

Coal Seam Gas Content Controlling Factors and its Trends in Eastern Surat Basin, Australia*

Xiangwen Kong¹

Search and Discovery Article #10862 (2016)**

Posted September 19, 2016

*Adapted from oral presentation given at AAPG 2016 Annual Convention and Exhibition, Calgary, Alberta, Canada, June 19-22, 2016

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Abstract

The Middle Jurassic Walloon Coal Measures (CM) is a prolific, low-rank coal seam gas (CSG) resource in the Surat Basin, Australia. Gas content is one of the main factors that control the resource abundance. Continued successful exploration and production, and possible future microbial regeneration of the Walloon CSG resource require an improved understanding of the controls on gas content distribution across the core region of production in the eastern Surat Basin. The interplay of four geological factors has been identified as determining coal seam gas content: (1) depositional setting; (2) tectonic and structural setting; (3) coal petrology and quality which could be related to gas content, such as coal rank, coal type, mineral matter content, moisture content, volatile matter, ash content, macerals; and (4) hydro-geological properties including water geochemical analyses, drainage systems, gas isotope analyses, reservoir temperature and pressure, burial and charge history, fracturing, hydraulic gradient and overburden sealing capacity. Most of the controls above were examined in eastern Surat Basin. Based on the gas content versus depth profiles of 58 wells, the gas content trends of different geological regions and the whole basin were obtained. Within individual wells, gas content either increases; increases, then decreases; or decreases with depth as the result of the variable coring intervals. While the total dataset shows a general increase-decrease trend in gas content (dry-ash-free: d.a.f.) with increasing depth, although there is considerable scatter in the distribution. The gas content maxima coincides with the Tangalooma Sandstone, regardless of depth. It will not cross-cut the stratigraphy in the majority of wells. The datasets analyses suggest a variety of mechanisms influence present-day gas content and relative saturation. Gas migration from underlying, higher rank coals, meteoric and biogenic recharge from above are possible interpretation for high gas content in the Tangalooma Sandstone. Alternatively, this distribution may be the result of alternating adsorption-desorption cycles linked to burial and uplift. Preferable gas content coincides with meteoric recharge areas, such as the Undulla Nose and Cecil Plains Anticline recharged by Condamine River and its tributaries. The results form the basis for the calibration of gas content-depth fitting formula used in geomodelling, thus a more reliable prediction of gas content.

Selected References

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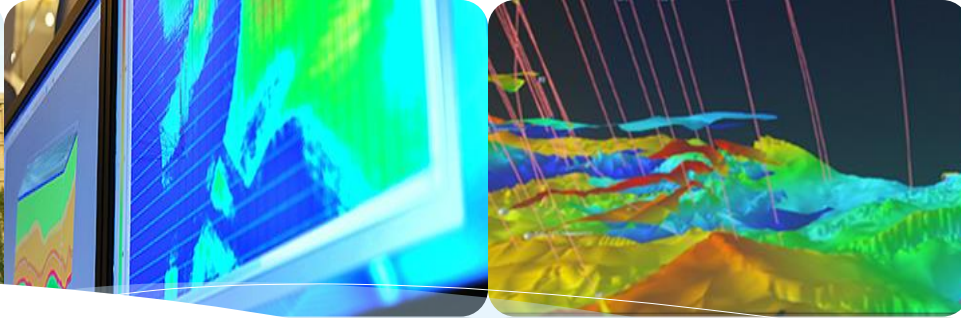
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June 2016



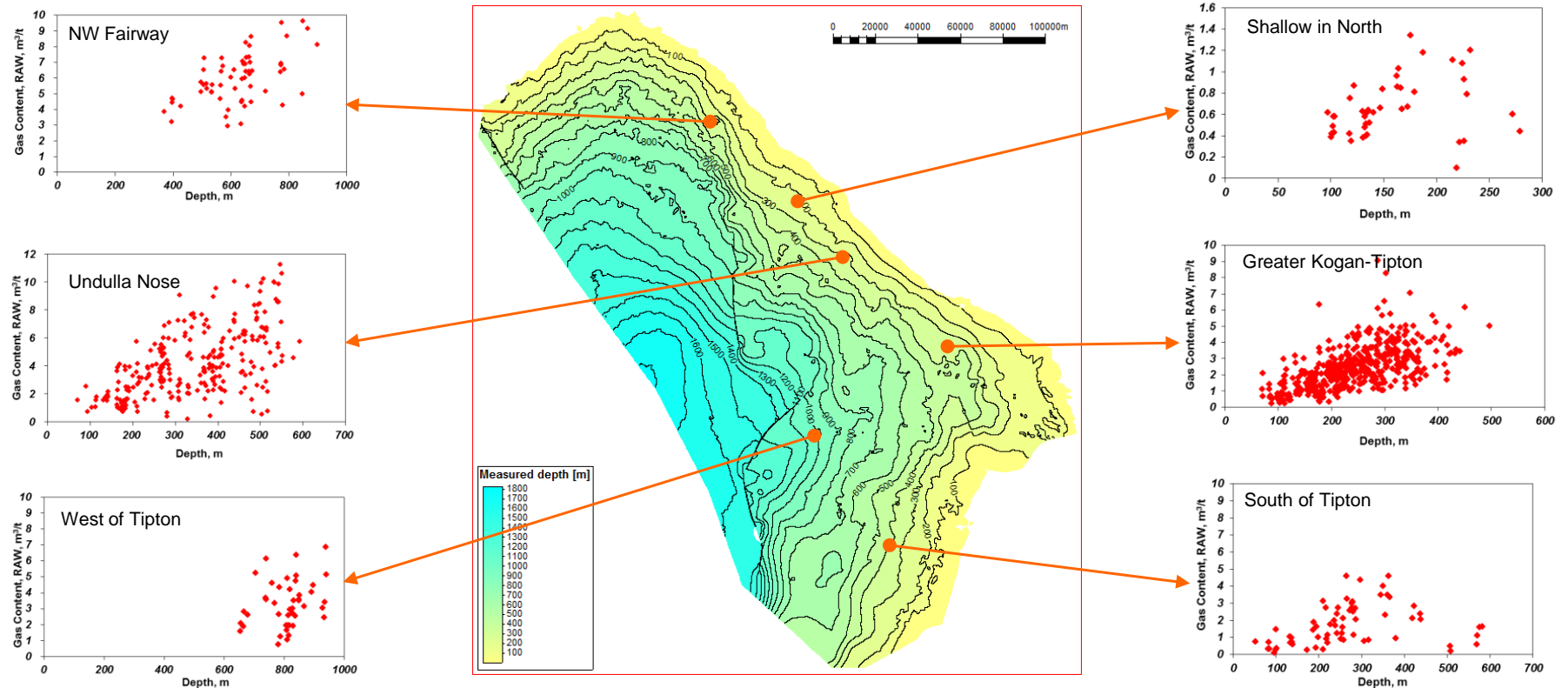
Outline

- **Introduction**
- **Gas Content Controlling Factors**
 - Coal Properties
 - Hydrogeology
- **Gas Content vs. Depth Trends**
 - Three Trends from Individual Wells
 - Basin Wide Increase-decrease Trend
- **Gas Content Trend Control Mechanism**
 - Gas Type - Existence of Biogenic Sources
 - Gas Content is Controlled by Surface Water Recharge
- **Property Modeling Improvement**
- **Summary**

