Deep Basin Gas: A New Exploration Paradigm in the Nappamerri Trough, Cooper Basin, South Australia

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Deep Basin Gas

- Cooper Basin: *quo vadis*
- North American experience
- exploration strategy
- Nappamerri Trough evidence
- Nappamerri Trough strategy
Deep Basin Gas

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Creaming Curve: SA Anticlinal Gas Play

Cumulative Reserves (Pj)

Wildcat Wells Drilled

(Johns, 2000)
Creaming Curve: Alberta Basin

(Ryan, 1973)
Creaming Curve: Alberta Basin

Cumulative Initial Recoverable Oil (Billion STB)

Cumulative Newfield Wildcats

- D3
- Cardium
- Beaverhill Lake
- Viking
- D2
- Gilwood
- Keg River

(Ryan, 1973)
Deep Basin Gas

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"the entire Mesozoic rock section in the Deep basin [Western Canada] is saturated with gas below a depth of about 3,500 ft. Within this area it is not possible to drill a dry hole .... Every stringer of porosity holds gas"

(Masters, 1979)
Western Canada Basin

LEGEND
- Sand
- Conglomerate

(Davis, 1984)
Western Canada Basin

(Davis, 1984)
Green River Basin, Wyoming

(Davis, 1984)
Green River Basin, Wyoming

(Davis, 1984)
"Due to their hydraulically isolated nature, nested pressure compartments [in the Anadarko Basin] may provide drilling prospects that are not constrained by structural position ..."

(Al-Shaieb et al., 1994)
Western Canada
Deep Basin Sweetspots

(Masters, 1984)
"it needs to be stated clearly again that the [Western Canada] Deep Basin accumulation is not all in tight sands ... with permeabilities up to darcys ... These "sweetspots" are analogous to the fracture trends in the San Juan Basin tight sands which provide high well deliverabilities and large total recoveries"

(Masters, 1984)
Western Canada
Deep Basin Sweetspots

“You could hear the goddamn seagulls!”

(Masters, 1992)
Gas saturation may depend on equilibrium between gas generation and loss. Low $\phi/k$ of gas-saturated zone and relative permeability effects in two-phase flow may be essential for existence of basin-centre gas accumulations.
Relative Permeability
Travis Peak Tight Gas Sand

(after Johnson et al., 2000)
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A New Exploration Paradigm

Deformational-structural-diagenetic-sweetspots (DSDS)

'Pressure Seal'

Normal pressure

Anomalous pressure

Depositional-structural-diagenetic-sweetspots (DSDS)

(after Surdam et al., 1997)
A New Exploration Paradigm

1. Does deep basin gas exist (logs and well tests)?
2. Map regional overpressure (logs and seismic attributes)
3. Define sweetspots (depositional and/or structural and/or diagenetic: DSDS)
4. Exploit with appropriate drilling and completion strategy
Sweetspot Strategies: DSDS

Sweetspots

Depositional
beach bar sands at Elmworth/Hoadley

Structural
fracturing in the San Juan and Green River Basins

Diagenetic
grain rimming clay rims and absence of lithic grains in Washakie Basin
Deep Basin Gas
Reserves/Resources

Western Canada Deep Basin Resource: 1750 tcf
WCDP Reserves: 45 tcf
Elmworth: 17 tcf & Hoadley: 6-7 tcf
(Masters, 1984 & Chiang, 1984)

After 18 years Elmworth had produced nearly 2 tcf
In 1990 Elmworth produced 550 mmcf/da
Proved plus probable reserves (including past production): 5.6 tcf
Elmworth's ultimate potential as measured by Canadian Hunter: 16 tcf
(Masters, 1992)
North American Experience

- new paradigm proven
- gas saturation outside closure, no obvious seal
- abnormal pressure
- sweetspots
- rich source rocks
- new exploration model
- engineering practice
- vast resource, tough reserve
Deep Basin Gas

- Cooper Basin: *quo vadis*
- North American experience
- exploration strategy
- **Nappamerri Trough evidence**
- **Nappamerri Trough strategy**
Kirby 1

pressure (MPa)

depth (m)

Top Mackunda

Top Cadna-Owie

Top Nappamarti Group

Top Toolachee

Total Depth

(Van Ruth & Hillis, 2000)
Regional Log Correlation, Nappamerri Trough
Log Evaluation of Bulyeroo-1, Nappamerri Trough
Rich Source Rocks

Total gas generative potential of Alberta Basin source rocks: ~10 000 tcf

*Masters (1984)*

Total gas generative potential of Cooper Basin source rocks: 4 027-8 055 tcf

*Morton (1998)*

Cooper Basin source rocks volumetrically much smaller than Alberta Basin, but higher total organic carbon, higher hydrogen index and higher maturity
Deep Basin Gas

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A New Exploration Paradigm

(after Surdam et al., 1997)

Depositional-structural-diagenetic-sweetspots (DSDS)

‘Pressure Seal’

Anomalous pressure

Normal pressure

Deep Basin Conventional

(after Surdam et al., 1997)
Sweetspot Strategies: DSDS

Sweetspots

- Depositional
  - beach bar sands at Elmworth/Hoadley

- Structural
  - fracturing in the San Juan and Green River Basins

- Diagenetic
  - grain rimming clay rims and absence of lithic grains in Washakie Basin
Depositional Sweetspots

- look for most sand-prone sequences irrespective of traditional structural or stratigraphic closure
- in intracratonic basins best net:gross can be in fluvial channel systems and crevasse splays
- in Nappamerri Trough best net:gross where genetic intervals containing channel systems thicken
Depositional Sweetspots

- Syndepositional lows were structurally controlled and many remain as present-day structural lows
- Highs drilled to-date are pre-disposed to have poor net:total — drilling on conventional closure precludes finding the best permeability
- In order to find the best reservoir quality, must embrace deep basin gas concept and drill outside conventional closure
"Prior to discovery, the Hoadley Glauconitic sand bar had been penetrated by hundreds of wells"
Chiang (1984)

"Before discovery of the Falher sand [Elmworth] … nearly 100 wells drilled (in ~18 000 km²)"
Sneider et al. (1984)

2000 wells drilled in the Western Canada Deep Basin between from 1980-1984
Masters (1984)
The Prize

30 wells drilled in the basin-centre gas of Green River Basin over 20 years: all with overpressured gas shows but none economic

UPR Rock Island 4-H horizontal well: after producing 3 bcf still producing at 10 mmcfd, ultimate production of 10-20 bcf

Resistivity imaging witnessed 400 fractures in 1 750 ft horizontal leg (~15 000 ft depth)
Conclusions

- play extensions or new plays required to discover major new gas reserves in Cooper
- vast deep basin gas reserve and resource proven in North America
- in several basins porosity is almost entirely gas-saturated beneath a regional pressure seal
- due to the hydraulic isolation of pressure compartments, deep basin gas accumulations not constrained by traditional structural or stratigraphic traps
Conclusions

• no unequivocal evidence of deep basin gas in the Nappamerri Trough, but:
  thick gas columns,
  anomalous pressures,
  rich source rocks

• deep basin gas model must be embraced to find best reservoir quality in Nappamerri Trough
The concept that the Nappamerri Trough hosts a deep basin gas accumulation has been long in developing, and remains in gestation. We acknowledge many colleagues at NCPGG, PIRSA and Santos whom have contributed to our ideas on the concept.