Appendix 3 – Halo Plays – Amadeus Basin

Central Petroleum Limited

Prospective "Halo" Plays in the Amadeus Basin

CONTENTS

1. Introduction

There are a myriad of structural stratigraphic plays in the Amadeus Basin. The sedimentary history, tectonic controls and maturation history of the various petroleum systems, all favour the “Halo” type structural stratigraphic play type which is the subject of this report. This play is important because: 1) it is large scale and very widespread offering potentially large incremental in-place oil/wet gas/gas potential for future drilling programs, and 2) the play targets several petroleum systems and associated reservoir-seal couplets occurring at multiple stratigraphic levels.

The “halo” play can only have regional context if generative source rocks are widespread. This capacity is well known and documented in the basin north of the Central Ridge. However, recent geochemistry of source rock sequences south and west of this ridge is also very encouraging. In the far west of the basin, near Long Range, oil mature Pertatataka/? Aralka source rocks are in the oil window at very shallow depths (480m in NTGS DD01-05) and a minor oil show confirmed this result. The oil had a very unusual geochemical signature typical of Neoproterozoic (Sturtian) crude oils from Siberia and Oman. This result hints that Aralka and Pertatataka source rocks are mature for hydrocarbon generation over wide areas of the southern Amadeus Basin where data is extremely sparse. Confirmation occurs in Murphy-1and Erldunda-1 where the onset of the oil-early gas generation window occurs at depths of 1000 m and 1300 m respectively in the Aralka Formation. On the southern margin of the Central Ridge in Wallara-1, Aralka Formation shales lie in the oil/early gas window at depths of 1300 m; this maturity was confirmed by MPI index analysis. In Magee-1, geochemical analysis of Gillen Member shales indicates gas prone source rocks are currently in the oil window at a depth of 2300 m.

In summary this geochemical/maturation data indicates:

1) oil/gas/wet gas generation from Neoproterozoic source rocks occurred over a wide area of the southern and northern Amadeus Basin.
2) regional basin uplift and unroofing has occurred largely in the south of the basin during the PRO and in the north at the end of the ASO.
3) hydrocarbon generation from Sturtian-Marinoan source rocks probably occurred during Pertatataka/Arumbera time while maturation occurred much earlier for Gillen Member source rocks (Bitter Springs time). It should be noted that ASO structures in the northern part of the basin have received charge from Neoproterozoic source rocks developed in major depocentres like the Missionary Plain Trough (eg Ooraminna and Dingo fields) but there is no evidence of this in the southern part of the basin.
4) Over wide areas of the southern Amadeus Basin, PRO structures and “Halo” plays are attractive targets while younger ASO structures probably post-date migration from Proterozoic source rocks except in the Missionary Plains Trough. The influence of ASO structuring gradually decreases north-south across the basin and PRO structuring dominates the southern margin of the basin.

Over wide areas of the Amadeus Basin, but most commonly in the northern part of the basin where Devonian – Carboniferous Alice Springs Orogeny (ASO) structuring predominates, current day outcrop patterns reflect a largely elongate E-W trending, enechelon style of compressional folding. This structural pattern is dominated by broad synclinal structures complimented by very tight anticlinal axes sometimes thrust over adjacent synclinal zones and often cored by salt. The current outcrop expression of basinal synclines largely reflects major N-S compression during the latter stages of the ASO. This structuring was preceded by a multi-phase structural history encompassing two major phases of foreland basin development during the PRO (Late Neoproterozoic to Early Cambrian) and the ASO (Late Ordovician to Carboniferous). Intervening rift tectonic/ sedimentary regimes were in place during most of the Neoproterozoic and Lower Middle Palaeozoic but PRO and ASO structural overprints generally mask earlier tensional tectonics. Major block faulting occurred during the Sturtian Areyonga Orogeny and halotectonics linked to Gillen Member and Chandler Formation evaporites were intermittent throughout the basin's history.

2. Petroleum Systems

The petroleum systems (ie source rocks) and target reservoir seal couplets relevant to the Amadeus Basin in general and to "Halo" plays in particular, are outlined below:

1) **Gillen Member shales** (methane,wet gas, Helium)
   Targets – Heavitree Quartzite-Gillen seal
   - Johnny's Creek Member (hot sands) / Sturtian shale seal
2) **Aralka Formation shales** (oil, wet gas, methane)
   Targets - Intra Aralka Formation sandstones
   - Pioneer Sandstone-Pertatataka Seal
   - Hot sands in the Johnny's Creek Member-intraformatonal seal
3) **Pertatataka Formation shales** (oil, wet gas , methane)
   Targets - Intra Pertatataka sandstones (eg Cyclops Member)
   Pioneer Sandstone - Pertatataka seal
   - Arumbera Sandstone/ Chandler seal
   Note: The Pertatataka Fm commonly records TOC's of less than 1.0% but hydrocarbon generation can reduce TOC content by up to 50% (Hunt, 1995).
3) **Giles Creek Dolomite** (oil,wet gas, methane)
   Targets - Illawarra Sandstone- Hugh River Shale/ Deception Siltstone seal.
   - Intra Hugh River Shale sands.
4) **Horn Valley Siltstone** (oil, wet gas, methane)
   Targets – Pacoota Sandstone-Horn Valley seal

- Stairway Sandstone - Stokes Siltstone seal, intra formational seal.

5) **The Mereenie Sandstone** may be a target where it is sealed by the **Parke Siltstone**. Potential DHI's have been recognised along the northerm basin margin in the Johnston area. This reservoir seal couplet could be highly prospective in the far northern part of the basin.

Depositional onlap of reservoir-seal couplets onto ancestral highs, combined with massive hydrocarbon charge from basinal synclinal areas provide the dynamics necessary for widespread hydrocarbon entrapment. The resultant " Halo" plays occur over almost all of the basin including major trends as discussed in the following sections:

3. Stratigraphic Overview

The stratigraphy and basin evolution of the Amadeus Basin is summarised in Lindsay and Korsch (1991). Some new ideas relating known petroleum systems to sediment loading events have evolved over time and a brief overview of these occurs below:

3.l **Bloods Range Sequence**: Rift sequence. No source rocks.

3.2 **Heavitree Quartzite**: Pre-rift. No source rocks

3.3 **Bitter Springs Formation**: Syn-rift. Gillen Formation source rocks Developed – sheet like development
Hydrocarbon generation was probably triggered in the main depocentres during Bitter Springs Formation loading
The unit is often through the dry gas window. Over platformal areas with thin Bitter Springs Formation cover, Pertatataka Formation sediment loading could have triggered hydrocarbon generation eg in Magee-1 the Gillen Member is in the oil window.

Areyonga Movement

Regional Uplift and Erosion (Extensional Block Faulting)

3.4 **Areyonga Formation:** Pre-rift Sturtian glacials- no source rocks

3.5 **Aralka Formation:** Pre-rift shales - source rocks developed- sheet like development.
Hydrocarbon generation probably occurred in the main depocentres during deposition of the Pertatataka Formation where the unit is through the gas window. On platform areas lacking thick Pertatataka Formation these source rocks are probably thermally immature or in the oil window. eg Murphy-1 and Erldunda-1 .

3.6 **Pioneer Sandstone:** Prerift – no source rocks

3.7 **Pertatataka Formation**: Synrift – source rocks developed. Rapid thickening into rift grabens and half grabens.
Hydrocarbon generation probably commenced in the main depocentres during Arumbera / Chandler Formation loading continuing through to the Alice Springs Orogeny. In some platform areas oil mature shales are encountered. Due to denudation of TOC's during generation the importance of these source rocks has been underestimated.

3.8 **Julie Formation:** Synrift – no source rocks

Petermann Ranges Orogeny

Major compression in the south - southwest. Little structuring in the north of the basin or strongly overprinted by ASO structuring.

3.9 **Arumbera Sandstone:** Foreland Basin clastic sequence prograding from the southwest into basinal areas to the north where extension was dominant. No source rocks.

3.91 **Chandler Formation:** Basin sag phase. No source rocks. Major thickening seen into the Missionary lains Trough.