Introduction

Question Raising

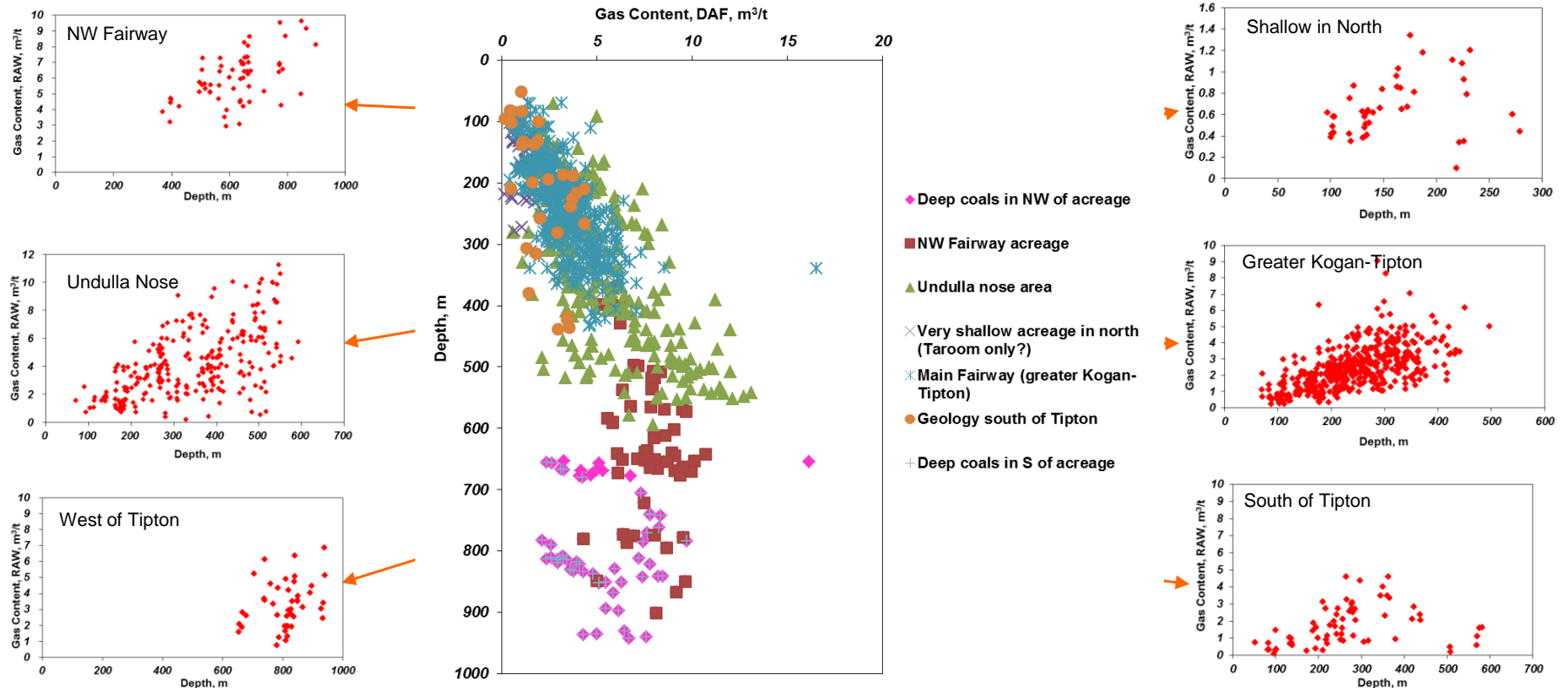
- Gas content vs Depth Crossplots show a variety of trends in different geological regions
- The combination of all data points indicates an increase-decrease trend in a regional perspective



Introduction

Question Raising

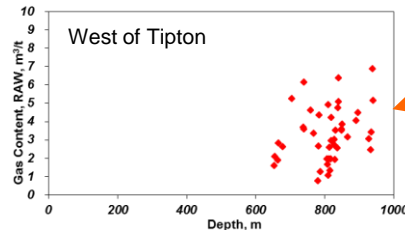
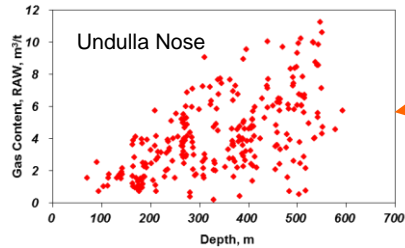
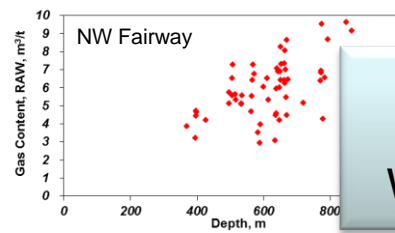
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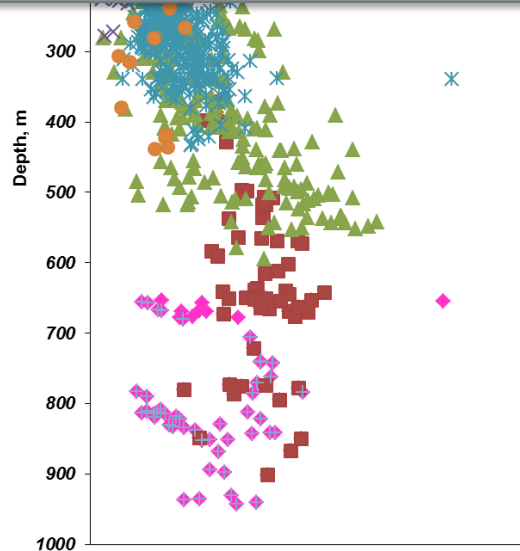
Introduction

Question Raising

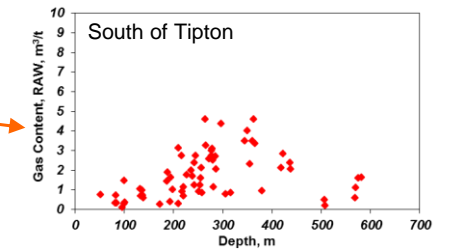
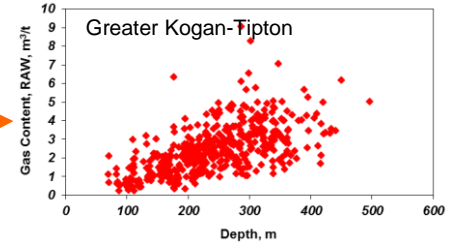
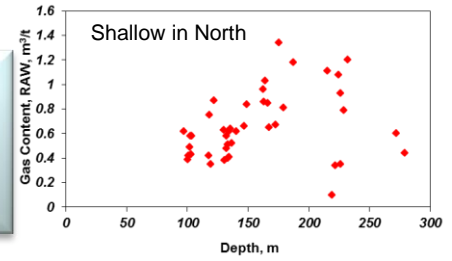
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Is this trend reasonable?
Why does the critical depth occur at 600m?



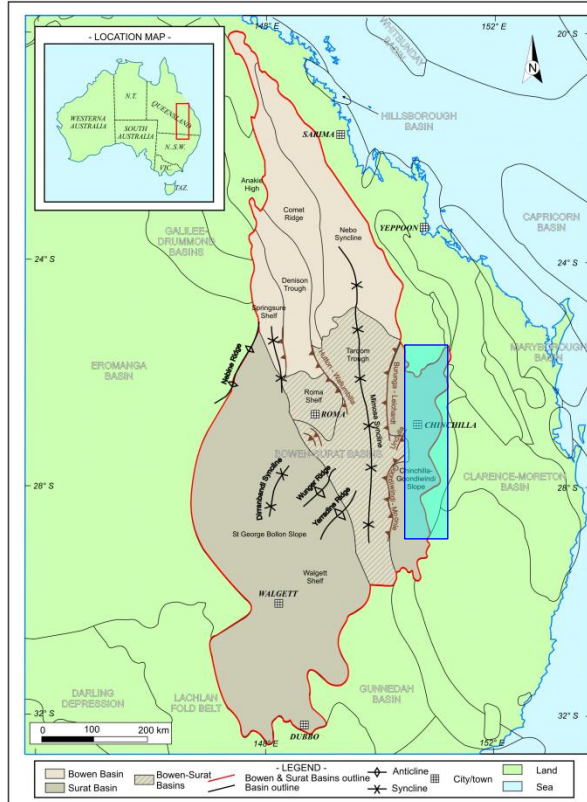
- NW Fairway acreage
- ▲ Undulla nose area
- × Very shallow acreage in north (Taroom only?)
- × Main Fairway (greater Kogan-Tipton)
- Geology south of Tipton
- ⊖ Deep coals in S of acreage



