

A Review of Hydrocarbon Habitat in the Lower Cretaceous Of the Simpson Desert Area.

Executive Summary

- **Lower Cretaceous hydrocarbon targets are widespread in CTP's tenements in the Simpson Desert area. The sheet like Toolebuc Formation is a well documented source rock whose unconventional oil/gas potential is being investigated by several operators including Central. This formation may be the source for potential gas plays in the overlying Oodnadatta Formation.**
- **Significant gas shows (up to 65 units C1, 3% C2 +) occur in 'hot' sandstones in the lower Oodnadatta Formation in the Simpson-1 structure south of the Hale River Block. The gas is probably of biogenic origin being derived from bituminous shales in the underlying Toolebuc Formation. Minor heavy HC molecules probably originated from early mature oil extracts originating from the same source rock. The gross gas column could exceed 40 m.**
- **This potential gas play may be a conventional structural play relying on reservoir/seal couplets formed in structural closure. However there may also be an unconventional component to the trap.**
- **The 'hot' sands of the Oodnadatta Formation are vfg-fg and tight, and any commercial productivity would rely on reservoir stimulation. The Toolebuc Formation is itself a target but the unit is thermogenically immature on a regional basis and assessment of its potential requires further exploration and application of new ideas / technology. Given the high hydrogen indices of the shale's organic material there may potential for wet gas but the likelihood of thermogenic oil appears low.**
- **There are important implications for well site operations regarding full evaluation of these zones during the drilling of the upcoming Madigan-1 exploration well and succeeding wells in the Simpson Desert area.**

Introduction

Two potential early Cretaceous source /reservoir rocks. are of interest in the Simpson Desert area, namely the Toolebuc Formation and the overlying basal Oodnadatta Formation. The former is widely discussed in the literature and to the east, in the area of the Galilee Basin, greenfields explorer Exoma Energy has mounted a regional exploration program to establish it's potential. There is much anecdotal evidence of oil and gas shows in the Toolebuc in this area but the thermal maturity is generally low and hence the resource type remains uncertain. In the Julia Creek area the sequence is considered an oil shale while Boreham and Powell (1987) indicated that in a general sense the unit should be regarded as an immature petroleum source rock.

The early Cretaceous Toolebuc Formation was deposited in a late Albian transgressive epicontinental sea. The sequence is sheet-like and very extensive, varying in thickness from 10-50 m in the study area south of the Arunta Block in central Australia. The unit occurs in the middle part of a Cretaceous succession up to 2000 m thick consisting of deltaic, marine and lacustrine mudstone, siltstone, sandstone, coquinite, limestone and minor coal. Measured high organic contents and numerous intersected oil and gas shows in stratigraphic and exploration wells in the south – central Eromanga Basin led to a number of published papers in the 1980's (Ozmic, 1986; Sherwood and Cook, 1986; Boreham and Powell,1987; Saxby,1986). Intermittent studies have been undertaken since then but the sequence has really come under increased scrutiny with the advent of unconventional gas/oil plays emerging in central Australian basins.

More recently Exoma Energy, who are exploring the Galilee Basin to the east, have two dedicated wells cored through the Toolebuc: 1) Bessies -1 recovered live liquid hydrocarbons on the core barrel and tests on recovered samples are progressing, 2) Euston-1: displayed evidence of gas release and gas desorption studies are continuing. The shaly Toolebuc sequence in this area is up to 40 m thick (averages 20 m in thickness) with mean TOC's of 9% ranging up to 20%. The unit comprises mainly carbonaceous shale becoming more limey to the west with occasional coquinite. Exoma are currently carrying out laboratory studies, including gas desorption work, prior to further drilling which may include lateral drill holes and staged fracture stimulation.

In CTP' s areas in the Simpson Desert area, the Toolebuc Fm is an enigmatic source rock; it is a rich oil/gas source rock which sometimes gives up minor gas shows (sometimes with a minor component of heavy hydrocarbon molecules) on drill penetration. It is not known to be thermally mature for oil/gas generation anywhere in CTP's areas and hence the gas shows are believed to be biogenic in origin. There are no known analogous source rock formations in North American basins so comparative studies are lacking.

A more leading edge scenario invokes the ideas of Dr. F. Mango (a former Stanford University professor) who proposes two paths to the formation of natural gas:

- 1) A traditional, thermogenic path operating almost exclusively at high temperatures.
- 2) A low temperature catalytic path (metathesis). The proposed catalysts in this process are low valent transition metals. This process redefines the time-temperature dimensions of gas habitats opening the possibility of gas generation at very low subsurface temperatures. This remains a highly speculative model for Toolebuc gas but it may be significant that Boreham and Powell (1987) report high vanadyl group metals in several samples of Toolebuc Formation.

Further study is needed to rationalise the origin of the Toolebuc Fm wet gas and oil shows in the area of the Galilee Basin. It may be the methane component is of biogenic origin while the heavy molecules result from early – mature oil extracts residing in the rock and released during the drilling process. It is noteworthy that thermally immature Permian coals in CBM 93-001 give gas shows with a similar heavy molecule content to the Toolebuc shows – no thermogenic hydrocarbons are present in either case. The methane component of the shows

in the Permian coals is largely derived from the inertinite /vitrinite component of the coal while the liptinite/exinite component provides the heavier HC molecules.