3.92 **Upper Pertaoorta Group**: Middle Cambrian Carbonate Ramp (Transgressive –regressive). Source rocks present in Giles Creek Fm- are a very poorly documented/ understood petroleum system. Oil bearing shales are recorded and sandstones at the top of the cycle may be analogous to the highly prospective Steamboat Sandstone in the Georgina Basin.

3.93 **Larapinta Group**: Broad marine shelf with low rates of subsidence. Source rocks developed- Horn Valley siltstone has sheet like development.
Hydrocarbons generated during sedimentation associated with foreland molasse resulting from ASO compression on the northern basin margin (Devonian).

3.94 **Pertnjara Group**: Foreland basin molasse shed from the northern basin margin during the ASO. No source rocks. This was an important thermal-loading event.

NB Most folds outcropping north of the Erldunda Fault Zone belong to the latter phase of ASO folding. In the southernmost part of the basin this phase is largely absent and PRO folding and thrusting was succeeded by uplift and peneplanation during the Early Devonian Pertnjarra Movement of the ASO.

4. Tectonic Elements and Areal Distribution of Petroleum System Generation.

The initiation of the Amadeus Basin probably coincided with the onset of Mesoproterozoic rifting, which was associated with the Giles Event (1080–1040 Ma) and may have centred on the Musgrave Province. A number of the resultant northwest-trending faults were reactivated at this time (SRK 2004). This process defined the shape of the basin and location of basement highs. Renewed rifting, related to continued northeast-directed extension, occurred at the commencement of the Neoproterozoic (800–840 Ma) and ultimately lead to the breakup of the Rodinian Supercontinent along the Tasman line (Powell *et al* 1994). Faults defining the basement fabric were intermittently rejuvenated during later rifting and orogenesis through to the Palaeozoic.

Within the Amadeus Basin, the Central Ridge separates two very different subsidence regimes. This ridge may have largely resulted from flowage of Bitter Springs salt from the Carmichael – Missionary Plains depocentre into the ridge (Lindsay and Korsch,1993). However, new depth to economic basement mapping (based on regional aeromagnetics) has virtually altered the notion of a central ridge separating the basin into northern and southern components. A more detailed interpretation occurs in the next section.

The areal distribution of generative shales in source rock sequences (petroleum systems) mentioned earlier has only been previously attempted for the Ordovician Horn Valley Siltstone (Gorter, 1984). New geochemistry, particularly related to thermal maturity, is discussed in the context of defining petroleum generative depocentres for the other Neoproterozoic petroleum systems.

In a broad sense in the northern-central part of the basin, major synclinal axes reflect basinal areas and attendant anticlines often reflect reactivation of antecedent intra-basinal highs. The structural reactivation of the original depositional footprint sets up some potentially important onlap plays (“Halo” plays) around partially bald structural highs bounded by synclinal source kitchen areas. This study relies heavily on new aeromagnetic basement mapping which has rescinded the notion of a central ridge subdividing the basin and instead invokes the Erldunda Fault Zone, and the Carmichael and Mt Currie orogeosynclines and other thrust belts and platform areas as the prime tectonic elements.

In a regional sense over much of the Amadeus Basin, away from the main basin margin depocentres, NW trending faults define half-grabens and sometimes grabens at depth which relate to SW-NE rifting responsible for the initial breakup of Rodinia. The distribution and source potential of the more important depocentres and entrapment potential either on or against basement highs is described below.

4.1 Highway - Finke - Mt Winter Terrane

4.1.1 Structural setting/ Petroleum Systems

This is a zone of elongate NW orientated basement structures where a number of basement highs have been drilled eg Highway-1, James Range-1, Gardiner Range, East Johnny's Creek-1, Ochre Hill-1, and Mt Winter-1.This terrane includes much of the area originally assigned to the Central Ridge by previous authors. Drilling results indicate the highs were dominant during Marinoan to Early Cambrian times and were certainly a focus for uplift and erosion (block faulting) during the Sturtian Areyonga Orogeny. Later compression during the ASO formed the fold axes seen today in outcrop. The southern margin of the terrane is clearly defined by the Erldunda Fault Zone and basement faulting within this area largely parallels this trend.

Decollement zones along the Gillen salt layer and associated halotectonics resulted in salt withdrawal and intrusion of diapiric salt into the core of many tight anticlinal structures during PRO structuring ; these were later rejuvenated during ASO compression. Thick early Cambrian Chandler Salt sequences occur in the eastern part of the basin and the style of structural development via halotectonics characterising the ASO is similar in many respects to that seen in the Gillen Salt during the PRO.

Three NW elongate grabens occur in this terrane and Gillen source rocks would have been gas generative at depth. The later Neoproterozoic section would include Aralka Formation and Pertatataka Formation source rocks in the dry-wet gas window. In the Mercury Syncline immediately north of Mereenie field, oil and gas generated from the Horn Valley Siltstone migrated into the adjacent Mereenie Structure during the latter stages of the ASO.

4.1.2 Halo Play – Leads and Prospects

4.1.2.1 The Highway Anticlinal High

Key Well: – Highway-1

Stratigraphy included :

	Depth
: Giles Creek Dolomite	514 m
Chandler Formation	784 m
Johnny's Creek Beds	818 m
Loves Creek Member	865 m

A type area for the Marinoan and Early Cambrian section in the Missionary Plains Trough (ie the Orange Creek Syncline) is typified by that seen in the

Dingo Field where thick sequences of Arumbera Sandstone and Chandler Salt reflect syn-sedimentary structural growth. This ceased by Giles Creek Formation time as demonstrated by the uniform sheet-like deposition of these units both in the basin and over adjacent palaeohighs such as the James Range – Finke trend. Potential “Halo” plays arise where the following reservoir / seal couplets pinch out against the high: 1) the Pioneer Sandstone/ Pertatataka Formation, 2) The Arumbera Sandstone / Chandler Salt and 3) intra- Pertatataka sands. Hydrocarbon charge to these traps could come from Aralka and/or Pertatataka Formation source rocks. These “Halo” plays have significant potential around the southern edge of the Orange Creek Syncline but need to be mapped seismically.

b) The Finke – James Range Anticlinal High

Key Well : - Finke 1

Green shale	
Chandler Formation	179 m
Arumbera	195 m
Johnny’s Creek Beds	273 m
Loves Creek Mbr	399 m

Key Well: - James Creek-1

Green Shale
Arumbera Sandstone
Areyonga Tillite
Loves Creek Member

Notes: 1) Abundant oil shows in the Arumbera Sandstone/Johnny’s Creek Member in both wells denote a ? breached oil column. This means the relatively thin Chandler section intersected was a seal, prior to breach during the ASO. This is important when considering “older” oil charged structures. Retention of potentially large gas columns as seen at Dingo, Orange and Alice may require a thick salt (Chandler) seal which is generally only developed in basinal areas like the Orange Creek Syncline.

2) Initial oil charge to the Finke-James Creek High was probably sourced from Aralka Shales developed down-flank. The initial gross oil column of 136 m was trapped at Finke-1, probably on an ancestral high formed during PRO block faulting. There was major restructuring and breach during the ASO.

The absence in both wells of the Pertatataka-Pioneer reservoir-seal couplet predicts a “ Halo” play at this level on the northern flank of the structure on the edge of the Orange Creek Syncline. Given the long history of growth on the structure, the same play should be present on the south side of the high, into the Mercury Syncline. The Mercury Syncline extends over 200 km from the Arunta Block southeastwards to the southern edge of the James Range High and has clear expression on aeromagnetics depth to basement mapping. It is a very important source kitchen area, and being shallower than the Missionary Plains High to the north, portends oil generation from the Horn Valley Siltstone as indicated by entrapment in the Mereenie field.

c) Walker Creek Anticlinal High

Key Well: West Walker-1

This well reached TD in Top Pacoota Sandstone.in a downflank test of the western end of the structure. A gas flare may have originated from an isolated sand in the Horn Valley Siltstone- an unusual SP response needs to be further investigated. The remaining Ordovician reservoirs are water saturated.

Key Well: Tent Hill-1

This well reached TD in the Top Pacoota Sandstone which was wet; the anticline is clearly breached at this stratigraphic level.

