[PS]Tectonic and Stratigraphic Mapping Framework of the Lower Arthur Creek, South Georgina Basin, Northern Territory, Australia*

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Abstract

Potential economic hydrocarbon resources of the South Georgina Basin have been identified by using tectonic/stratigraphic studies and horizontal drilling.

The South Georgina Basin (SGB), NT, Australia contains sediments that range from Neoproterozoic to Devonian in age. The major tectonic events that have deformed the area are the late Neoproterozoic Petermann Ranges Orogeny, Middle Cambrian extension followed by mild compression and the Devonian/Carboniferous Alice Springs Orogeny (ASO).

Middle Cambrian to Devonian sediments were deposited in several sub depo-centres: the Marqua, Arganargada, Manners, Dulcie and Toko Troughs. Up to 1500 m and 4000 m of post Neoproterozoic section is interpreted in the Dulcie and Toko Troughs respectively, however, the other troughs remain mostly unexplored. Within these depo-centres Lower to Middle Cambrian south facing mixed clastic/carbonate, but primarily carbonate, platforms developed. These platforms supplied carbonate rich sediment into the deeper anoxic parts of the basins where background, black, high TOC carbonaceous rich carbonate silts and shales of the The Lower Arthur Creek (LAC) accumulated. Deposits from the shelf inter-fingered with the high TOC units and diagenetic scavenging of radioactive isotopes occurred to create what is today called the LAC or "hot shale" zone.

The "hot shale" is the target of active unconventional hydrocarbon exploration in the SGB. Two recent horizontal wells in the Dulcie Trough (Baldwin-2H ST1 and MacIntyre-2H) have encountered elevated "heavy" gas readings over their horizontal lengths, and demonstrated the

potential for unconventional hydrocarbon recoveries. The feasibility of exploiting the "hot shale" is dependent on lithology, geomechanical properties, TOC% and source maturity, as well as there being sufficient depth to allow for environmentally sensitive fracture stimulation completions.

New seismic studies have refined the understanding of the SGB tectonic setting first established by potential field mapping. In addition to using conventional isopach maps, areas where the "hot shale" has been uplifted close to the surface need to be identified. Uplift has occurred along ASO reactivated pre-existing fault trends and has resulted in bringing parts of the "hot shale" to depths of less than 500m. However, only when deeper than ~500m it is possible to use controlled fracture stimulation and horizontal drilling to stimulate hydrocarbon production from the "hot shale".

Tectonic & Stratigraphic Mapping Framework of the Lower Arthur Creek

South Georgina Basin, Northern Territory, Australia

Abstract

Tectonic and Stratigraphic Mapping Framework of the Arthur Creek "Hot Shale", South Georgina Basin, Northern Territory, Australia

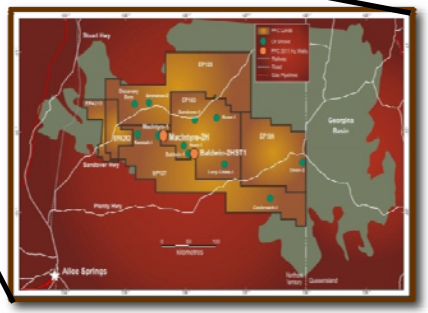
Paul J. Bennett HBSc, MSc (PetroFrontier) and Dr. Peter Boult (Gingko Resources) HBsc Phd

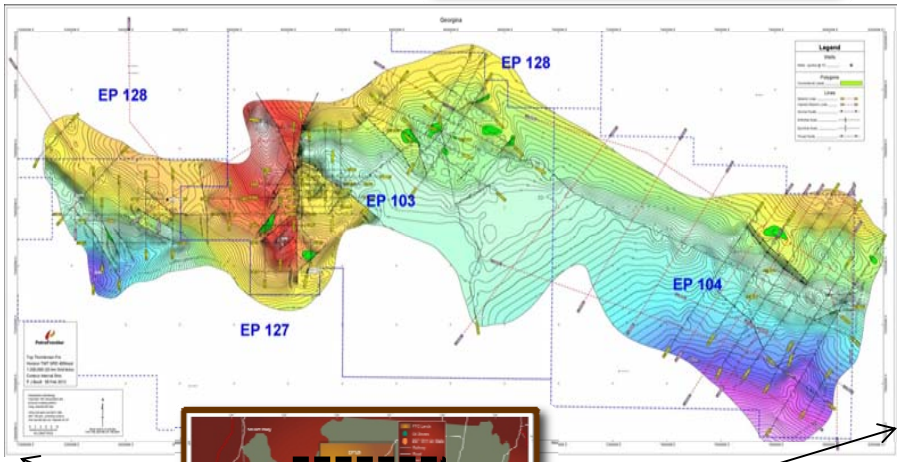
The current distribution of the Middle Cambrian Arthur Creek "Hot Shale" in the South Georgina Basin, Northern Territory, Australia is controlled by tectonic and stratigraphic parameters. The South Georgina Basin is of early Paleozoic age and contains section that ranges from a basement of Neoproterozoic rocks up to formations of Devonian age which are themselves overlain by variable thicknesses of Cenozoic material. The major tectonic events that have deformed the area are: the late Neoproterozoic Petermann Orogony (PO), the Ordovician- Devonian Delamanian Orogeny (DO) and the Devonian/Carboniferous Alice Springs Orogeny (ASO).