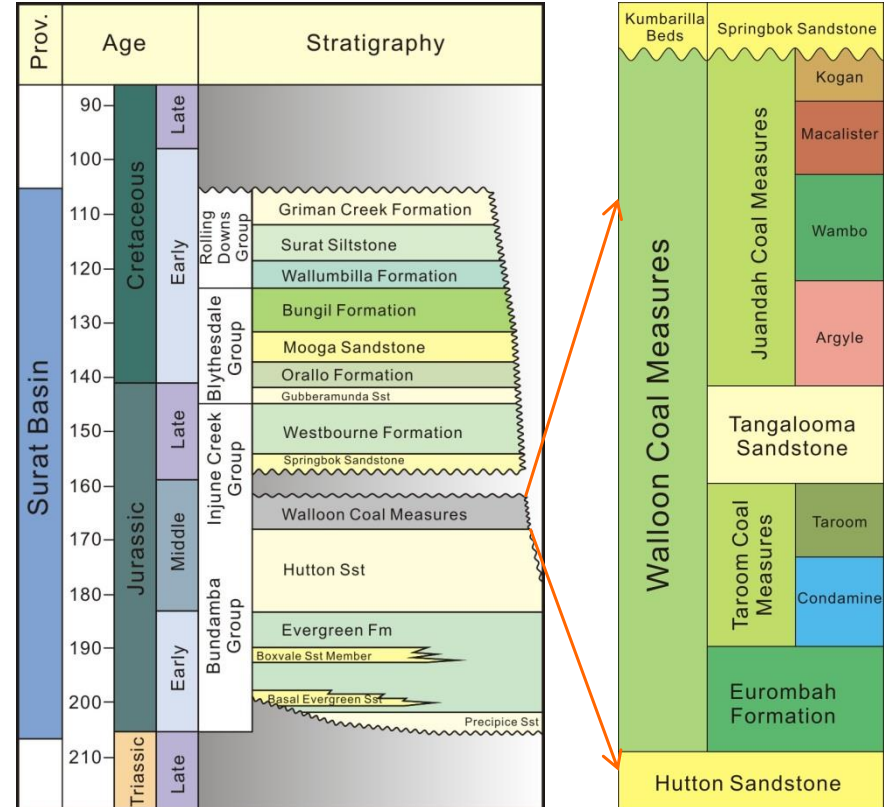
Introduction

Geological Setting

- **Basin Overview**
 - Jurassic-Cretaceous
 - Intracratonic basin
- **Walloon Coal Measures**
 - Juandah (Upper)
 - Tangalooma Sandstone
 - Taroom (Lower)



Structure Map of Bowen and Surat Basin (IHS, 2009)



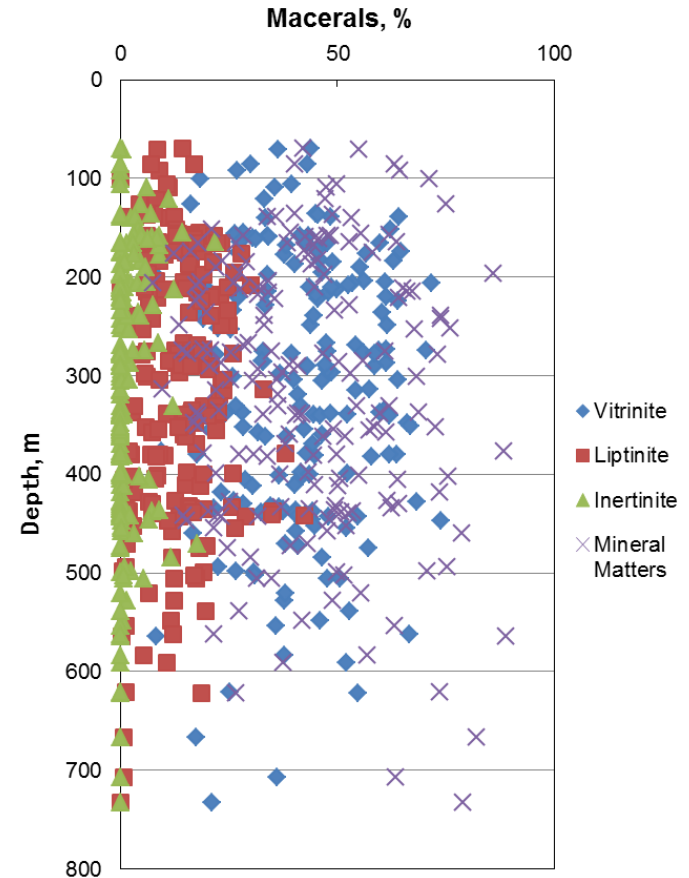
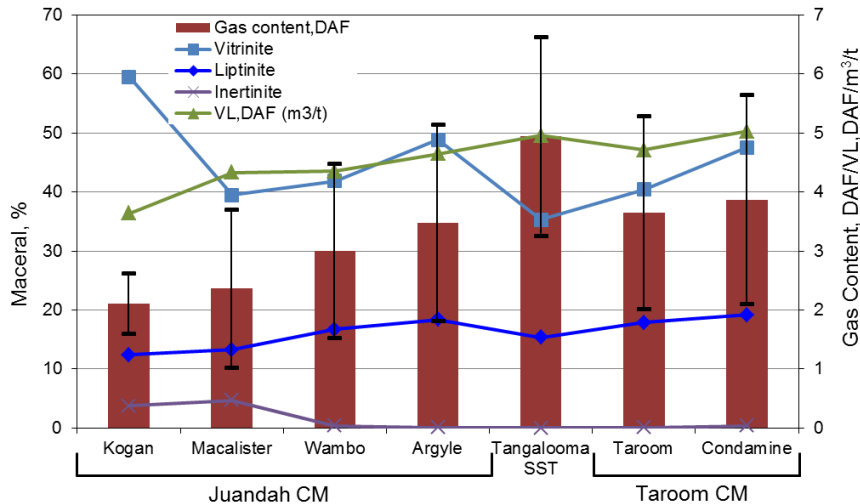
Stratigraphic column for Surat Basin (Modified from McKellar, 1998)

Gas Content Controlling Factors

Coal Properties – Maceral Contents

➤ Gas content trend coincides with liptinite

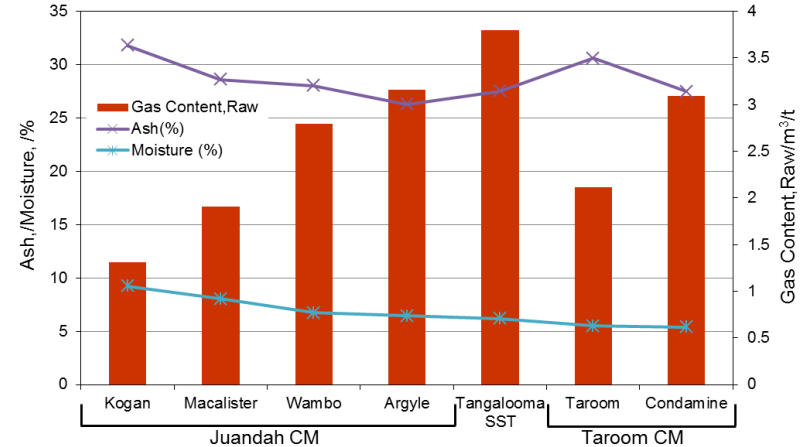
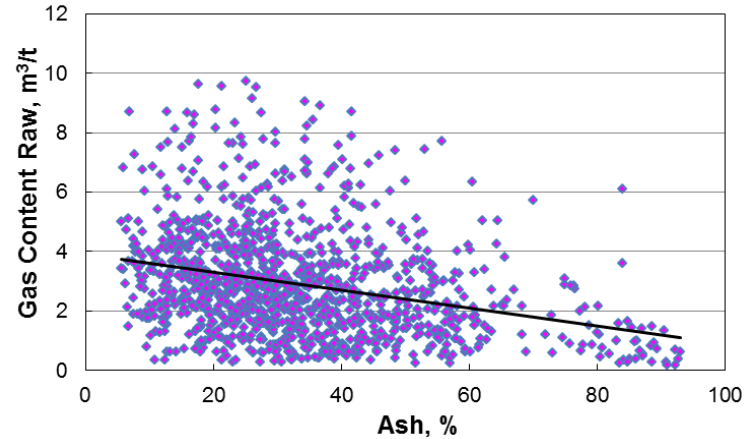
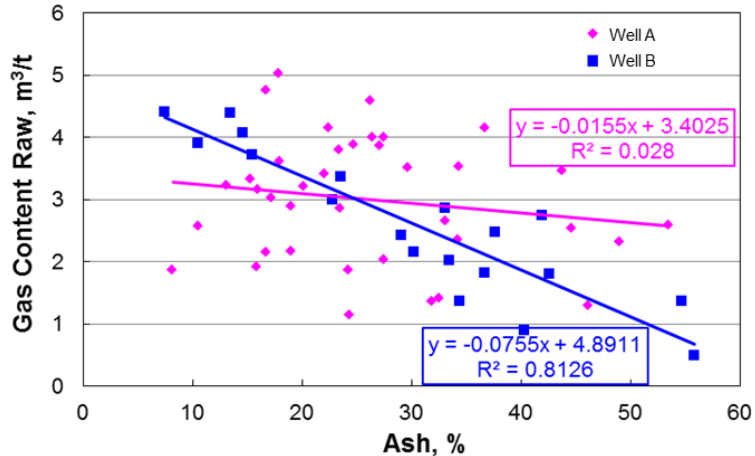
- Maceral contents are highly variable:
 - Vitrinite: 7.7%-96.5%(average 42%)
 - Liptinite: 0-42.4%(average 13.4%)
 - Inertinite: 0-21.8%(average 1.7%)
 - Mineral matters: 3.5%-89%(average 42.8%)