There is no drilling information on the deeper section other than what is described in outcrop.
At the crest of the structure outcrop comprises:
Op -- Ordovician section-complete.
Cp – Condensed Pertaoorta Group (siltstones , shales and limestones)
Cq – Quandong Conglomerate - Conglomeratic Sandstone (local development only – may be local channels developed on diamictite
Pua -- Areyonga Formation (diamictite)
Pub—Bitter Springs Formation.

Note; important source/seals at the Aralka, Pertatatataka, Chandler and Giles Creek levels are missing at the crest.
The section thickens significantly into the Mercury Syncline but the stratigraphy is uncertain.
"Halo" plays should exist at the level of the following reservoir-seal couplets:

- the Pioneer Sandstone - Pertatataka Formation
- the Arumbera Sandstone - Chandler Formation
- Horn Valley stratigraphic plays

The northern flank of the structure into the Mercury Syncline is most prospective. The presence of gas in West Walker-1 suggests deeper source horizons at the Pertatataka and Aralka levels will also be in the gas window.

Indeed most petroleum systems in the Mercury and Liebig Synclines are believed to be in the gas window. Oil targets are high risk as they may be thermally cracked in the reservoir or flushed by later gas charge.

d) McMint Anticlinal High

The high is on trend with the Walker Creek High being separated to the east by the compressive Illamurta Structure. The high dips to the north into the Mercury Syncline.

The stratigraphy is similar to that seen to the west on the Walker Creek Anticline with the exception that:

1) The Pertatataka Formation is present over the crest of the high but there is no evidence of Pioneer Sandstone thus hinting at the presence of a "Halo" play.
2) There is no evidence of the Aralka/Chandler source-seal units over the crest. Pinchout of the Arumbera/ Chandler seal is viable "Halo" play

e) Petermann Creek Anticlinal High

Key Outcrop: This is a narrow EW trending anticline bound to the north by a south dipping thrust fault . On the southern limb a broad syncline, the Levi Syncline offers halo plays at several stratigraphic levels.

The geology over the crest of the structure comprises:

Op -- Ordovician section-complete.
Cp – Condensed Pertaoorta Group (siltstones , shales and Limestones)
on the westerly plunging nose the Pertaoorta Group comprises:
Petermann Sandstone
Deception Formation (Red Siltstone and Shale)
Illara Sandstone
Tempe Formation
Pua -- Areyonga Formation (diamictite)
Pub—Bitter Springs Formation.

Regional geology suggests the Horn Valley Siltstone is probably immature in the Levi Syncline while the deeper Adelaidean source rocks are possibly in the oil window.
This stratigraphy, together with the fact that thick Pertatataka Formation /Aralka Formation source rocks occur downflank in Wallara-1 and are mature for hydrocarbon generation, raises the possibility of Pioneer/Pertatataka and also Arumbera Sandstone/Giles Creek "Halo"plays.

Key Well: Wallara-1 on the southern limb of the Levi Syncline includes the following sequence. Thickness
Goyder Formation 30 m+

Petermann Sandstone	105 m
Deception Siltstone	225 m
Illara Sandstone	40 m
Hugh River Shale	65 m
Giles Creek/ Green shale	120 m
Arumbera Sandstone	83 m
Julie Formation	87 m
Pertatataka Fm	477 m
Pioneer Sandstone	9 m
Aralka Formation	26m
Areyonga Formation	117 m
Bitter Springs Fm	576 m+

Note: A potential ASO four-way dip closure occurs updip of Wallara-1. Aralka Fm shales are in the oil/early gas window in this well at 1300 m.

Wallara-1 gives a good approximation of the sediments that could be present in the basinal section in the Levi Syncline. Reservoir-seal couplets include: Illara Sandstone/Deception Siltstone, Arumbera Sandstone/ Giles Creek, and the Pioneer Sandstone/ Pertatataka Fm.

Two reservoir/seal couplets absent at the crest of the Petermann Creek Anticlinal High are the Arumbera/Giles Creek and the Pioneer/Pertatataka Fm. The main seal/source rocks in the basinal Wallara-1 well are the Aralka Formation and the Pertatataka Formation and possibly the Giles Creek Formation. This data suggests that downflank of the anticlinal high, Halo plays at these stratigraphic levels are prospective.

Potential source rocks include both the Aralka and Pertatataka Formations, and to some extent the Giles Creek Formation . There is potential for oil generation and maturities should be less than the overmature gas generative source rocks seen in the Orange, Missionary Plain and Mercury Synclines to the north. Thus in this area of reduced burial the potential for wet gas and perhaps even oil is a lot higher than is the case to the north.

f) Bacon Range Anticline

This structure is an EW anticline having its dominant origin during the ASO but also with a PRO component to the structure. Outcrop is scattered and generally inconclusive but a broad anticlinal closure comprises Bitter Springs Formation in the core of the anticline overlain by Areyonga Formation. The structure is complex but has potential for “Halo” plays at the level of the Pioneer Sandstone; this structure requires further delineation by seismic and other geophysical techniques. Additional potential occurs at the level of the Heavitree-Gillen reservoir /seal couplet.

g) Seymour Range Anticlinal High and Seymour Range Syncline

This feature is a narrow anticline intervening between two broad synclines.

Outcrop is poor but the broad synclinal outline is clear on aeromagnetics first derivative maps. 2008 seismic will test the likelihood of “Halo” plays in areas of poor outcrop.

Key outcrop information

Southern Limb of the Seymore Range Anticline/Canteen High
Inindia Beds(Areyonga equivalent)
Winnall Beds (Pertatataka Formation)
Pertaoorta Group (condensed)
Stairway Sandstone
Stokes Siltstone
Mereenie Sandstone

Significantly the Pacoota and Horn Valley Siltstone are missing on the anticlinal high but may be present at depth in the intervening syncline. It is possible the Horn Valley Siltstone overlaps the Pacoota Sandstone providing a “Halo” play possibility at this stratigraphic level. However, the play is largely negated by perceived immaturity of the Horn Valley Siltstone in the Seymour Syncline. 2008 seismic will throw some light on this potential play which may be resurrected if the Horn Valley is sufficiently deeply buried.

The Neoproterozoic geology is very poorly represented in outcrop hence definition of potential plays at this level will be reliant on seismic. Seismic modelling should elaborate on the presence of potential source/seal horizons and help unravel maturation history given there has been a major component of uplift and erosion in the area.

NB It is encouraging that two wells closer to the southern basin margin, Murphy-1 and Erldunda-1, have intersected thick sections of the Pioneer/Pertatataka reservoir/seal couplet. Gas and oil prone Aralka Formation source rocks are also well developed in both wells and are mature for hydrocarbon generation as is the Pertatataka Formation. Over wide areas of the central-southern Amadeus Basin it is believed considerable uplift and erosion has left generative sequences of Pertatataka/ Aralka source rocks at relatively shallow depths. The same may be true for the Giles Creek Formation. Geochemical data from the Wallara-1, Murphy-1 and Erldunda-1 wells support these conclusions.

h) Canteen Anticlinal High/ Aimorn Syncline/ Erldunda Range Anticline – Sunday Range Anticline

This is a narrow EW anticline (ASO structuring with PRO precursor) bound to the north and south by two broad synclinal structures of ASO origin.

Key Wells
Erldunda-1: Intersected Tops
Arumbera Sandstone

Pertatataka A
Cyclops Sandstone
Pertatataka B
Pioneer Sandstone
Aralka Formation
Areyonga Formation
Johnny's Creek Member
Loves Creek Member

It is encouraging that two wells relatively close to the southern basin margin, Murphy-1 and Erldunda-1, have intersected thick sections of the Pioneer/Pertatataka reservoir/seal couplet. Gas and oil prone Aralka Formation source rocks are also well developed in both wells and are mature for hydrocarbon generation. The Pertatataka Formation is also believed to be in the oil window.

Canteen Anticlinal High

A westerly plunging anticline with Pertatataka Formation and Areyonga Formation exposed in the core. In the west there is little chance of "Halo" plays over the high as all target reservoir seal-couplets are breached. What potential may exist under an area of dunes to the west remains uncertain. There is some potential for a Pioneer play to the east but outcrop is very sparse.

Aimorn Syncline

The syncline is very similar to the Seymour Syncline in terms of aeromagnetic signature but there is sparse outcrop and no seismic thus hindering an interpretation.