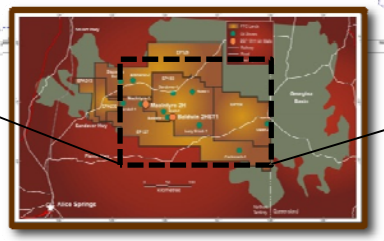
The basin first developed Cambrian sediments when a structural sag formed to the north of the Arunta Block, a high grade metamorphic and igneous terrain. Subsequently two sub depo-centres developed in the main South Georgina Basin: the so called Dulcie and Toko Synclines. Greater than 1000m of post Neoproterozoic section was deposited in the Dulcie Syncline and over 2000m in the Toko Syncline. Within these depo centres Lower and Middle Cambrian south facing carbonate platforms developed, and these areas supplied carbonate rich sediment into the deeper anoxic parts of the basins. In the anoxic depo-centres black carbonaceous rich (high total organic carbon –TOC) Middle Cambrian radioactive silts ,shales and carbonates of the Lower Arthur Creek "Hot Shale" unit were deposited. Deposits from the shelf inter fingered with the high TOC units to create what is today called the Lower Arthur Creek "Hot Shale".

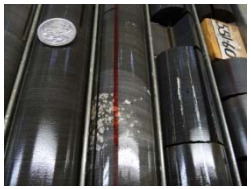
The Arthur Creek "Hot Shale" is the target of active unconventional hydrocarbon exploration in the South Georgina Basin. Two recent horizontal wells (Baldwin 2-HZ1 and MacIntyre 2HZ) have encountered elevated "heavy" gas readings over their considerable horizontal lengths, and have demonstrated the potential for unconventional hydrocarbon recoveries. The feasibility of exploiting the "Hot Shale" unit is dependent on lithologic composition, TOC% and source rock maturity, as well as there being sufficient formation depth to allow for environmentally sensitive fracture stimulation completions.

Regional seismic studies have recently been conducted to augment the understanding of the basin tectonic setting first established by gravity and magnetic mapping. It is insufficient to just produce an isopach map of the "Hot Shale" interval to understand where it is prospective. In addition areas where the "Hot Shale" has been uplifted close to the surface need to be identified. Uplift has occurred along ASO activated pre-existing fault trends and has resulted in bringing relatively thick sections of the "Hot Shale" to depths of less than 500m. Deeper than 500m it is possible to use controlled fracture stimulation and horizontal drilling to stimulate hydrocarbon production. Very shallow near surface areas (<100m ?) may be amenable to shale oil mining extraction technology at some future date. Using this combined tectonic stratigraphic techniqu,e key hydrocarbon strategic areas of the South Georgina Basin have been identified and mapped.









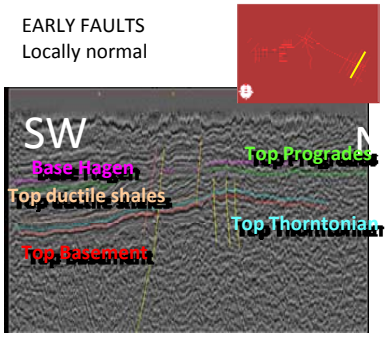
LAC and Thorntonian contact in NTGS991

Tectonic & Stratigraphic Mapping Framework of the Lower Arthur Creek

South Georgina Basin, Northern Territory, Australia

Faulting Styles – Eastern Area

EARLY FAULTS
Locally normal



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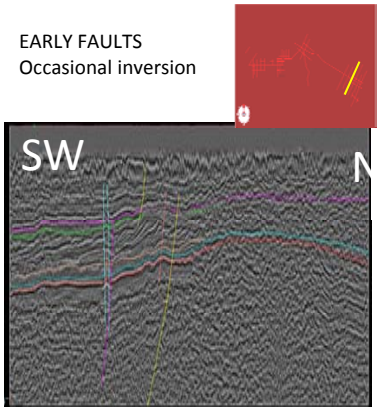
EARLY FAULTS
Occasional inversion