Gas Content Controlling Factors

Coal Properties – Proximate Analysis

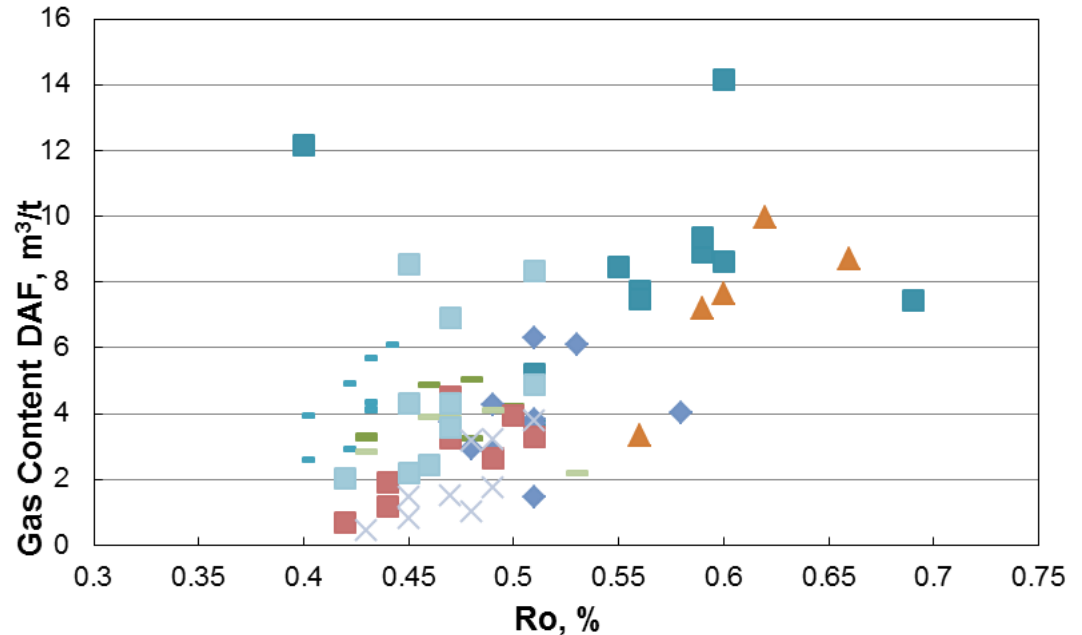
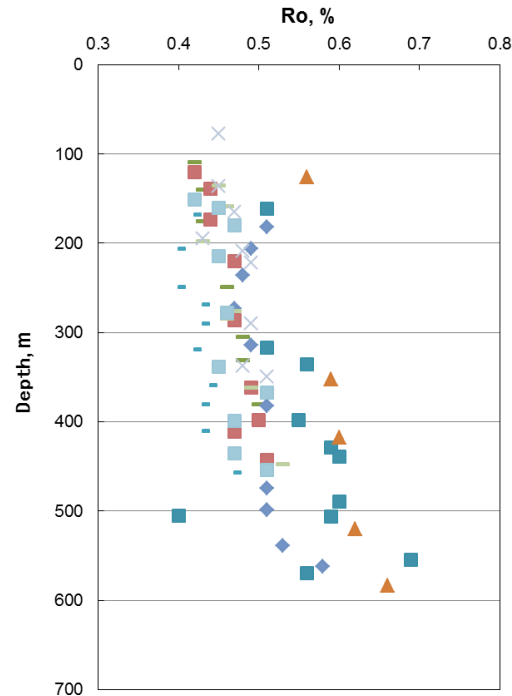
- **Gas content trend opposes ash yield**
 - Ash contents ranging from 5% to >60%, averaging 32%
 - Correlations between Gas contents and Ash yields vary remarkably within the same field



Gas Content Controlling Factors

Coal Properties – Rank

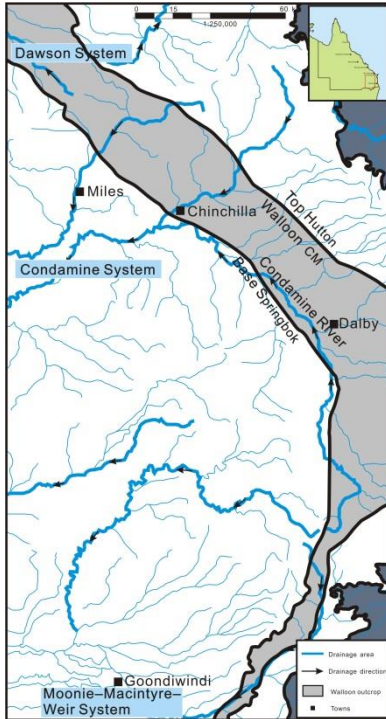
- **Gas contents increase with rank regionally**
 - Regionally, gas contents increase with coal rank
 - R_o range is narrow in eastern Surat Basin



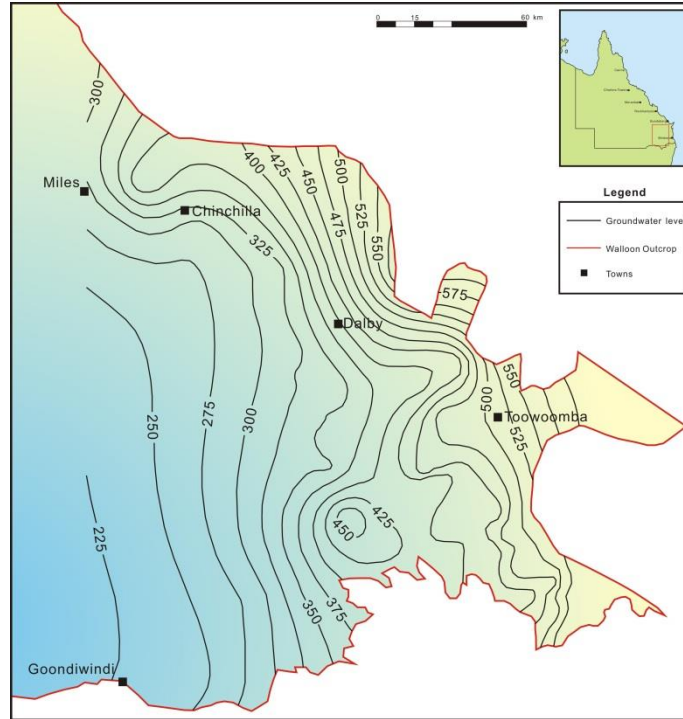
Gas Content Controlling Factors

Hydrogeology

- **Horizontally:** Three drainage systems, mainly to southwest, and groundwater level declines westward
- **Vertically:** The Walloon CM separate two major aquifers



Drainage Systems in eastern Surat Basin
(Modified from Hamilton, 2012)



Groundwater level contour of Walloon CM in eastern Surat Basin
(after Arrow Energy, 2010)