The Erldunda Range Anticline – Sunday Range Anticline

The western part of the trend outcrops on the Kulgera 1:250,000 sheet where Areyonga and Pertatataka Fm occur in outcrop. Seismic is required to discern the possibility of "Halo" plays which may occur at the level of the Pioneer Sandstone . The deeper Heavitree Quartzite play may also come into play in this area but confirmatory seismic is required.
NB Considering obvious stratigraphic subdivisions in the nearby Erldunda-1 well it is clear that the names Inindia and Winnall can be relaced by a more regional nomenclature; ie Areyonga-Aralka and Pioneer- Pertatataka respectively.

Given current understanding of petroleum systems and stratigraphy in this region it is considered the Pertatataka/Pioneer/ Aralaka petroleum system, and reasonably shallow Heavitree Quartzite plays are the most attractive targets.

i) Watson Range Anticline

The Watson Range Anticline trends NE-SW for about 80 km and is bound to the NE by the Liebig Syncline and to the SW by an extension of the Foreman Syncline. The southern extension of the anticline parallels the Erldunda Fault Zone. The structure was defined during a late phase of the Alice Springs Orogeny.

Key well: Mt Winter-1

Tops	
? Aralka Formation	1250m (35 m of med-dk grey shale)
Pioneer Sandstone	1293m
Aralka Formation	1299 m
Areyonga Formation	1350 m
Unnamed Sturtian (alluvial-aeolian)	1475 m
Johnny's Creek Member	1678 m
Loves Creek Member	1752m
Gillen Member	2111m

Key well: Ochre Hill-1 (sandy Cambrian section on Johnny's Creek Member)

Goyder Formation	Surface
Cleland Sandstone	420 ft
Tempe Formation	2180 ft
Johnny's Creek Mbr	2630 ft
Loves Creek Mbr	3285 ft

The well data along this trend indicates the main "Halo" play targets are the Pioneer/Pertatataka Formation reservoir-seal couplet and the Arumbera/Chandler reservoir-seal couplet and to a lesser extent the Heavitree/Gillen reservoir-seal couplet.

Wallara -1 is a significant well in assessing geological risk. It was drilled downflank on the Wallara structure and intersected a thick Pertatataka seal on Pioneer Sandstone. Similarly there was a viable shale seal developed on the Arumbera Sandstone which was allocated to the basal Tempe Formation which could be a lateral equivalent of the Chandler Formation. Two wells updip on palaeohighs East Johnny's Creek-1 and Ochre Hill-1, both lacked any significant Pertatataka seal or indeed Chandler seal, suggesting possible onlap of these reservoir-seal couplets on to the palaeohighs.

Source kitchens in the Foreman and Liebig Synclines would have ample maturity to push the Adelaidean petroleum systems into the gas window and the HornValley Siltstone would also be variably in the oil/gas window.

j) Mt Burrell Anticlinorium

This is a strongly folded and faulted anticlinal structure lying southwest of the Camel Flat Syncline. The Pioneer Sandstone has potential for both “Halo” plays and fourway dip closure as does the Heavitree Quartzite – Gillen Member petroleum system.

Potential Pertatataka source rocks outcrop over the structure but there is no modern seismic in the area and the only modern geophysics is recently flown aeromagnertics.

k) Deep Well Anticline

This is an anticlinal structure lying east of Highway-1 and south of Ooraminna -1. Outcrop confirms the structure is breached to the level of the Pertatataka Formation and the outcroppinf sequence is confirmed below:

Giles Creek Formation
Arumbera Sandstone
Pertatatataka Fm

Potential for “Halo” and 4 way dip closures thus exist at the level of the Pioneer Sandstone. There may also be potential at the Heavitree-Gillen level.

l) Highway Anticline

This is the first anticlinal structure lying south of the Orange Syncline. Outcrop confirms the structure is breached to the level of the Pertatataka Formation and the outcropping sequence is confirmed below:

Giles Creek Formation
Arumbera Sandstone
Pertatatataka Fm
Bitter Springs Fm

The nearest well control comes from Highway -1 to the west. In the lower section the well intersected:

Hugh River Shale
Green Shale
? Unnamed Sandstone
  Areyonga Formation
  Johnny’s Creek Beds

Potential for “Halo” and 4 way dip closures thus exist at the level of the Pioneer Sandstone but also possibly at the level of the Arumbera Sandstone. There may also be potential at the Heavitree-Gillen level.

M) Foreman Anticline

Outcrop at the Foreman anticline is described below:

Giles Creek Formation
Arumbera Sandstone
Pertatataka Formation
Areyonga Formation
Bitter Springs Formation

There is potential for Pioneer pinchout on the flanks of the high and potential for Heavitree –Gillen 4 way dip closures at depth.

4.2 Carmichael Sub-basin/ Missionary Plains Trough

4.2.1 Structural Setting and Petroleum Systems

This sub-basin is largely controlled by thrust faults forming the southern margin of the Arunta Block. The deepest sub-basin in the Amadeus Basin, the Carmichael Sub-basin shallows eastwards towards the Missionary Plains Trough. The sub-basins were essentially extensional at certain times (ie during Bitter Springs,Pertatataka and Arumbera/Chandler times) but the main sedimentary fill relates to foreland molasse sedimentation caused by compression during the Devonian- Carboniferous ASO. Seismic indicates at least 14 km of Neoproterozoic and Palaeozoic sediment fill which gradually thins to the east. Several EW and SNW trending ancestral highs (eg Waterhouse High, Palm Valley) were locii for ASO folding within the sub-basin.

Petroleum systems (source rocks) present in this sub-basin are summarised below:
1) Gillen Member: super mature- dry gas window (initial Bitter Springs loading). The unit has a sheet-like distribution.
2) Aralka Formation: initial oil generation but shales are now in the gas window (gas would have displaced early oil accumulations)- Initial Pertatataka/ Arumbera loading. The unit has a sheet like distribution.
3) Pertatataka Formation: (gas window) Initial loading during Arumbera and Chandler time when extension dominated the sedimentary regime. Further gas charge was triggered by foreland molasse loading during the ASO.The unit thickens into synrift basins.
4) Horn Valley Siltstone: The Horn Valley Siltstone has a sheet like distribution and went through the dry gas window during loading associated with the Alice Springs Orogeny but all structures are breached by erosion.

NOTE: a). The source kitchen has progressed to the dry gas window flushing any early formed oil to the basin margin. Isotope geochemistry indicates the source of gas in Dingo field is the Pertatataka Formation and there is evidence that the structure is filled below spill. ASO traps (Devonian – Carboniferous) at Ooraminna and Dingo are flushed with dry gas indicating gas charge continued from the Early Cambrian through to the Devonian – Carboniferous.

4.2.2 Halo Plays – Leads and Prospects

a) The Waterhouse Anticlinal High

Key Outcrop Information (Waterhouse High)- Stairway Pinchout

Applying the same aforementioned geological rationale derives an Ordovician " Halo" play in the Orange Creek Syncline around the Waterhouse Anticline. One of these is the oil prone Stairway Sandstone "Halo" play on the flanks of the Waterhouse High. Outcrops on the southern flank of the Anticline comprise oil prone Horn Valley Siltstone source rocks directly underlying the Mereenie Sandstone. Shales in the Horn Valley Siltstone are oil and gas mature in the adjacent Orange Creek Syncline.

The Stairway Sandstone, which is gas bearing to the east, pinches out downflank from the crest and presents a prime target if it is overlapped by a viable seal. Possible overlapping seals could occur via shales in the upper Stairway Sandstone or silty shales of the Stokes Siltstone. Earlier studies of the Tempvale-1 well indicated an intra-Stairway seal directly above the basal Stairway Sandstone is the first seal above the latter rather than the usually invoked Stokes Siltstone. If this relationship holds on the southern flank of the Waterhouse High, an important Stairway Sandstone "Halo" play can be invoked. The play could encircle the Waterhouse anticline.

Waterhouse 3 Implications

Waterhouse 3 will test the possibility of gas charged Pioneer Sandstone on the Waterhouse Anticline. If the structure is bald at this level it will invoke a zero edge play sourced and sealed by thick shales of the Pertatataka Formation; this unit was 158+m thick in Waterhouse-2. The latter suggests the structure was basinal at Pertatataka time which certainly increases the likelihood of Pioneer Sandstone development over the crest.
Project: The play needs to be mapped out on seismic but has the potential to entrain large volumes of OGIP. Once the position of the "halo" is established further seismic will define prospects on both sides of the high.