There follows a review of the Toolebuc Fm in and around CTP's tenements in the Simpson Desert area with a drill hole summary occurring in Table-1.

Table-1

Well	Base Toolebuc	Top Toolebuc	Isopach	Lithology	HC Shows
Simpson-1	775 Sandstone in	735 L.Oodnadatta FM. Toolebuc on seismic	40	fg-vfg lithic ss, ? grey sh. HS ABSENT	65 units C1 0.5 units C5+ in ss. Gas 97:1:1:1
Simpson-1	901 Toolebuc on	906 seismic	Shale High Res	HS ABSENT	No gas show
Blamore-1	Undiff.	Present on	seismic	HS ABSENT	No gas show
Hale River-1	641.9	677.8	35.9	Sh,md-dk gry HS 2m at base Lsst, Inoceramus	None noted in WCR No gas log.
Colson-1	1082	1111	29	Dk gy-black sh,limey stks HS present	5m HS but No gas shows rec.
McDills-1	Undiff.				
Etingimbra-1	? 130	158	28	HS 3 m at base	3 m HS but ? No shows
CBM 93-001	Toolebuc log signature is missing~340	~360	20	HS ABSENT But seismic Sig. present	2 units of gas with trace heavies in Toolebuc.
CBM 93-002	Undiff.	? eroded		HS Undiff	No gas show
CBM 93-003	245	262	17	HS 4 m thick	Wk gas show 8/2 units
CBM 93-004	244	262	18	HS 1 m thick	Wk gas show 12/2 units No heavies.
CBM107-001	248	262	14	HS 3 m thick	No gas show
CBM107-002	Eroded or facies change			HS Undiff.	No gas show
Thomas-1	1107	1159	52	Dominantly Organic shale inc HS	No gas show

				Sh,lsst,coal	
Mokari-1	876.2	911.5	35.3	?	? No Gas Show
Mount Hammersley 1	Undiff.			?eroded	No gas show
Dalmatia-1	Undiff.			?eroded	No gas show
Glen Joyce-1	998	1021	23	Silt, one lsst, Tr vfg ss	No gas show
Killumni-1	1142.6	1173	30.4	V.carb silt, vfg ss	No gas show
Witcherie-1	120.6	~140		Blk organic sh, tr siltst	No gas show
Beachcomber 1	871	942	71	Claystone	1 unit C1
Poolowanna-1	1280	1317.8	37.8	Dk gy carb.silt Lsst, vfg ss	No gas show
Poolowanna-2	1278	1322.7	43.9	Dk gy carb.silt	? No gas show
Poeppels Cr-1	1119.1	1185	65	Dk Gy 2 x HS carb.sh	No Gas show

An important conundrum relevant to exploration of the Toolebuc Fm throughout the Eromanga Basin as a whole is that despite the presence of numerous oil and gas shows there is a general absence of thermal maturity on a regional basis. It should be noted that in the Simpson Desert area high mud weights applied during early exploration drilling may have inhibited gas shows to some extent thus accounting for their general sparsity. The Toolebuc Fm has not recorded any flows to surface although a slightly older-sheet like sandstone, the Coorikiana Sandstone, recorded a small gas flow from a well in SA .

Gas Shows in the Toolebuc Formation in the Simpson Desert Area

- 1) Well CBM 93-004 : A thin Toolebuc unit gave a 12 unit gas show which was all C1. Background gas was all C1 (2 units). The absence of heavy HC molecules would suggest only gas prone source material is present – the methane may be of biogenic origin.
- 2) Well CBM 93-003 : a thin Toolebuc Formation unit gave a 8 unit gas show which was mainly C1 but included 10 ppm heavier molecules. The gas stayed in the system into the top Algebuckina Sandstone where the background gas was <1 unit.

Note that no other gas shows have been recorded but this may in fact result from 1) no gas detector being run through this section which is unlikely 2) Overbalanced mud systems suppressing gas shows, which is more likely. Oil and gas shows appear to be far more intense to the northeast in the area of the Galilee Basin.

Hydrocarbon Potential of the Lower Oodnadatta Formation Sandstones

The Bessies-1 well drilled in the Galilee Basin by Exoma intersected 40 m of primary Toolebuc shale with gas shows as well as recovering a small quantity of free liquid hydrocarbons. In this well gas shows were also recorded in the overlying shale/silt sequence which may be equivalent to the lower Oodnadatta Formation. A review of the lower Oodnadatta Fm in the Simpson Desert area occurs below, the most important show occurring in Simpson-1.