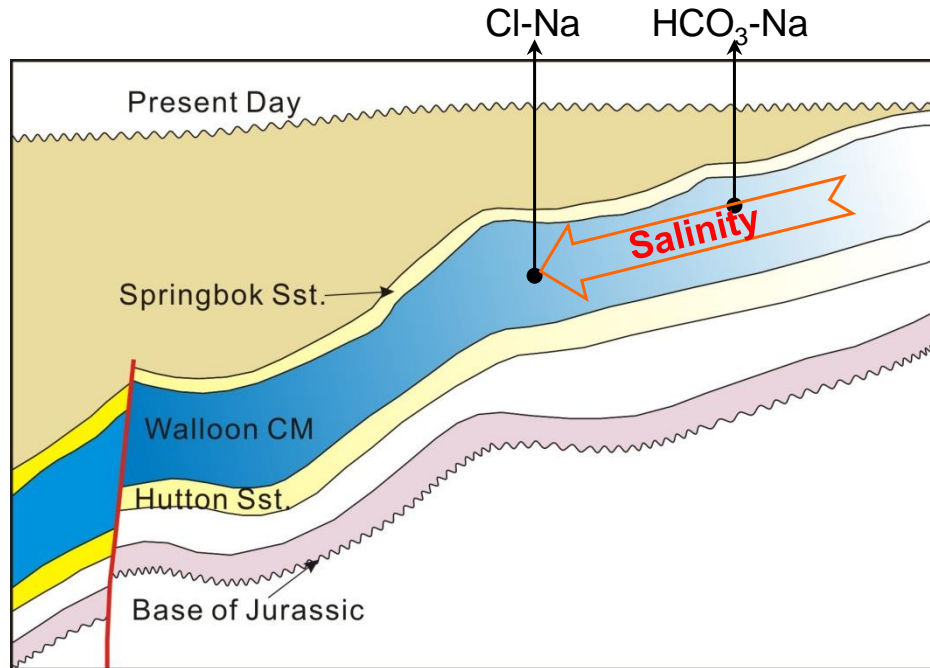
Shallow	Condamine Alluvium	Unconfined Aquifer
	Gubbemunda Sandstone	Confined/Unconfined Aquifer
Intermediate Groundwater System	Westbourne Formation	Aquitard
	Springbok Sandstone	Confined/Unconfined Aquifer
Coal Seam	Walloon Coal Measures	Confined Aquifer
Deep Groundwater System	Eurombah Formation	Aquitard
	Hutton Sandstone	Confined Aquifer
	Precipice Sandstone	Confined Aquifer

Hydrogeologic units in eastern Surat Basin
(after Arrow Energy, 2010)

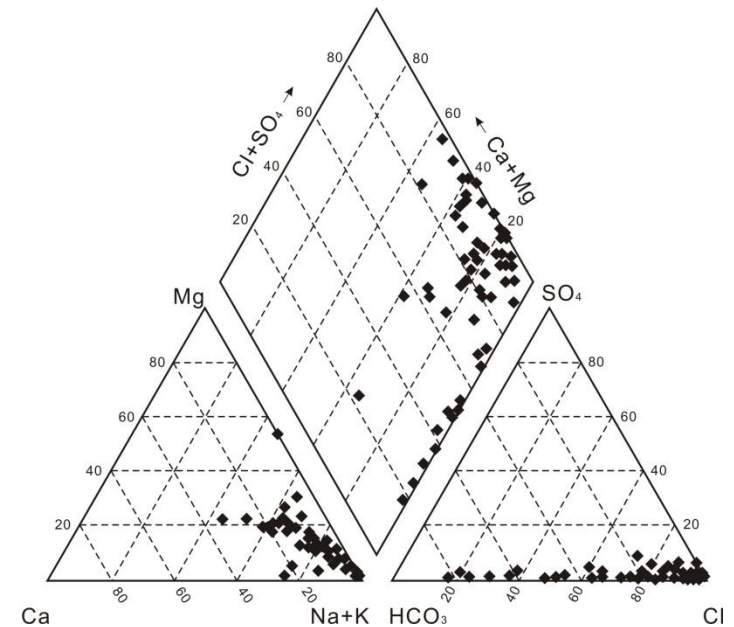
Gas Content Controlling Factors

Hydrogeology

- **Water Type of Walloon CM is dominated of sodium-bicarbonate-chloride**
 - The water type changed from bicarbonate dominant to chloride dominant with increasing salinity
 - Co-Produced water from Walloon CM indicates a moderate hydraulic setting



Hydraulic section in Eastern Surat Basin

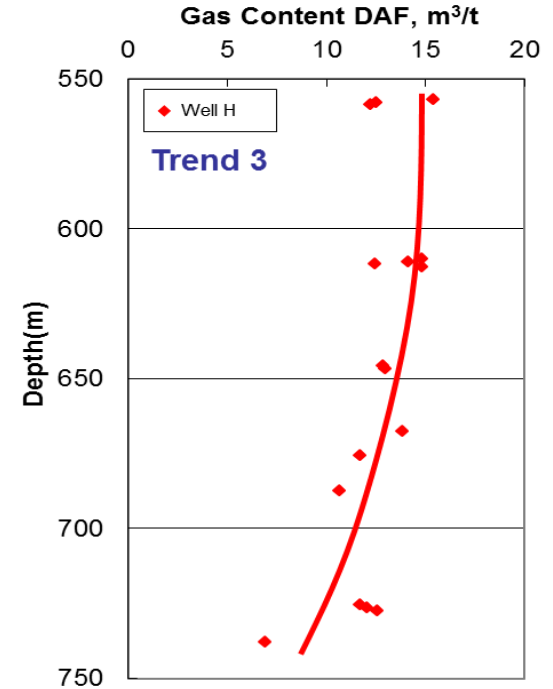
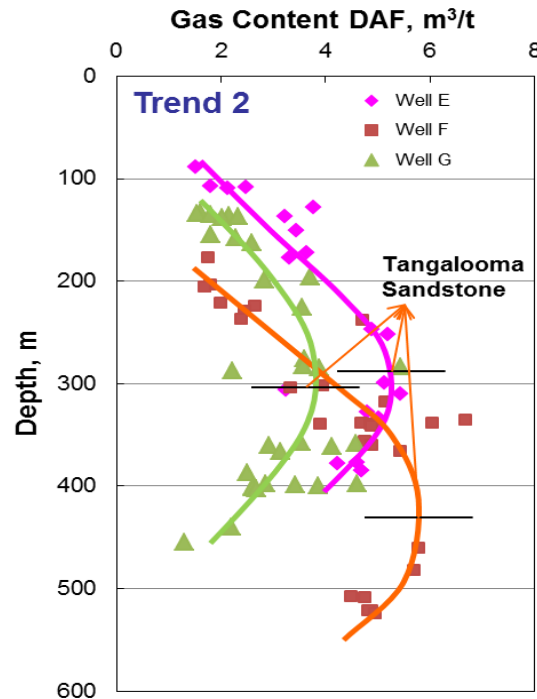
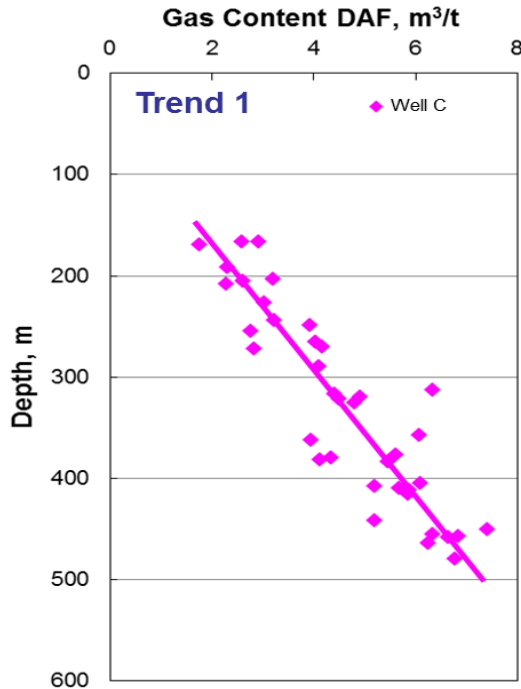


