The Northern Territory Geological Survey is two years into a Petroleum/Minerals exploration initiative whereby program results and products are being made available free of charge to explorers. The results presented herein derive from this initiative.

**GEORGINA BASIN**

The southern Georgina Basin covers an area of 250,000 square kilometres and includes a prospective Middle Cambrian petroleum system which to date has attracted only minor exploration. Only 750km of modern seismic has been acquired in addition to stratigraphic drilling undertaken by Government agencies and an eight well exploration programme undertaken by Pacific Oil and Gas during the last decade (Figure 1). Most, if not all of these wells were drilled outside structural closure but hydrocarbon shows, mainly in the Middle Cambrian, are abundant. The southern portion of the basin is dominated by two depocentres, namely the Dulcie and Toko synclines, which include up to 1200m and 5000m of Palaeozoic sediments respectively. The basin was deformed during the Alice Springs Orogeny (Late Devonian – Early Carboniferous) by minor to moderate folding and faulting especially in the south and east. Recent work by Pacific Oil and Gas has shown that mainly flat lying Ordovician sediments can conceal and disguise earlier Palaeozoic structuring viz. Delamerian Orogeny. The presence of common oil shows throughout much of the Cambrian in wells drilled in the Dulcie and Toko Synclines, in addition to a small gas flow from the Ordovician in Ethabuka #1, suggest considerable volumes of hydrocarbons were generated in the southern Georgina Basin. A Russian research group estimated, from pyrolysis data, that in excess of 40 billion tonnes of hydrocarbons has migrated from the Middle Cambrian. Oils extracted from Middle Cambrian sediments are mainly unaltered, mature, aromatic crudes of marine algal/bacterial source affinity (Questa Australia Pty Ltd, 1994).

The NT Geological Survey has undertaken a review of the southern Georgina Basin incorporating previously unpublished E-log correlations, acquisition of new stratigraphic and regional aeromagnetic data, seismic and field mapping, basin/thermal history modelling and relogging of available core and palaeontological studies. The entire stratigraphic section, from the Neoproterozoic to Devonian, is under review but this paper concentrates on the hydrocarbon potential of the main petroleum system related to the Middle Cambrian Arthur Creek Formation and Thorntonia Limestone. Figure 1 is a Palaeozoic isopach map which also outlines the extent of maturation in this sequence.

New E-log correlations from the southern portion of the basin have resulted in a simplification of the previous stratigraphic subdivisions as described in Questa Australia Pty Ltd (1994). Two regional electric log markers denote the base and top of the Middle Cambrian Arthur Creek Formation, and are regional sequence boundaries. The elucidation of these lithostratigraphic markers has greatly clarified the geology of the Middle Cambrian petroleum system. The basal E-log marker denotes a ‘hot’ carbonaceous shale/siltstone lying unconformably on altered carbonate grainstones of the Thorntonia Limestone. Vugs, fractures and stylolites in the latter result in fair reservoir quality in several wells. Source and seal is provided by the overlying and near ubiquitous basal Arthur Creek Fm ‘hot shale’ which reaches TOC’s of up to 16% and is enriched in microbial source material. This unit was deposited by a rapid transgressive event marked by anaerobic sedimentation, and preservation of organic matter under reducing conditions. The sediments are oil mature over a wide area of the southern Georgina Basin. The overlying sequence comprises dark dolomitic siltstones and shales with some excellent source potential but poorly developed reservoir facies. Shallow water and more oxygenated conditions prevailed in the upper Arthur Creek carbonates and reservoir quality ‘shoal’ grainstones (K>1110md), offer reservoir potential and possibilities for stratigraphic entrapment. There was considerable structural growth in the main depocentres during deposition of the Arthur Creek Formation until sedimentation was terminated by minor uplift, erosion and peneplanation prior to deposition of the Arrinthunga Formation. This unit has a regional sheet like extent with occasional source and reservoir facies, but seal is problematical. Late Cambrian structuring (Delamerian Orogeny) variably eroded this sequence prior to deposition of the Ordovician Tomahawk Beds.

The main target petroleum system relates to the Thorntonia Limestone/Arthur Creek Formation reservoir – source couplet. Reservoir quality in the former is variable and has been affected by diagenetic and post – diagenetic alteration processes, but DST results from several wells are encouraging particularly in Ross #1. The
unconformably overlying Arthur Creek ‘hot shale’ is a regional seal and world class source rock and the main challenges to a commercial discovery are migration and entrapment. It is suggested the Thorntonia Limestone is best targeted as a structural play and a number of leads have been identified. Relatively thin grainstone ‘shoals’ and sandstones in the upper Arthur Creek Formation present opportunities for stratigraphic entrapment.