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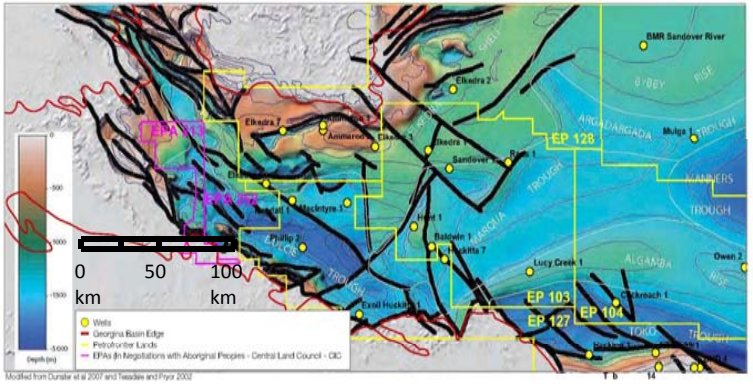
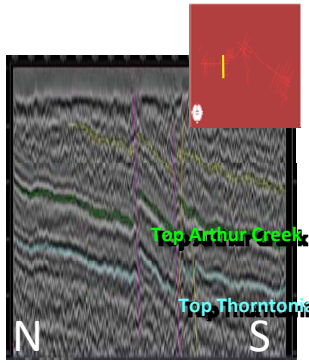


Faulting Styles – Western Area

EARLY
Predominantly
reverse



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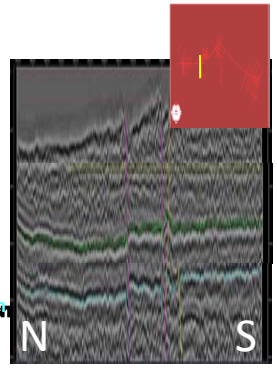
EARLY
Predominantly
Reverse - with occasional footwall growth



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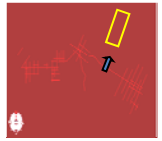
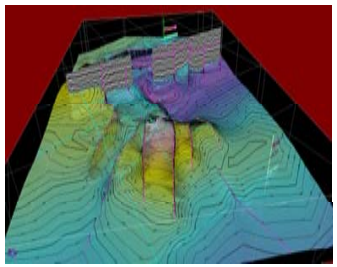
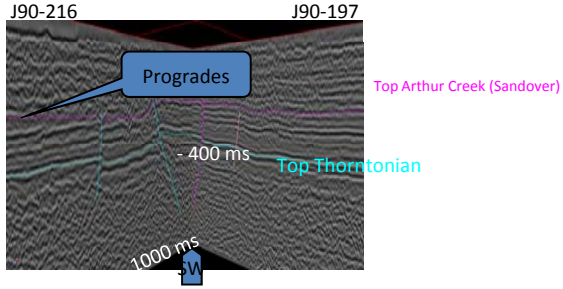
Example of
strike slip pop-
up structures





Cross section PPP prospect

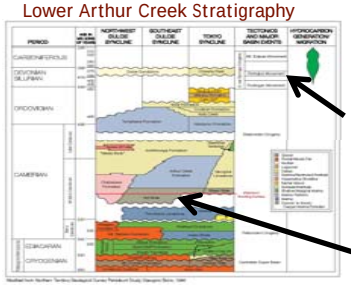


Hunt well & PPP prospect @top Thorntonian -- Grid = 10x10 km

Tectonic & Stratigraphic Mapping Framework of the Lower Arthur Creek

South Georgina Basin, Northern Territory, Australia

Lower Arthur Creek Stratigraphy



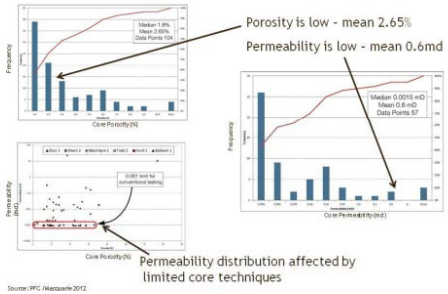
Three Phase Alice Springs Orogeny

Major late orogenic event affecting LAC

Lower Arthur Creek (LAC)