Ion Content of co-produced water from Walloon CM

Gas Content vs. Depth Trends

Three Trends from Individual Wells

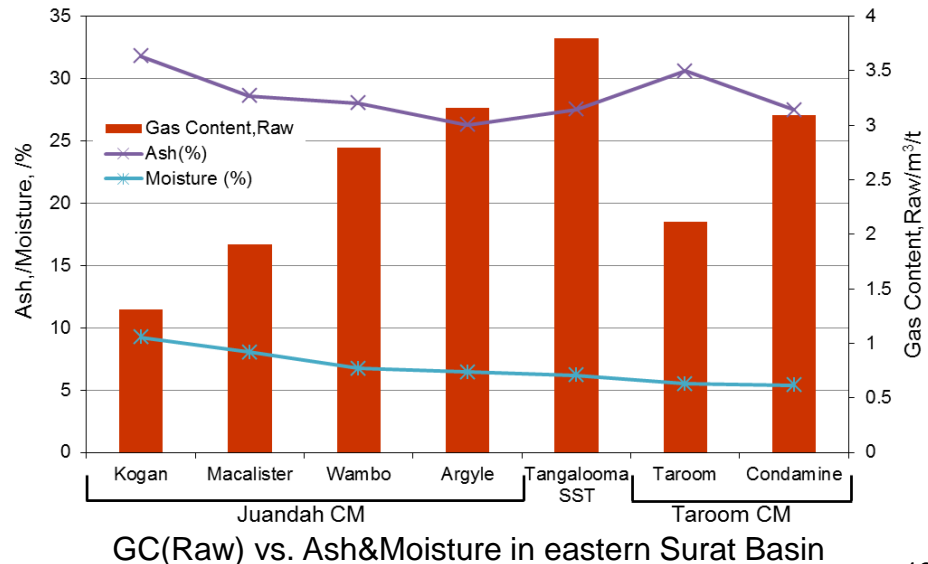
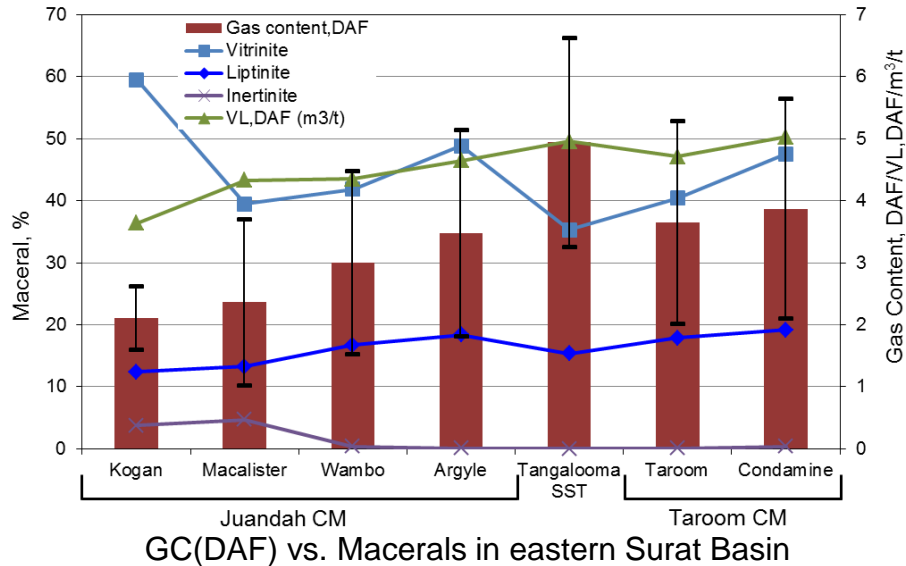
- Three basic well profiles were identified in eastern Surat Basin, Trend 2 dominated
- Gas content either:
 - increases (Trend 1)
 - Increases, then decreases (Trend 2); or
 - decreases (Trend 3) with depth



Gas Content vs. Depth Trends

Basin Wide Increase-decrease Trend

- Mean GC(Raw & DAF) of each Coal Measures peak at Tangalooma Sandstone
- GC(DAF) vs. Macerals
 - Liptinite is consistent with GC(DAF)
- GC(Raw) vs. Ash & Moisture
 - Ash mirrors GC(Raw)

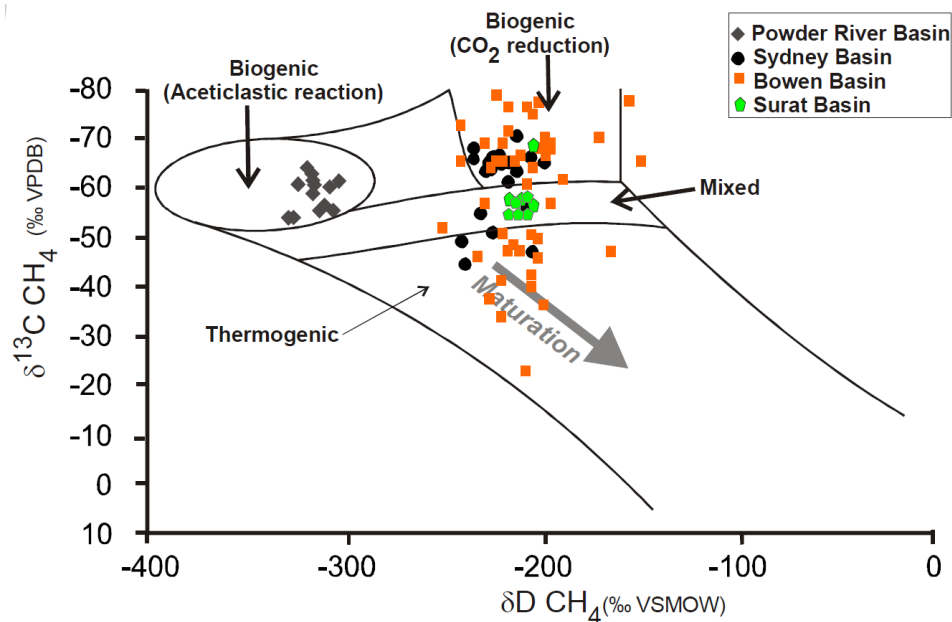


Gas Content Trend Control Mechanism

Gas Type - Existence of Biogenic Sources

- **Gas Type**

- Gas Isotope: $\delta^{13}\text{C}$, $-57.3\text{‰} \sim -54.2\text{‰}$
- Mainly mixed gas
- Some biogenic(CO_2 reduction) gas
- Secondary biogenic sources DO exist



Classification system from
Whiticar et al., (1986)

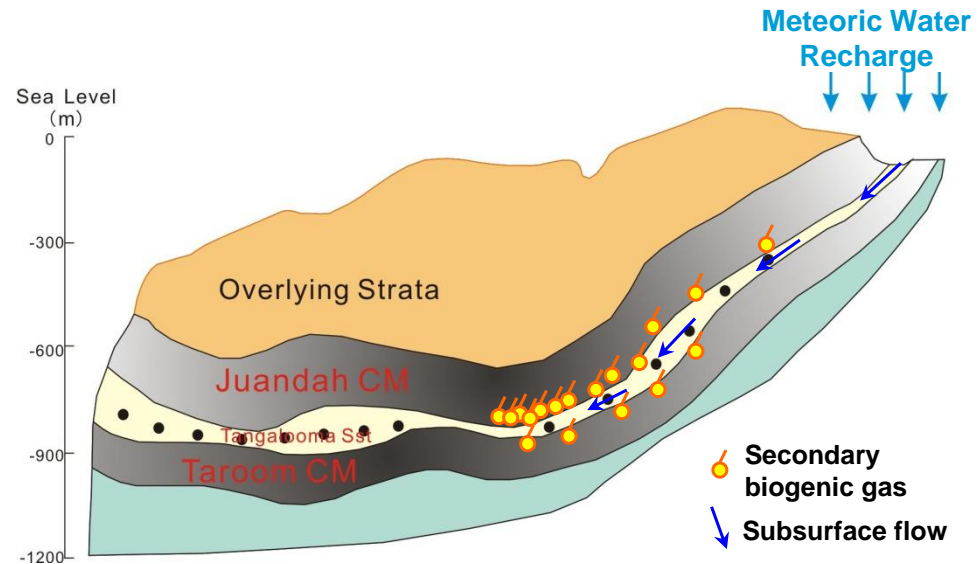
Data from Smith et al (1985), Faiz et al (2003)
Draper and Boreham (2006), Gorody (1999)

Gas Type Identification Chart(after Arrow Energy, 2010)

Gas Content Trend Control Mechanism

Gas Type - Existence of Biogenic Sources

- In order to have the secondary biogenic gas generation in the coal seams, it needs:
 - Meteoric water - bring the microbes and nutrients into the coal seams
 - Permeability - easy access to the coal seams
- Conditions of Eastern Surat Basin
 - Water recharge in eastern margin
 - Moderate hydraulic conditions
 - High permeability in Tangalooma Sandstones

