstones, second four samples coals.							

Table 2. Rock Eval results from analysis of Permian Lower Freshwater coal samples from Cotas Creek north of St Marys.

Sample	Site	T max	VR equi	HI	TOC	S2	S2/S3
Cat 1	Cotas	424	0.4	442	70.40	311.73	0.00
Cat 2	Cotas	432	0.5	354	74.80	265.03	41.86

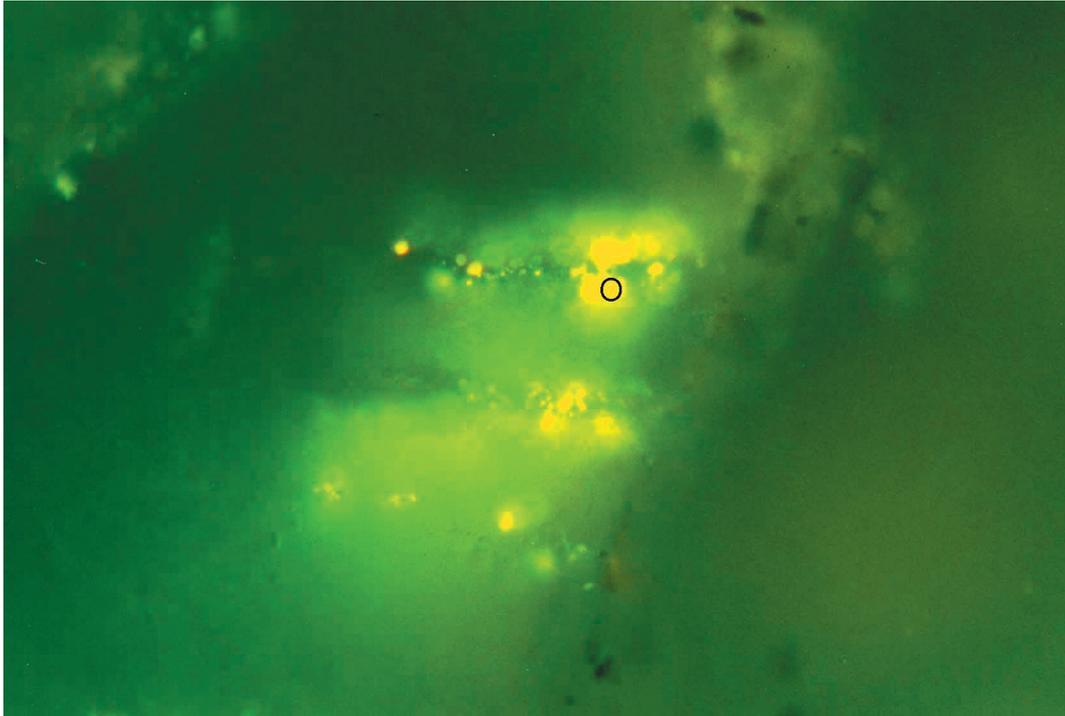


Figure 4. Photograph of Upper Permian silty sandstone Badger River. Bright yellow oil inclusions aligned along fractures within quartz grain. Fluorescence-mode field width 0.22 mm. Photograph by Alan Cook.