Prior to the drilling of Waterhouse -3 it would be prudent to map the Pertatataka isochron over the entire structure to ensure it provides blanket seal including at the crestal location.

b) The Gardiner Range Anticlinal High

There has been only shallow stratigraphic drilling on the high without any penetrations below the Ordovician.

The only unbreached reservoir - seal couplet is the Pioneer Sandstone/ Pertatataka Fm on the northern flank of the structure. The northern flank also hosts a subcrop play in the footwall at a number of stratigraphic levels. The equivalent of the Arumbera-Chandler seal is breached on the anticlinal axis and only the Pioneer/Pertatataka target has potential for stratigraphic entrapment on the northern flank of the high. Precedents for stratigraphic thickening at this level into the Missionary Syncline come from seismic and drill data giving the play a higher level of confidence.

On the broad southern flank of the structure the Pertatataka Formation does outcrop but there is no evidence of the Pioneer Sandstone being breached; seismic studies should determine the confidence level of Pioneer pinchout southwards into the Mercury Syncline where target depths should be much shallower than to the north into the Missionary Plain Syncline. The Gardiner Anticline also needs to be reassessed for Heavitree Quartzite potential to test the possibility of onlap onto the southern flank of the high.

Project: The Pioneer play needs to be mapped out on seismic and has the potential to entrain large volumes of OGIP. Once the position of the "halo" is established further seismic will define prospects on both sides of the high, although the southern flank is most attractive. The potential sources are the Aralka and Pertatataka Formations which would be gas mature in the adjacent Missionary Plains and Mercury synclines.

c) Orange Syncline –Pioneer Sandstone 4wd at depth

d) Dingo Anticline – Pioneer Sandstone 4wd at depth

4.3 Central Platform Half - Grabens and

a) Liddle Anticline (Henbury 4-mile sheet)
b) Preiss Anticline "
c) South Bank Anticline "
d) Gravestock Anticline "
e) Junction Anticline "
f) Pararana Hill Anticline " and Lake Amadeus
g) Tucker Anticline (Lake Amadeus)
h) Ochre Hill Anticline " Arumbera, Pioneer Sandstone Halo
i) Johnny's Creek Anticline "
j) Black Hill Anticline (Lake Amadeus) - Pioneer Halo, Dean Quartzite

b

4.3 Western Platform and its Sub-basins

4.3.1 Structural Setting and Petroleum Systems

The only maturity data on the western platform comes from NTGS drill hole DD05-01 located near Long Range. Pertatataka and ?Aralka source rocks are in the oil window at 480m in this drill hole testifying to major uplift and erosion in this area, and oil shows were recorded at this depth. This hints that much of the platform has been unroofed but wide areas are expected to be in the oil/gas window at Aralka/ Pertatataka levels while the Gillen Member is expected to be in the gas window on a regional scale. The Ordovician is believed to be largely non-prospective in this area but the Neoproterozoic is an important target; there is likely to be great complexity at depth over large areas where there is little or no seismic and where the ASO structural grain and surficial deposits mask structuring in the Neoproterozoic. For instance Oaks et al(1991) on the basis of limited outcrop studies define a relatively thick Pertatataka shale sequence (up to 2000 m thick) in the south - central portion of the Amadeus Basin east of the Mt Currie sub-basin. This suggests the shale section can thicken rapidly into local grabens thereby pushing the Aralka and Gillen source rocks into the oil/ gas window. In less deeply buried areas (eg DD05-01) the source rocks will be in the oil window. This whole region is very sparsely explored.

Three important sub basins developed on the Western Platform all being bound to the north by the Erldunda Fault Zone. These were the Wallara, Ochre Hill and Mt Winter sub-basins.

4.3.2 Mt Winter Sub-basin

This half-graben is bound by the NW trending Mt Winter High which forms part of the Erldunda Fault Zone. Sparse seismic data is available and indicates the key known petroleum systems are present from the Gillen Member at depth to the Horn Valley Siltstone. The Gillen Member would be in the dry gas window as would be the Aralka (present in Mt Winter-1) and Pertatataka Formations. The Neoproterozoic petroleum systems are likely to be in the gas window while the Horn Valley Siltstone would be in the oil/wet gas window given the abundant oil shows in Mt Winter-1 and Tempe Vale-1. The southern extent of oil mature Horn Valley source rocks to the sequence zero edge was published by Gorter (1984) but will be fine tuned when new 2008 seismic data becomes available.

4.3.3 Ochre Hill Sub-basin

This sub-basin, is also essentially a half graben bound to the north by the Erldunda Fault Zone; its deepest point lies south of Johnny’s Creek-1. The basin fill is probably similar to that in the Wallara Sub-basin. Gillen Member source rocks would be in the dry gas window at depth while a thickened Pertatataka Formation and Aralka Formation would also be in the gas widow. The Aralka/Pioneer section is absent in the Ochre Hill-1 well suggesting the possibility of a “halo” play around this high; this section is present in East Johnny’s Creek-1. Significantly the important Pertatataka – Julie Fm - Arumbera synrift sequences are missing along the nearby NW trending Central Ridge in both East Johnny’s Creek-1 and Ochre Hill -1with the suggestion of “halo” plays at this stratigraphic level. Note that the ASO structural grain trends SNW at a slight angle to the deeper basement structural grain.

4.3.4 Wallara Sub-basin

The Wallara Sub-basin is a half graben bound on its northern side by the Erldunda Fault Zone. The Wallara sub-basin occurs immediately southwest of Wallara-1, and may be over 7 km deep. Young and Ambrose (1991) report basement involved compressional and possibly wrench tectonics associated with the PRO and ASO. Interval thicknesses are relatively constant across some faults suggesting mainly ASO structuring but the Erldunda Fault Zone is an ancestral, deep crustal feature exhibiting transpression

Wallara-1 provides well control in the footwall block. No significant shows were recorded but subsequent analysis indicated that minor migrated oil is present in the Aralka Formation and in this well the Bitter Springs, Aralka and Pertatataka Formations are in the late oil window at depths around 1300m implying major basin unroofing.

Basement is elevated beneath the Wallara-1 structure and is coincident with gravity, magnetic and SEEBASETM depth-to-basement highs. PRO structuring, with pronounced crestal thinning (truncation) of the Pertatataka Formation appears to be basement involved, although sub-salt imaging is poor. Because of severe crestal erosion during the ASO, oil maturity indicators occur at anomalously shallow depths over the structure. In the half graben to the southwest (Wallara Sub-basin), potential source rocks (Pertatataka/Aralka formations) would have passed through the gas window, possibly during or after PRO trap formation.

The fully cored Wallara -1 well is a critical data point as it fully calibrates core lithology against wireline log signature. The stratigraphy in a number of key wells has changed considerably on this basis eg Sturtian / Marinoan correlations in Mt Winter -1, Johnny's Creek East -1, Ooraminna-1, Murphy-1 and Erldunda -1.

There is no data in the half graben, but the sequence probably includes Bloods Range style rift sediments at depth and younger Neoproterozoic rift sequences which are too deeply buried to be preserved in outcrop; it is believed relatively thick sequences of gas prone source rocks are developed here. Whilst the Horn Valley Siltstone did not form part of the graben fill the shales are believed to be immature to early oil-mature in this region.

4.3.5 Western Platform: "Halo" Leads and Prospects

a) Wells "Halo" Lead

Well Control: Mt Winter-1 (45 km to the northeast)

Tops

? Pertatataka Formation	1250m
Pioneer Sandstone	1293m
Aralka Formation	1299 m

Areyonga Formation	1350 m
Unnamed Sturtian (alluvial-aeolian)	1475 m
Johnny's Creek Member	1678 m
Loves Creek Member	1752m
Gillen Member	2111m

NB The Horn Valley Siltstone was full of oil shows at 200 m suggesting the structure was heavily rejuvenated removing molasse sedimentary load sequences associated with the ASO structuring. There were also minor gas shows in the top Bitter Springs Formation.