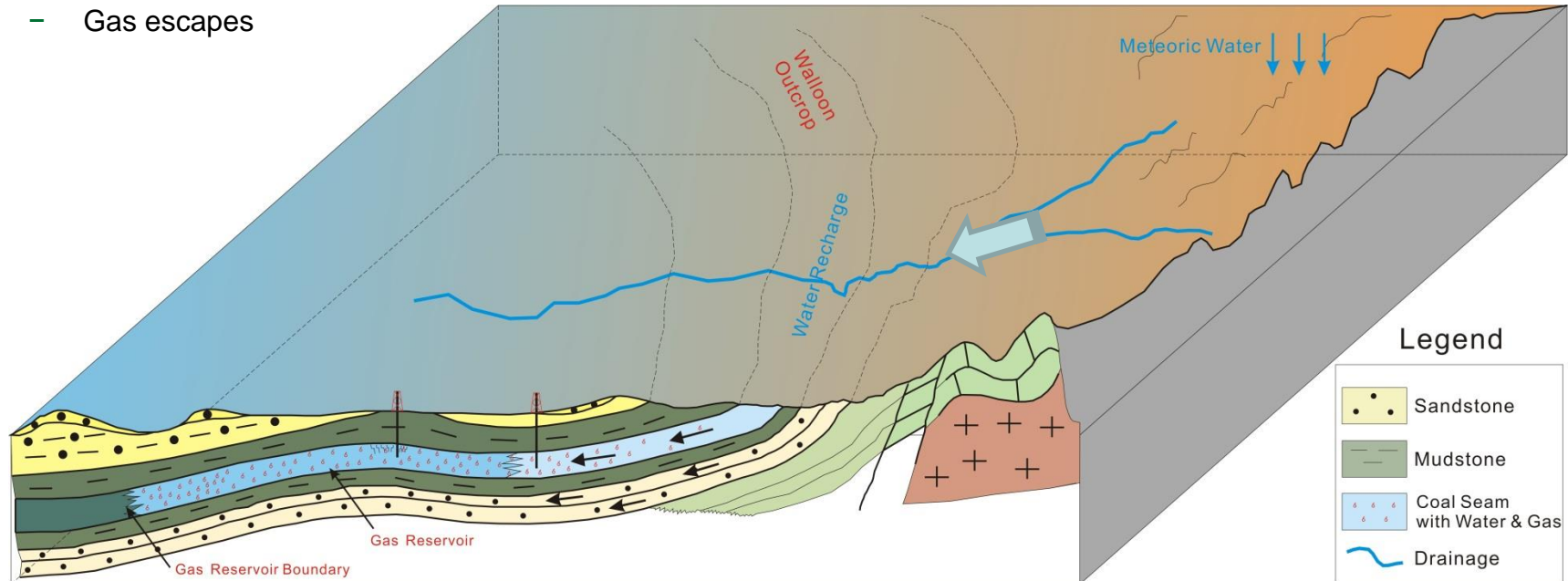


Schematic Diagram of Secondary Biogenic Gas Generation

Gas Content Trend Control Mechanism

Gas Content is Controlled by Surface Water Recharge

- **Higher Gas Content:** Surface run-off direction in accordance with regional dip
 - Hydraulic overpressuring or hydrodynamic trapping
 - Surface water recharge, nutrients & microbes input
- **Lower gas content:** Surface run-off direction opposes regional dip
 - Hydraulic underpressuring or hydrodynamic damaging
 - Gas escapes

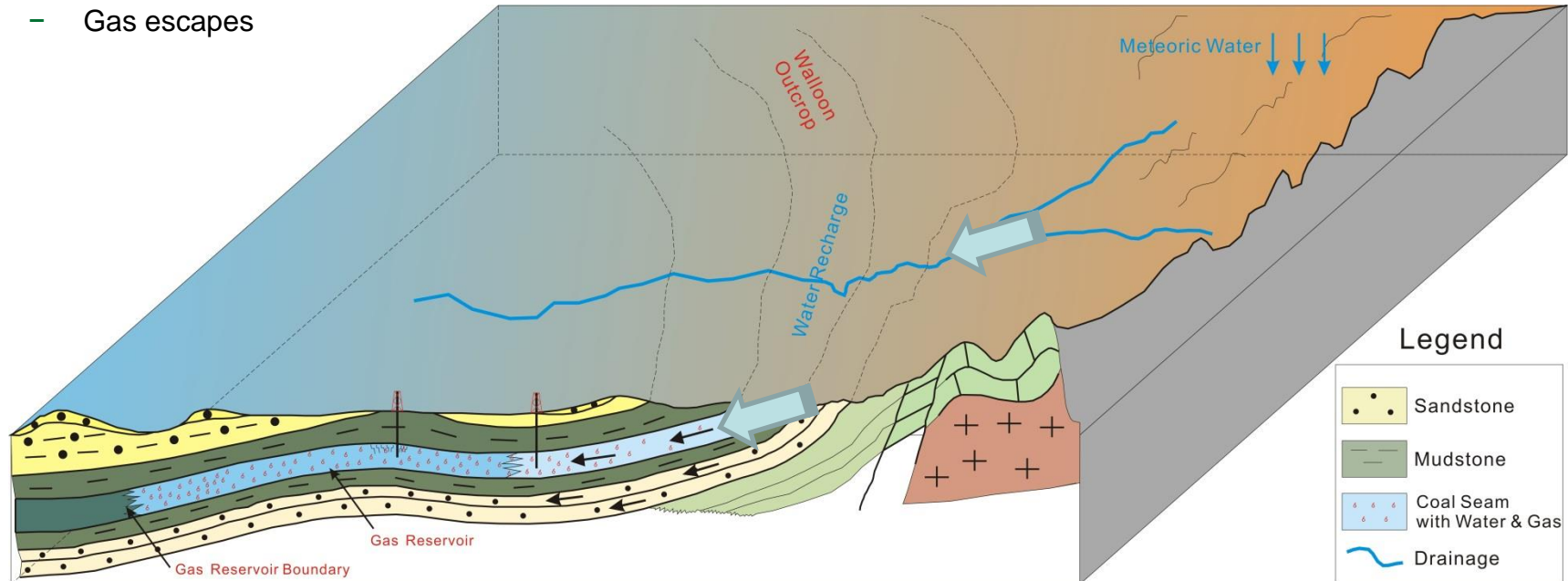


Typical section of hydraulic conditions in eastern Surat Basin

Gas Content Trend Control Mechanism

Gas Content is Controlled by Surface Water Recharge

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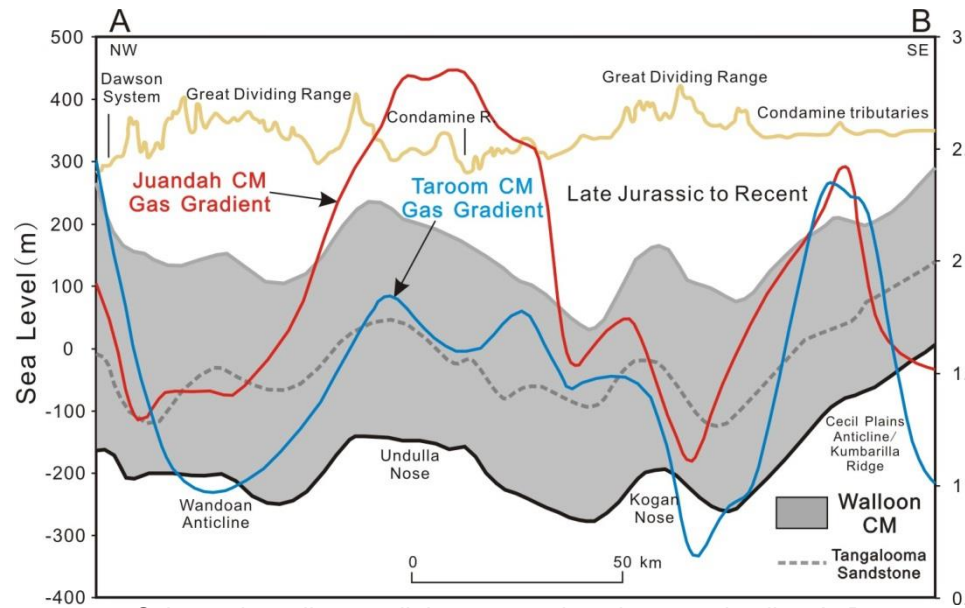