Well	Base Oodnadatta	Top Oodnadatta	Isopach	lithology	HC Shows
Simpson-1	775	735	40	fg-vfg lithic ss, gy sh,gl	65 units C1 3% heavies
	Interbedded	Ood clayst	Are carbonaceous	Gas 97:1:1:1:	Several gas peaks in ss
Blamore-1	No basal Ood ss	NA	NA	NA	No gas shows
Hale River-1	No basal Ood sands	NA	NA	NA	No gas shows
Colson-1	Oods sands present	635	775	vfg-fg lithic ,gl ss	No gas shows
Thomas-1	804 Minor ss	1107	NA	Vfg tight ss	No gas shows
Mc Dills-1	Eroded				
Etingimbra-1	Eroded				
Poeppels Cr-1	815.9	1119.1	303.2	Tr vfg ss	Trace gas
CBM93-001	No ss noted.		Show in the	Toolebuc but	2 units C1 (Toolebuc)
			No significant	ss noted	10 ppm C5
Beachcomber	610	871	261	Silt claystone,ss	No gas show
CBM93-002	? eroded				No Gas Shows
CBM93-003	Thin sands in Lower Oodnadatta				No gas shows. Bg=2 units, no heavies
CBM93-004	No ss noted	Probably eroded			No gas show
Macumba-1	695.8	1149.9	454.1	Vfg-fg.,tight Int.clayst,silt	No gas show

Poolowanna-1	882.6	1280	397.4	Vfg-fg,tight Int.clst,silt	No gas show
Purni-1	475	783.2	308.2	Minor ss a/a	No gas show
Witcherie-1	15.2	120.6	105.4	Silty ss,clayst	No gas show
Mt Hammersley-1	eroded				
Dalmatia-1	eroded				
Glen Joyce-1	871	998	127	Allaru,ss at top,tight	No gas show
Kilumni-1	820.5	1142.6	322.1	a/a	No gas show

Interpretation of Gas Shows in the Oodnadatta Formation, Toolebuc Fm, Simpson Desert area.

It has been proposed herein that the wet gas shows in the Toolebuc Formation in the Galilee area are self sourcing – ie the methane component is locally sourced and of biogenic origin while the heavier hydrocarbon molecules come from early-mature oil extracts residing in the source rock and released during the drilling process. In the same way thermally immature coals give up wet gas shows (when liptinite and vitrinite macerals are present) eg CBM 93-001.

In the Simpson Desert area gas shows in the Toolebuc are fairly sparse compared with the Galilee area but this could in part result from the use of over-balanced mud systems during drilling. However, at this stage it appears this unit may not be as organically rich (or as thick) as that seen to the east in the Galilee area although no core or cuttings have been analysed. The gas shows in the Lower Oodnadatta Formation in Simpson-1 are of major interest as they occur in high GR, v.f.g to f.g. glauconitic 'hot' sandstones containing gas peaks of up to 65 units (C1 97:1:1:1). The sandstones occur over a gross interval of about 40 m. Given the complete absence of gas shows at this level anywhere else in the study area, the following tentative conclusions are drawn:

- The sandstones are gas charged but this cannot be definitely confirmed as there was no testing or coring undertaken and the only Elog coverage was through casing; this precludes accurate definition of hydrocarbon saturation and porosity.
- The gas play may be structural formed in a 4 way dip closure at this level; such closures are mapped at deeper horizons.
- The most likely source of gas are the Toolebuc organic rich shales – the gas in this case must be biogenic while the small percentage of heavy HC molecules are probably derived from very early mature oil extracts associated with the Toolebuc shales. There is a much smaller chance that these are Devonian sourced hydrocarbons migrating up a ?fault plane but given the absence of shows lower in the section this seems unlikely.
- At least three sand:shale interfaces occur in a gross column of about 40 m.

Recommendations

- The lower Oodnadatta Fm (3 m samples recommended) and Toolebuc Fm (1 m samples recommended) should be carefully monitored in Madigan-1 for gas/oil shows and evidence of source, reservoir and seal.
- If significant gas shows are encountered an appropriate program of coring, testing and logging may be warranted. The sands are "hot" which needs to be considered in designing log coverage.
- Gas samples should be acquired during drilling and / or testing for isotope studies which will establish the veracity of the biogenic gas model.
- SWC's should be acquired through the Early Cretaceous section, especially in the Toolebuc Formation, to establish source rock parameters.
- Where appropriate mud weights should not exceed hydrostatic pressure when the Toolebuc Formation and lower Oodnadatta Formation are encountered during exploration drilling.

Conclusions

- The Toolebuc Fm is an enigmatic source rock in the Simpson Desert area where there are sparse, weak gas shows (sometimes with a minor component of heavy hydrocarbon molecules) but it is thermally immature on a regional basis. However, a possible explanation may be that the methane component is of biogenic origin while the heavy molecules result from early – mature oil extracts residing in the rock and released during the drilling process.
- The gas noted in the lower Oodnadatta Formation in Simpson -1 is probably sourced from the Toolebuc Formation being of biogenic origin and comprising mainly methane. This type of gas show is rare thus far and may relate to the fact that viable sandstones reside in structural closure immediately above the Toolebuc Fm. Interbedded thick claystones appear to provide vertical seal
- The Simpson East Prospect should be carefully monitored for Cretaceous gas during drilling and should be fully evaluated from an exploration standpoint. A similar approach should be applied during the drilling of the Madigan structure which has definite major closure at deeper levels and is likely to have Oodnadatta Fm sandstones developed in the Cretaceous section. A review of seismically defined closure at Cretaceous levels in both prospects is advisable.