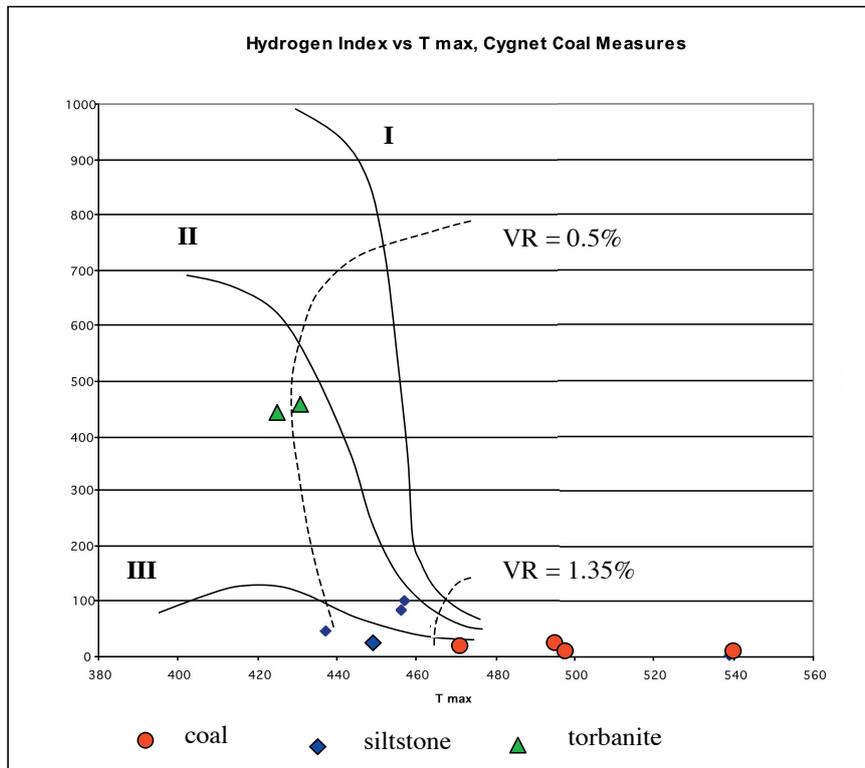


Figure 5. Chart showing a comparison in Rock Eval pyrolysis results from Permian coal and siltstone samples across Tasmania. Cygnet Coal Measures coal samples are shown in red and siltstone in blue to highlight differences in samples taken from similar stratigraphic levels. Note that coal samples show high Tmax values and low HI indicating very low potential as source rocks. The siltstone samples fall within the “oil window” of maturity and have HI values indicating gas potential as source rocks. Lower Freshwater torbanite samples, shown in green, are of marginal maturity but HI values indicate good potential as source rocks. Analysis by AMDEL.

the standard measurement for reflectance and the equivalents shown are derived from the  $T_{max}$  figures.  $R_v$  0.6-1.4 is considered the oil range.

Hydrogen Index (HI) can be used to determine potential of source rock, 0-50 indicating gas potential, 150-300 gas and oil, 300+ oil.

S2 can be used to determine generative potential, 0-2.5 poor, 2.5-5.0 fair, 5-10 good, 10+ very good.

S2/S3 or Type Index is used to determine gas or oil, 0-3 gas, 3-5 gas and oil, 5+ oil.

The results indicate that siltstones have fair to very good potential as source rocks and are likely to generate both oil and gas. The Cygnet coals have poor potential as source rocks but may generate some gas. The Lower Freshwater torbanites do seem to have some potential as source rocks.

## MATURITY ZONING

The samples used for source rock assessment were collected initially to determine the source of the bitumen in the Zeehan area and then further samples were collected across a range of outcrops to determine potential of the Cygnet Coal Measures throughout its distribution in Tasmania. Although very few samples have been tested the maturity zoning is in accord with previous measurements taken on Permian samples in Tasmania. Samples in western Tasmania had not previously been tested and these have maturity within the oil window. Samples from the far south of the state are post-mature for oil. One sample of Cygnet Coal Measures was tested from the north of the state and found to be immature for oil and Lower Fresh Water coals from St Marys area were of marginal maturity for oil. Vitrinite reflection measurements are shown in locations from which samples were collected on map in Figure 6.