The Wells Anticline is a large ASO structure extending over the Mt Rennie , Mt Liebig, and Lake Amadeus 4 mile sheets, over a distance of nearly 100 km. Outcrop is very sparse but the core of the anticline comprises Bitter Springs Formation probably overlain by Tempe Formation, Cleland Sandstone, Pacoota Sandstone, Horn Valley Siltstone, Stairway Sandstone, Carmichael Sandstone and Mereenie Sandstone. ASO synclinal axes lie immediately to the northeast (Foreman Syncline) and to the southwest (Ranford Syncline). The structure is probably cored by Gillen Salt but 2008 seismic transects the structure and will greatly advance understanding of this anticline.

The main "Halo" plays relate to pinchout of Marinoan and Sturtian reservoir/seal couplets on the flanks of the anticline while a structural/stratigraphic plays could exist at the level of The Heavitree Quartzite. Interpretataion of the 2008 seismic will determine which of the following reservoir/seal couplets should be targeted.

1) Heavitree Quartzite/ Gillen Member
2) Intra Aralka sandstones
3) Pioneer Sandstone/ Pertatataka Fm. This play would rely on the Synrift Pertatataka Formation thickening in the adjacent synclines.
4) Arumbera – Chandler Formation seal

Given good shows in Ordovician source rocks in Mt Winter-1, it is likely the that potential Pertatataka, Aralka and Bitter Springs source rocks would be well into hydrocarbon generation window both at this location and to the south in the Ranford and Foreman synclines. The Wells Anticline is breached at Ordovician levels but intra-basinal rollovers, fault blocks and Halo plays could in some circumstances be charged with Ordovician oil.

b) Johnson High-Murray Anticlinal High- Fairbairn Anticlinal High: (Foreman Syncline)

The Murray and Fairbairn anticlines occur to the south of Ranford Syncline and appears to be doubley plunging according to BMR mapping. The structures could be charged either from the Ranford Syncline or the Foreman Syncline. Little is known of the stratigraphy in these depocentres. The nearest Horn Valley Siltstone outcrop occurs in the Wells Syncline and there is doubt whether this key source rock extends into the area of the Foremen Syncline.

Assuming it does the shales would be expected to be in the oil window; according to maturation studies this source rock should be in the oil window between 500 and 1500 m (Milne, 1988). The presence and maturity of Adelaidean source rocks is largely unknown and there needs to be careful analysis of seismic to determine which petroleum systems are present and whether or not there are Halo plays on the margins of the Liegertwood Syncline. A review of the Neoproterozoic in SPA 704 where a number of measured sections have been published would be beneficial.

c) Long Range Anticline – Gorter Anticline

Key Wells: NTGS DD05-1

Formation	Depth
Pertatataka	55 m
Areyonga Fm	485 m
Johnny's Creek Mbr	532 m
Loves Creek Mbr	1069 m

Key Well: NTGS LLO5 - 1

Formation	Depth
Pacoota	55 m
Petermann	115 m
Tempe Fm	414 m
Arumbera Fm	615 m

For both anticlines the structural precursor is the PRO with mild folding during the ASO. The two cored drillholes span stratigraphy from the Pacoota Sandstone to the Johnny's Creek Member. There are major unconformities at the top Johnny's Creek Member, base Arumbera Sandstone and the top Petermann Sanstone. The key petroleum system is the Pertatataka Fm which recorded bleeding oil shows at the base which show the source rock is in the oil window at 480 m and has generated oil with highly specific geochemistry indicating a similar origin to Neoproterozoic oil fields in Oman and Siberia.

The targets in this area are limited. In particular: 1) the Horn Valley Siltstone is absent / immature in this region 2) There is no seal to the Arumbera Sandstone 3) The Pertatataka Formation is a viable petroleum system but its complimentary target reservoir, the Pioneer Sandstone, is absent. The best exploration option is the Heavitree – Gillen reservoir seal couplet which was subject to the most robust structuring during the PRO.

d) Areyonga Anticline

Outcrop in this area comprises:
Pertatataka Formation
Areyonga Formation

Bitter Springs Formation

Pioneer Sandstone “halo” plays are possible on the northern and southern limbs of this anticline. Heavitree –Gillen plays are possible at depth.

e) Camecho Anticline

Outcrop in this area comprises:
Pertatataka Formation
Areyonga Formation
Bitter Springs Formation

Pioneer Sandstone “halo” plays are possible on the northern and southern limbs of this anticline. Heavitree –Gillen plays are possible at depth.

f) Heugh Anticline

Outcrop in this area comprises:
Pertatataka Formation
Areyonga Formation
Bitter Springs Formation

Pioneer Sandstone “halo” plays are possible on the northern and southern limbs of this anticline. Heavitree –Gillen plays are possible at depth.

g) Bradshaw Anticline

Outcrop in this area comprises:
Pertatataka Formation
Areyonga Formation
Bitter Springs Formation

Pioneer Sandstone “halo” plays are possible on the northern and southern limbs of this anticline. Heavitree –Gillen plays are possible at depth.

4.4 Eastern Platform

4.4.1 Structural Setting and Petroleum Systems

Blue Bush Area

The Bluebush area forms part of the overall terrane and this summary of the petroleum geology is drawn from Young and Ambrose (2007). The Bluebush area is located northeast of the Erldunda Fault Zone and comprises a lightly dissected shelf, dominated by conjugate northwest and northeast faults, the latter controlling a basement depocentre adjacent to the Newlands Range Ridge. The major structural element is the Camel Flat Syncline (or Camel Flat Thrust Sheet), which is bounded to the south by the Rodinga and Pillar Range Anticlines and to the north by a backthrust and hinterland duplex complex along the Train Hills/Steele Gap Anticlinal trend (Young and Ambrose, 2007). The major structural elements in the Bluebush area are dominantly of halotectonic origin. There is evidence of extensive Chandler Formation salt deposition(early Cambrian) in this terrane, and salt withdrawal and diapirism were triggered during the Alice Springs Orogeny. This style of deformation is very similar to that affecting Bitter Springs salt layers to the west during the PRO.

There is only one well in the area (Bluebush-1) which intersected 400 m of Pertatataka Formation shales. . The well bottomed in the Gillen Member, approximately 500 m above basement. No significant hydrocarbon shows were recorded, and limited geochemical data indicates that the post-Bitter Springs Formation section is immature (Bell,1983)- NB maturation levels into the adjacent synclines is uncertain. Current mapping confirms closure at the top of the Gillen Member and probably down to an interpreted basement horizon. The extent and hydrocarbon potential of the Pertatataka Formation (and also the Aralka Formation) in this general area is uncertain. The Aralka Formation is likely to be very sparsely developed whereas the Pertatataka Formation shales are intersected in three wells (Bluebush-1, Magee-1 and Mt Charlotte-1 and to the south in Erldunda-1). It is possible thermally mature Gillen shales occur at depth but data is sparse. However, a small gas flow in Magee-1 from Heavitree Quartzite supports geochemical analyses indicating thermal maturity of Gillen Member shales in that area . The terrane lies completely beyond the Horn Valley zero edge and hence there is no possibility of Ordovician hydrocarbons.

The Camel Flat Syncline is interpreted primarily as a salt-withdrawal feature, although it developed in association with other thrust-related structures (Magellan Petroleum 1984, Stewart *et al* 1991). Salt withdrawal probably began prior to the Sturtian glaciation, creating a sedimentary mini-basin (and potential stratigraphic trap), which then subsided to form a depositional "syncline". It is postulated that as evaporite walls began to rise, they reached the surface and extruded tongues of breccia. These edges collapsed down on themselves, creating discordant diapiric boundaries, which have been interpreted, incorrectly in some cases, as tectonically nucleated thrusts. Some thin-skinned thrusting of the overburden did occur during the PRO and ASO (Dyson and Marshall, 2008). North-dipping thrust faults, associated with southward-directed ASO thrusting, bound the Camel Flats and Rodinga thrust sheets and have surface expression along the Pillar and Rodinga ranges(Stewart *et al* 1991). On seismic, the faults are poorly imaged and their location is inferred on the basis of apparent dips and reflection terminations, at and above the top Chandler salt horizon. On balance, the pre-Chandler section does not appear to be offset and faults, if present, probably detach at base Chandler level or immediately above the Bitter Springs Formation.