**PEDIRKA BASIN**

A discussion of the Pedirka area encompasses four superimposed sedimentary basins viz. the Palaeozoic Amadeus Basin, and Permo – Carboniferous Pedirka Basin, the Triassic Simpson Desert Basin and the Jurassic/Cretaceous Eromanga Basin. This paper concentrates on the Pedirka/Simpson Desert/Eromanga Basin petroleum systems with emphasis on the Permian/Mesozoic source – reservoir couplet which is believed to be highly prospective. The exploration history of the northern Pedirka Basin dates back to the early 1960’s when the emphasis was on the Early to Middle Palaeozoic Amadeus Basin sequence (McDills #1, Hale River #1). The discovery of Permian gas to the south in the Cooper Basin in 1963 turned attention to sequences of similar age in the Pedirka Basin (e.g. Colson #1). The 1977 discovery of Jurassic and Triassic oil in Poolowanna #1 focussed efforts towards younger Mesozoic reservoirs (Thomas #1, Etingimbra #1 and Poeppels Corner #1). There is uncertainty about the veracity of these traps and all wells in the area predate now traditional exploration philosophy associated with the Permian/Mesozoic source – reservoir couplet in the Cooper Basin. As a result the Northern Territory Department of Mines and Energy (NTDME) undertook a programme of seismic interpretation in the northern Pedirka/Eromanga Basin in 1998, with the aim of updating the exploration potential of the area. For the first time a regional structural synthesis is available for key seismic horizons at Mesozoic and Palaeozoic levels. Alexander et al (1996) reviewed the hydrocarbon potential of the western most depocentre, the Eringa Trough, concentrating on maturation history utilizing fission track analysis. This paper concentrates on the exploration potential of another important depocentre, the Madigan Trough (Figure 2), which has a unique structural configuration and to date has received little attention.

The earliest sediments in the area are a sequence of Neoproterozoic to Late Devonian intra-cratonic sediments of the Amadeus/Warburton Basins, which occur extensively in the subsurface and onlap Mesoproterozoic gneiss, amphibolite, and granite of the Musgrave Block.

The Pedirka Basin and its associated depocentres, the Eringa and Madigan Troughs, date back to the Alice Springs Orogeny (Late Devonian – Early Carboniferous). The Permo-Carboniferous record is dominated by widespread glaciation and basalt diamicites (Crown Point Formation) which are usually disconformably overlain by intracratonic sediments of the Early Permian Purni Formation.

Triassic sedimentation was preceded by compressional reactivation of older fault systems, which deformed and eroded Pedirka Basin sediments, particularly along the McDills Trend. A regional southeasterly tilt was then imposed accommodating Triassic sedimentation in the Poolowanna Trough, the main depocentre of the Simpson Basin, where 300m of Triassic sediments are preserved. The basal unit, the Walkandi Formation, comprises continental shale, siltstone and sandstone and is probably the equivalent of the Nappamerri Group in the Cooper Basin. Unconformably overlying sediments of the Late Triassic Peera Peera Formation comprise shale, coal and sandstone.

Uplift and erosion in the Late Triassic preceded deposition of the Eromanga Basin sequence. Regionally this sequence comprises laterally continuous sheet sandstones of fluvialite origin (Hutton Sandstone, Adori Sandstone, Namur/Hooray Sandstone) with intervening overbank and lacustrine – swamp deposits viz Poolowanna Formation, Birkhead Formation, Westbourne Formation and the Murta Member of the Hooray Sandstone. These pervasive shaley units provide source and seal to varying degrees throughout the Eromanga Basin, but only the Poolowanna and Birkhead Formation occur in the Pedirka area and then intermittently. The onset of full marine conditions during the Early Cretaceous is represented by the Wallumbilla/Toolebuc/Allara/Mackunda sequence. In the Late Cretaceous non-marine conditions prevailed and the Winton Formation was deposited in a fluvial-floodplain environment. It was during the Winton Fm sediment loading that most hydrocarbon generation is presumed to have occurred. The hydrocarbon potential of the Permian/Mesozoic sequence is described in part by Alexander et al (1996). The Permian Crown Point is generally considered a poor source rock while the Purni Formation is a fair to good source containing type II/III kerogen. The Poolowanna Formation contains some of the richest source rocks in the area and coal seams are common and compliment the often abundant dispersed organic matter present in intraformational siltstones and shales. Similar source facies are recorded in the Triassic Peera Peera Fm which is also a viable source rock.
the eastern flank of the Eringa Trough coals within the Birkhead Formation are oil prone, being enriched in type II/III kerogen, but their extent into the Eringa Trough is uncertain, as is their maturity.