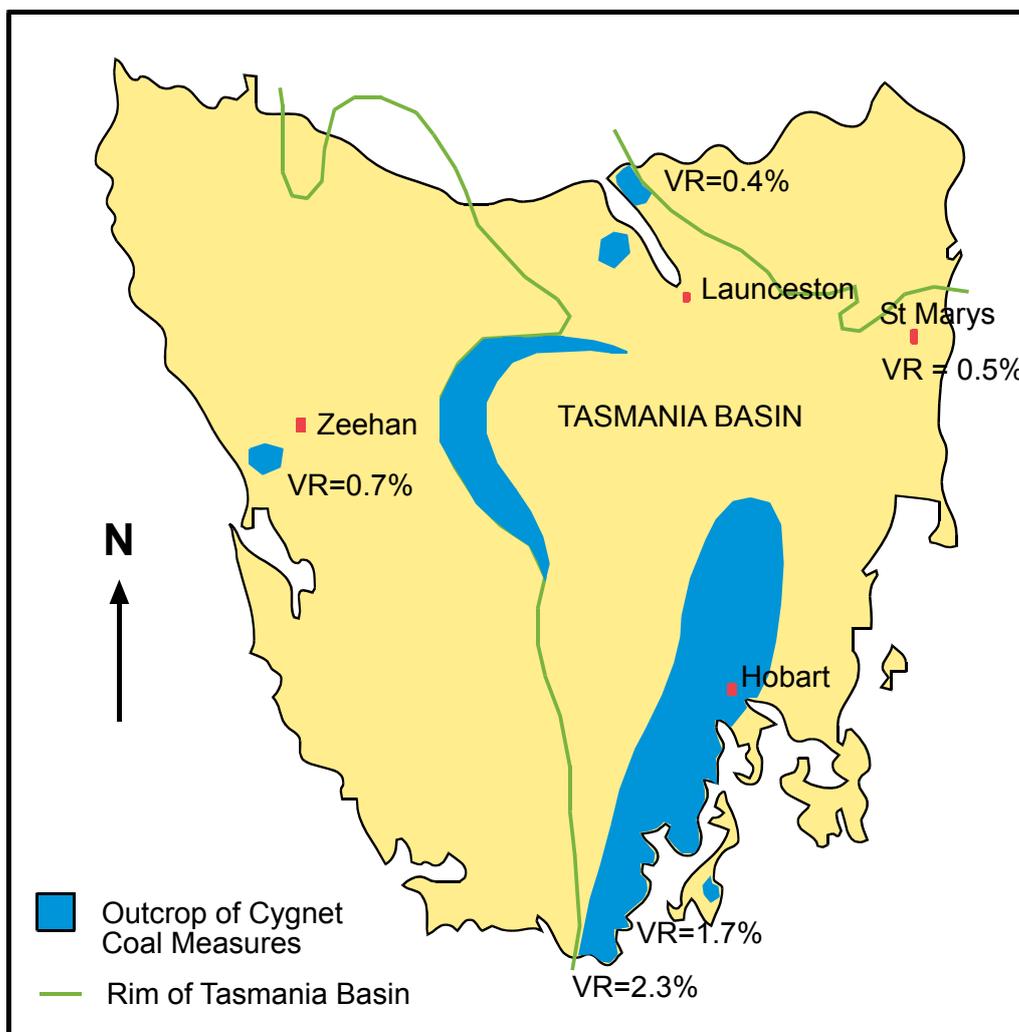


Figure 6. Map showing the distribution of Cygnet Coal Measures in Tasmania. Vitrinite reflection measurements taken from Cygnet Coal Measures are indicated showing that the sequence is immature in the north of the state and over-mature for oil in southern areas. The sequence is mature for oil near the west coast south of Zeehan.

## IMPLICATIONS OF THIS INVESTIGATION

Siltstone within the Cygnet Coal Measures can be considered the source of a significant volume of oil and gas generated from sources near Zeehan and bitumen-stained sandstone sequences can be seen between the Badger and Henty Rivers. Cygnet Coal Measures outcrop over a wide area of the Tasmania Basin but as yet no other reports have been made of oil or gas generated from this source. The high stratigraphic level at which these sediments were deposited has probably not allowed deep enough burial for maturity to reach hydrocarbon generation point within the main part of the Tasmania Basin. A second factor may be that organic-rich siltstones within the main Tasmania Basin are too thin and discontinuous to be capable of generating significant amounts of hydrocarbons. Further investigations are needed to confirm this assessment.

A likely contributing factor to the generation and migration of oil/gas near Zeehan was the high heat flows in the region during rifting events associated with the separation of Tasmania and Antarctica (Kohn et al., 2002). In areas away from coastal zones heating effects from rifting have not been as great and so sediments have been unable to reach maturity. Deep erosion has also occurred as evidenced by only scattered remnants of Permian-Triassic sediments remaining in the west coast region. Fission track studies also indicate that kilometre scale denudation may have occurred in this area during the Late Cretaceous (Kohn et al., 2002). Further evidence of extensive erosion of this area can be deduced from the sedimentary fill in the offshore Strahan and Port Davey Sub Basins where sedimentation started in Late Cretaceous (Moore et al., 1992).

## CONCLUSIONS

The small remnant of Cygnet Coal Measures found on the west coast near Zeehan appears to be a special case in terms of hydrocarbon generation and migration. Significant quantities of oil and gas have been generated and trapped by Permian sediments in a western outlier of the Tasmania Basin. Coarse-grained sandstones have acted as reservoir rocks and conglomerate beds with a fine matrix have sealed the reservoir. The source beds appear to have been thicker than in other parts of the state and thermal gradients during the Cretaceous were higher so that generation and expulsion of hydrocarbons was possible.

Major faulting has breached the seals and allowed trapped hydrocarbons to escape. The remnants of the trapped hydrocarbons can now be recognised from bitumen-stained rocks in the region.

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