In the general area, structural configuration at top Chandler salt is related to salt flowage that created the linear salt walls along the Pillar and Rodinga anticlinal trends. The exact timing of salt movement is uncertain and may have been concurrent with, or postdated the multi-phase ASO. The major features interpreted at this level are the Bluebush anticline, a smaller anticlinal feature on the Rodinga Range to the northeast and possible closures along the Pillar Range. To the north, possible salt-cored, hangingwall closures are interpreted in the Train Hills complex, although seismic coverage and data quality preclude confident mapping in this area.

Large basement structures, representing potentially attractive Heavitree Quartzite targets, have been mapped along the Pillar and Rodinga ranges. Although mapping is poorly constrained by existing seismic coverage SEEBASETM depth-to-basement structures,which are partly coincident, have been interpreted at depths of 2200 to 2500 m. A shallower (1500 m) and significantly larger basement feature has been interpreted in the area immediately to the south. Thickness of the Heavitree Quartzite cannot be determined seismically,although regional geological studies suggest that the unit may be 200–400 m thick in this general area.

4.4.2 Eastern Platform “Halo Plays” – Leads and Prospects

The absence of Neoproterozoic and Cambrian reservoirs at Bluebush-1 would appear to limit the potential of secondary targets in this area but the possibility of Halo plays at the levels of the Arumbera and Pioneers Sandstones cannot be ruled out but require additional seismic.

Key Well:
Bluebush -1
Undiff. Palaeozoic.
Chandler Salt
Pertatataka Formation
Loves Creek Member

4.4.2.1 Bluebush Anticline :

The source rock maturity of the Gillen Member shales sampled at 6850 ft in Bluebush-1, placed them in the early oil window (Vr0 = 0.5-0.6). Maturities would increase in the adjacent synclines (Camel Flat Syncline/Pillar Range Syncline/Camel Rise Syncline) validating the Gillen-Heavytree play as the primary exploration target in this area but there has been no regional mapping at this level.

In the Pillar Range Syncline, the BMR estimated the Pertatataka was buried to about 8-9000 ft which should have been sufficient to place the sequence in the oil window at least. However, the absence of the Pioneer Sandstone both in outcrop and in Bluebush-1 renders any Halo play at this level as very high risk. The Arumbera Sandstone is absent in this area.

In summary, hydrocarbon expulsion from the Camel Flat, Pillar Range and Camel Rise Synclines is doubtful. The Gillen Member may not be present southeast of Pillar Range and there are doubts about its maturity in this area. The Pertatataka shales may be present to some extent but they probably fall into the early oil window at best, given results from Bluebush-1. However, BMR mapping suggests these shales may be buried up to 3000 m deep in places southwest of Bluebush-1 in which case generative potential would exist. Several regional seismic lines are required to establish depths to key source rock intervals (ie Gillen, Pertatataka and Aralka shales) and delineate Heavitree / Pioneer plays, the former being the most attractive target.

4.4.2.2 Steele Gap A,B Anticlines

This anticline occurs in outcrop as Mereenie Sandstone with undifferentiated Cambrian in the core of the outcrop. It is likely Chandler Salt evaporites provided a decollement zone for tight ASO folding with basement unlikely to be involved. At depth source rocks may be present (Gillen, Pertatataka) but little can be predicted about maturities. The Gillen-Heavitree target is the most attractive target in the area.

Overall the area can be regarded as high risk for gas and additional seismic is required to progress exploration.

4.4.2.3 Train Hill Anticlinorium

This is an imbricate faulted anticlinorium structure with mainly Pertatataka Formation outcrop. Pioneer fault traps are possible however the Heavitree-Gillen at depth is the main target.

4.4.2.4 Magee Area

Background: In the Magee area, a dissected basement topography is interpreted on the basis of SEEBASETM mapping, although seismic evidence indicates that structuring is relatively mild compared to other areas in the southern Amadeus Basin. Major unconformities,corresponding to the Neoproterozoic Souths Range Movement, the base Cambrian PRO and the Early Devonian Pertnjara Movement (ASO), are clearly defined by reflection terminations on seismic. This discussion is based on studies in a paper by Young and Ambrose (2007).

Two wells, Mount Charlotte-1 and Magee-1, tested a PRO thrust-faulted anticline with seismically defined four-way dip closure. The primary target at Mount Charlotte-1 was the Ordovician Larapinta Group, but this succession was thin and poorly developed, and Palaeozoic source rocks are immature. The Heavitree Quartzite was not reached by Mount Charlotte-1, but a later crestal test of the structure (Magee-1) intersected a thin gas-bearing Heavitree Quartzite reservoir (4.5 m thick – fractured, intergranular porosity was 9 %). The well flowed methane, nitrogen and Helium from a single fracture at 63 mscfd.

In Magee-1, the Gillen Member can be split into two units, based on seismic response and the intersection in Magee-1 had a thermal maturity in the oil window. The upper unit (246 m thick) comprises massive halite, and is characterised by a chaotic, locally faulted reflection pattern.

The Pertatataka Formation Potential targets are shoreline sands (Cyclops Member) midway through the unit, intraformational turbidite sands and glacial outwash sands of the Pioneer Sandstone; the latter was not intersected in Magee-1 but may be present down flank. However, since post-Areyonga Movement source rocks (Aralka, Pertatataka Fm) can be shown to be present and are oil/gas mature over a wide area (NTGS DD01-05, Erldunda-1, Murphy-1, and Wallara-1) there are several candidate petroleum systems capable of charging both "Halo" plays and other structural/stratigraphic plays. In addition the Gillen Member is widespread and mature for hydrocarbon generation over a wide area.

Helium is an important target in this part of the basin where the geological framework favours entrapment of radiogenic Helium derived from igneous Basement. Fractured Heavitree quartzite is the host reservoir while thick Gillen Salt provides ehanced seal; thrust faults which displace basement and Heavitree Quatzite define the migration conduits which dissipate in the overlying Gillen Salt.

Key Well: Magee-1

Finke Group	10 m
Stairway Sandstone	360 m
Jay Creek Limestone	495 m
Chandler Formation	723 m
Pertatataka Formation	954 m
Bitter Springs Fm	1393 m
Heavitree Quartzite	2220 m
Basement	2348 m
TD	2395 m

The well flowed 63.1 mcfd including 6% Helium.
Leads are difficult to discern in this area because of a complete lack of outcrop, dearth of seismic and indefinite imaging of aeromagnetics. The Gillen Member is likely to be mature over a wide area but it is uncertain if the Aralka is present in the area and thermal maturity is uncertain for both the Aralka and the Pertatataka shales.

Leads and Prospects - Magee Area

, The lack of outcrop aeromagnetic signatures and seimic coverage precludes definition of leads and prospects in the general area. The aeromagnetic depth to basement mapping displays a NE trending half-graben near Magee-1, the age of which remains uncertain, but it is possibly of ASO age perhaps implying deeper burial of Aralka/Pertatataka source rocks in this area. Certainly the Gillen source is likely to be widespread although distribution of maturity away from Magee-1 is poorly understood. Acquisition of 2008 seismic over the Magee structure will throw new light on the area's prospectivity.

Leads defined by 2008 seismic in the Magee Area

a) Santo Lead (CM 08 line 03/04)
   2 wd at Arumbera, Cyclops, Pioneer levels. Fault Play at Heavitree.

b) Idacowra Lead (CM 08 LINE 03/08)

c) Charlotte Lead (CM 08 Line 03/08)
Heavitree 2wd, complex diapiric structure

d) Robinson Lead (CM08-01)
2WD at Heavitree, Pioneer, Cyclops sandstone

e) Black Hill lead (CM 08-06)
Gillen diapiric anticline

f) Hale River Lead (CM 08-01)
2WD Pioneer and Cyclops

g) Chambers Lead (CM08-10)

h) Pioneer Lead (CM 08-14). Diapiric Pioneer Play

i) Giles Lead (CM08-14).

j) Palm Lead (CM 08-05).
Pioneer 2wd, Cyclops subcrop

4.5 <u>Southern Thrust Belt</u>

4.5.1 Structural Setting and Petroleum Systems

The following discussion is drawn from studies in Young and Ambrose (2007) and also recent seismic interpretation in the Mt Kitty area.
Murphy-1 and Erldunda-1 provide the only well control in this fold belt which is dissected by NE trending faults at depth; these were heavily overprinted by north verging PRO thrusting. Further data comes from the Kernot Range fold belt.