The Permian Purni Formation is oil mature in the northern Eringa and Madigan Troughs and also on the eastern basin margin. The Triassic and basal Jurassic sequences are oil mature in the Poolowanna Trough and perhaps also in the northern Eringa Trough and the main depocentre of the Madigan Trough (Figure 2). The petroleum systems operating in the Pedirka area comprise the basal Jurassic/Peera Peera (Triassic) petroleum system and the Permian (dominantly Purni Formation) petroleum system. The latter correlates well with the oil prone lower Patchawarra Formation in the Cooper Basin, which has charged fields such as Tirrawarra, Fly Lake and Moorari, where the Early Permian Tirrawarra Sandstone provides the target reservoir.

However to date the only proven petroleum system in the Pedirka area is that relating to the Poolowanna Fm (Basal Jurassic)/Peera Peera Fm (Triassic) as evidenced by significant oil recoveries in the Poolowanna #1 discovery well. Geological and geochemical criteria, including maturity data, clearly indicate intra Poolowanna and Triassic sources (Alexander et al, 1996). Poor reservoir quality in the Poolowanna Trough hindered flow rates and oil volumes are small. Poor to fair oil shows occur in the Poolowanna Fm, and to a lesser degree the Peera Peera Fm in the Colson #1, Thomas #1, Erabena #1, Poeppels Corner #1, Killumni #1, Oolarinna #1 and Walkandi #1 exploration wells. At this level in the Cooper/Eromanga area there are also widely scattered oil shows but a dearth of commercial hydrocarbons with the exception of the Cuttapirrie and Gidgealpa fields in SA and also fields such as Black Stump, Bodalla South and Kenmore in Queensland. The bulk of Poolowanna reservoired oil in these areas is believed to be of Permian origin (Boreham and Summons, 1999). To date the potential for Poolowanna oil in the Pedirka area appears limited by source volume and maturation history and the fact that migration probably post dated diagenesis in the Poolowanna Trough which is the main source “kitchen”. These factors militate against large commercial oil fields at this level but the likelihood of small, scattered accumulations is high. Maturation levels in the Poolowanna Trough reach $R_o = 1.0$ and generation was probably initiated at about $R_o = 0.6$. The intensity and significance of oil shows decreases westwards away from the Poolowanna Trough. The other Poolowanna Fm depocentres, the Madigan and Eringa Troughs appear, from regional comparisons, to have some potential for commercial hydrocarbons. Overall it is likely at least small volumes of Poolowanna oil have been generated but there are no adjacent wells and little seismic.

A synthesis of new seismic mapping data over the NT sector of the Pedirka Basin suggests the Permian petroleum system is highly prospective and subordinates the previously favoured Poolowanna/Peera Peera system. The Permian occurs in a number of contiguous depocentres having separate maturation histories. On the eastern margin of the Permian basin the sequence is thin but well within the oil window as predicated by pronounced tilt of the basin to the southeast during the Triassic. This is evidenced in Oolarinna #1 where the base Permian is oil mature ($R_o = 1.0$) and gas shows of up to 80 units recorded in Purni Formation coals indicate the onset of gas generation. Importantly, in this area of known mature Permian source rocks, there has not been a crestal structural test at Permian or Jurassic levels. The same is true in the northern Eringa Trough where the Purni is thick and is in the oil window. Hanging wall fault traps against the McDills Fault are also viable targets as is the Hooray Prospect immediately to the east.

The other important Permian depocentre, the Madigan Trough, provides the best potential for Permian oil generation. Interpretation of early analog seismic indicates about 1500m of Permian sediments, including 750m of Purni Formation, which is buried to about 2800m with an expected maturity of $R_o = 0.7 – 1.0$, well into the peak oil generation window. As a result of these interpretations, prime targets within the NT sector of the Pedirka Basin are now viewed to be structures within the central Madigan Trough or first order structural traps on primary migration pathways out of this depocentre (Figure 2). A mitigating factor is the perceived absence of gas charge and associated displacement of oil to the basin margins. Limited oil migration dictates that the most proximal structures be tested at their crest, recognising that there has not been a valid structural test within 60km of this depocentre. Fortunately there are a number of suitably ‘old’ closures and structural noses encircling this source ‘kitchen’, none of which have been drilled (eg. the Simpson and Hooray Prospects). Further to the north the McDills Trend intersects the Hale River Fault zone which comprises a series of northwest trending, down to basin normal faults. A number of structural leads result including the Arrakis lead which is favourably located to trap hydrocarbons migrating northwards from the Madigan Trough. Overall in this area, and in the NT portion of the Pedirka Basin as a whole, there is a proliferation of exciting undrilled four way dip closures which should take precedence at this stage of the basin’s exploration history. Available seismic also indicates a plethora of stratigraphic and fault dependant trapping mechanisms but prospect definition awaits further seismic.
REFERENCES