Source: PFC /Macquarie 2012

Lower Arthur Creek Porosity/Permeability from Core

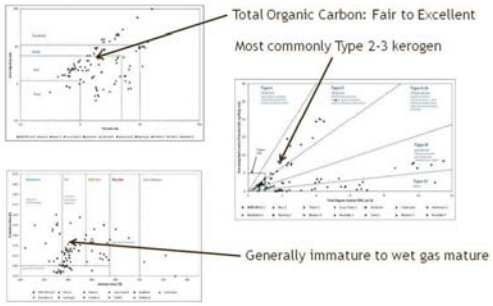


Porosity is low - mean 2.65%

Permeability is low - mean 0.6md

Permeability distribution affected by limited core techniques

Lower Arthur Creek Maturation & Richness from Core

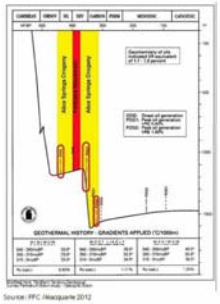


Total Organic Carbon: Fair to Excellent

Most commonly Type 2-3 kerogen

Generally immature to wet gas mature

Lower Arthur Creek Burial History

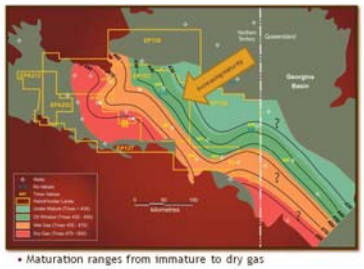


- Extensive faulting at several time periods within Southern Georgina Basin; clearly visible on 2D seismic and potential field data
- Tectonic events occurred before and after hydrocarbon source rock, reservoir and trap were formed
- Peak hydrocarbon generation after major structures formed
- Lower Arthur Creek Formation may be present in EPA 213 and EPA 252 beneath shallow cover

Lower Arthur Creek Deposition

- LAC generally thins into Queensland and changes composition (Georgina Limestone)
- LAC correlation becomes difficult to north and east - prograding shelf from north
- Thickest LAC in two broad depocentres: Dulcie and Toko
- LAC deposition affected by pre-existing troughs and Arunta Block to south

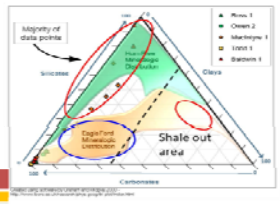
Lower Arthur Creek Maturation



- Maturation ranges from immature to dry gas
- Most mature adjacent to Arunta Block
- Immature to the north and east

Lower Arthur Creek Mineralogy

- LAC tends to be a siliceous mudstone in the west (Dulcie) to a carbonate in the east (Toko)
- Members in PFA, tends to shale content above 15%
- Clay may increase to north and west
- Lack of clay implies brittleness and the ability to be fracture stimulated
- Similar to the Eagle Ford (unconventional play in the USA and the Horn River (Tillevous) play in Canada



Majority of data points

Shale out at the

Eagle Ford Mineralogic Distribution

Siliceous

Clay

Carbonates

Highlights content inhibits the ability to effectively hydraulically fracture and produce unconventional reservoirs

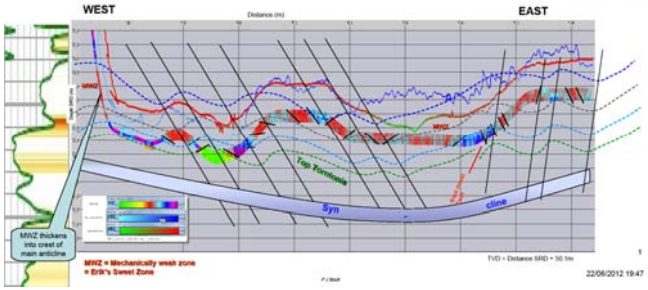
MacIntyre 2H Structural Interpretation

at 1838m

50x

Note: Up and down GR data not plotted when tool not working Gas seems to be ROP normalised now

PetroFrontier



WEST

EAST

Top Formation

Syn

cline

MWZ thickens into crest of main anticline

MWZ = Mechanically weak zone

= Brit's Sweet Zone

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The MacIntyre 2H well was directionally drilled while being tracked in near real time using TrapTester structural Interpretation software. The well was kept within a 1.5m vertical section over nearly 1000 metres of horizontal displacement.