In the Murphy-Erldunda area, the initial structural event was relatively mild resulting in pre-Areyonga tilting and erosion below the top Bitter Springs unconformity. A series of normal faults extending to the Gillen Salt are associated with this movement. Significant uplift and erosion occurred during the PRO, the second orogenic event, with development of “thick-skinned”, basement-involved thrust and backthrust pairs and “thin-skinned” low-angle thrusts with detachment above the Gillen Member evaporites (Ambrose and Young, 2007) .

The third event involved significant uplift and differential erosion during the Lower Devonian Pertnjara Movement, an early phase of the ASO, with movement on blind thrusts and further displacement on PO basement thrusts. Sheet-like alluvial sediments of the Finke Group were deposited on this erosional surface, with over 500 m of Horseshoe Bend Shale present in Murphy-1 (Edgoose *et al* 2002). There is little or no evidence of later ASO compressional folding.

Despite poor imaging below the Gillen Member evaporites, a basement seismic event can be correlated over most of the Murphy–Erldunda area. Basement becomes deeper to the northwest, with depth estimates ranging from 1800 m below a basement-involved thrust structure (“Mt Kitty Prospect”) to a depth of 4700 m to the west of Murphy-1 .

An isochron map of the Gillen Member horizon to basement interval provides an indication of salt thickness, which varies between 100 m up to a maximum of 2900 m, below a salt-cored, thrust-faulted anticline to the northeast of Murphy.

The Late Neoproterozoic interval, comprising the upper Bitter Springs Formation (Loves Creek Member and Johnnys Creek Member), the Areyonga and Aralka Formations , and the Pertatataka Formation, represents a period of stable and widespread deposition in the Murphy–Erldunda area. Seismically, it is characterised by a series of parallel, continuous and low–moderate amplitude reflections, which can be correlated easily across areas of PRO erosion (Young and Ambrose,2007).

The Mt. Kitty prospect area southeast of Murphy-1 is an extremely complex structural terrane dominated at depth by PRO age north verging, basement involved thrusts penetrating to the Gillen Salt. Complex halotectonics and salt diapirism complicate the structural picture. Recent seismic acquisition over the Mt Kitty structure supplies a blueprint for the structural style dominating in this area where outcrop is sparse and there is almost no regional seismic.

In the Murphy – Erldunda area and farther to the east in the NTGS DD05-01 area, the Pertatataka and Aralka shales are present and reside in the hydrocarbon generation (oil) window. In adjacent grabens these source rocks are probably through the dry gas window and the synrift Pertatataka shales may thicken markedly. Overall this complex, faulted terrane is likely to be gas prone but there may be opportunities for wet gas/oil accumulations given source rock maturities seen in Erldunda-1, Murphy-1 and DD05-01. Farther to the northeast, Gillen Member shales are in the oil window in Magee-1 suggesting this could be the case over a wide area and the Heavitree-Gillen reservoir –seal couplet is an important secondary target.

In a regional sense Pertatataka and Aralka formation shales are widespread in the south and southeastern portions of the basin but there is little maturity data available. In local grabens /half-grabens these potential source rocks may be through the gas window but these may be in the oil window over platform areas. Data is very sparse although outcrop mapping and the results from the Erldunda-1, Murphy-1 and NTGS DD05-1 well intersections suggest the Pertatataka Formation is up to 2500 m thick west of Murphy-1 in the Mt

Connor Sub-basin (Oaks et al 1993) and extends for over 100 km to the west and perhaps all the way to DDO5-01 where the section has thinned to 430 m in thickness. The Pertatataka Fm comprises synrift shales and siltstones deposited in extensional grabens and half grabens as turbiditic and pelagic deposits which were very extensive in the southern half of the basin. The shales are proven source rocks at Dingo field and are likely to be in the oil/ gas widow over wide areas of Southern Thrust Belt. The shales are believed to have been eroded from the Murphy-1 structure during the Souths Range Movement.

Helium is an important target in this part of the basin where the geological framework favours entrapment of radiogenic Helium derived from igneous Basement. Fractured Heavitree quartzite is the host reservoir while thick Gillen Salt is an ehanced seal; thrust faults which displace basement and Heavitree Quatzite define the migration conduits which dissipate in the overlying Gillen Salt.

4.5.2 “Halo” Leads and Prospects

Introduction (Kernot Range) : The following four leads are east-west anticlinal highs where Ordovician sediments overlie Areyonga or Pertatataka Formation. The folds present opportunities for 4 way dip closure but Pioneer / Pertatataka “Halo” plays have potential over these folds. The structures are antecedent PRO features and as such have dip closure potential at the Heavitree- Gillen level. At least some of the structures are controlled at depth by north verging thrusts which constitute the Kernot Thrust Zone.

a) Curtiss Springs Anticlinal High

Key Outcrop (Ayers Rock 1:250,000)
The structure is an ASO fold with a PRO precursor.
Outcrop over this lead has Areyonga Formation in its core in turn overlain by the Stokes Siltstone and Carmichael Sandstone. It is unlikely there is an opportunity for a halo play although there is some chance with the Pertatataka-Pioneer reservoir-seal couplet. The best exploration opportunity is the Heavitree-Gillen reservoir-seal couplet at depth which would be thermally mature.

b) Basedow Range Anticlinal High

Interpreted by the BMR as a PRO structure marking a major hinge controlling Bitter Springs and Areyonga Formation sedimentation. The only outcropping sediments present are Pertatataka Formation on Areyonga Formation. The structure was interpreted as being controlled by a major down to the north, EW trending normal fault . There may be a dip closure in the hanging wall to the north. There are other trapping mechanisms against the extensional fault which is unusual in this compressional thrust belt.

Given regional stratigraphic implications, the Pioneer-Pertatataka reservoir-seal couplet may be a target on the down trown side of the fault. On the upthrown side of the fault the Heavitree-Gillen reservoir/seal couplet may be a target.

h) Lasseters Syncline

The surface expression of this structure indicates Stairway Sandstone lies unconformably on Areyonga Formation. There is updip potential for Pioneer-Pertatataka "Halo" plays on the flanks of the syncline.

i) Red Hill Anticline – Stewart Anticline

The suface expression of these two adjacent anticlines indicates Stairway Sandstone on Pertatataka Formation thus presenting the possibility of downflank Pioneer and Arumbera "Halo" plays. At depth the Heavitree Quartzite/ Gillen Member reservoir-seal couplet is a target.

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4.6 Mt. Currie Sub-basin

4.6.1 Structural Setting and Petroleum Systems

There is no seismic or well control in the area. Late Neoproterozoic to Early Cambrian foreland molasse facies of the Mt Currie Conglomerate comprise a thick sequence of alluvial –fluvial sediments related to the PRO. A lateral equivalent is the Arumbera Sandstone which fed south to north into extensional sub-basins. Source sequences are unknown - any Neoproterozoic petroleum systems present are likely to be through the dry gas window as the Mt Currie Conglomerate was estimated by BMR mappers to be buried below 20,000 ft. Any potential Palaeozoic source rocks are thermally immature.

5.0 Conclusions

The discovered hydrocarbon fields in the Amadeus Basin ocurr in 4-way dip closures at a number of stratigraphic levels. The number of additional 4-way dip closures is unknown due to the sparceness of existing seismic data but new seismic grids acquired by Central Petroleum in 2007-8 suggest there is substantial remaining potential. However, it is uncertain if this play type can sustain extended exploration in the basin and the “Halo” play is an attractive supplement . Many of the major ancestral structural highs in the basin host potential “Halo” plays downflank from their crests and exploration success is proven in a number of other basins (eg the Cowan field in the Cooper Basin).

The first step in the exploration process is a remap of existing seismic, including the recent 2007-2008 seismic grids acquired by Central Petroleum. Subsequent exploration leads should undergo seismic detailing prior to drilling the most attractive plays. Those targets with potential for oil /wet gas are a priority but are likely to be secondary to dry gas targets.