Typical section of hydraulic conditions in eastern Surat Basin

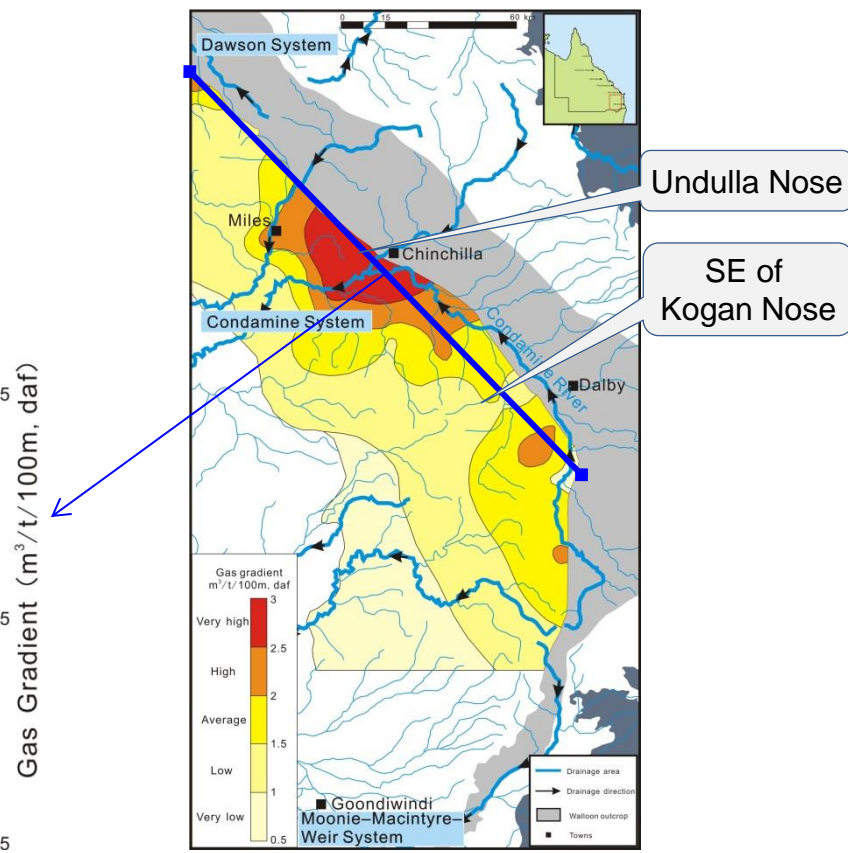
Gas Content Trend Control Mechanism

Gas Content is Controlled by Surface Water Recharge

- **Undulla Nose:** Highest gas gradient
 - Beneath the Condamine River
 - Surface run-off direction in accordance with Regional dip
- **SE of Kogan Nose:** Low gas gradient
 - Beneath the Great Dividing Range
 - NO / Very little water recharge



Schematic, strike-parallel cross-section along section line A-B
(Modified from Hamilton, 2012)

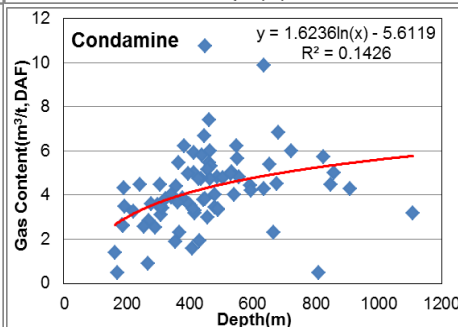
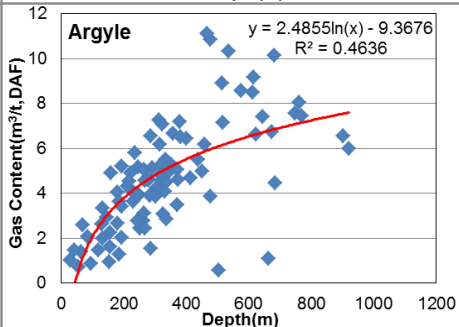
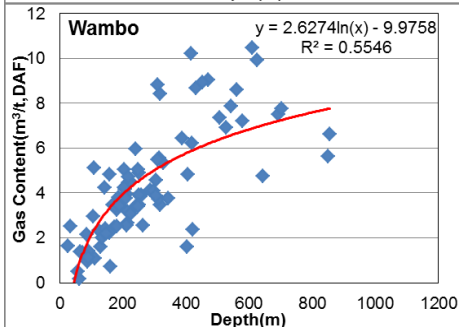
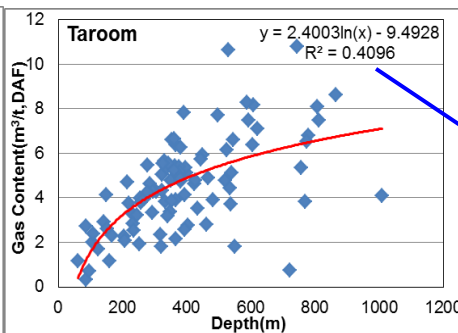
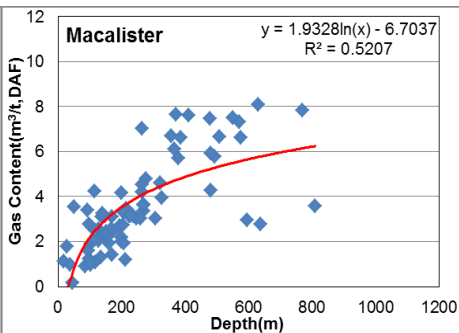
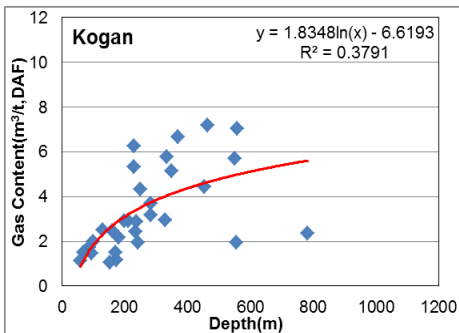


Contour map of gas gradient in eastern Surat Basin
(Modified from Hamilton, 2012)

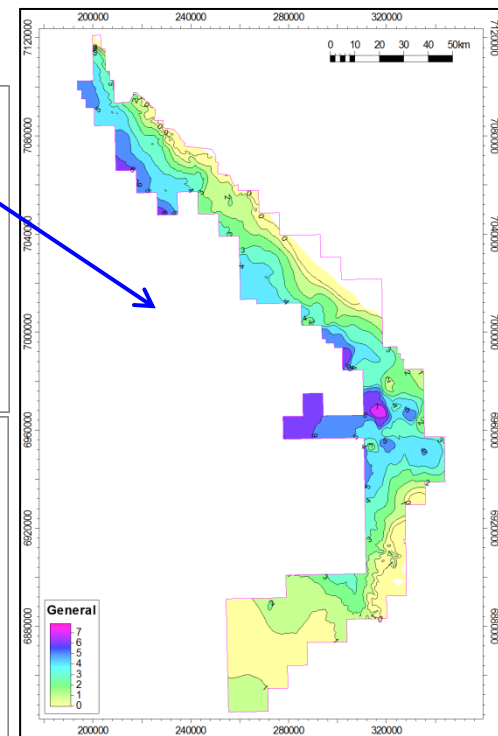
Property Modeling Improvement

Original Gas Content Model

- **Original gas content model**
 - Based solely on GC vs. Depth trend
 - Neglect geologic anisotropy
 - Low reliability



GC vs. Depth crossplots of Walloon CM

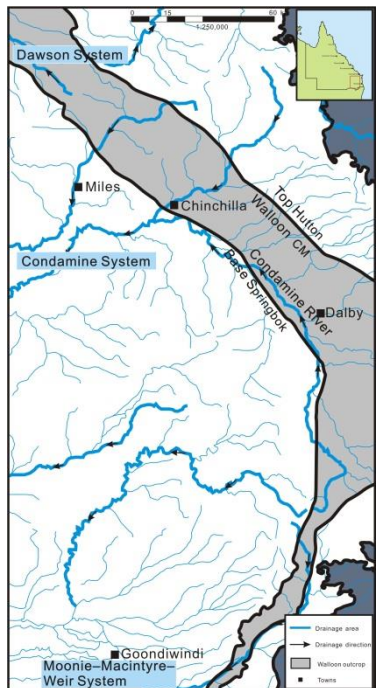


Gas content map of Taroom CM 19

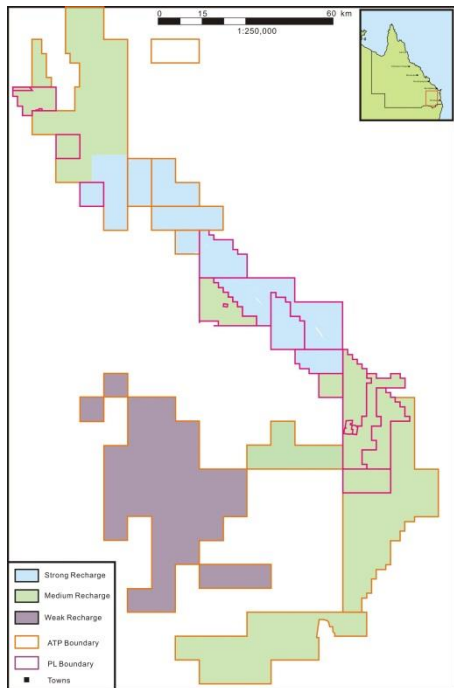
Property Modeling Improvement

Geologic Regions Reset Based on Surface Water Recharge

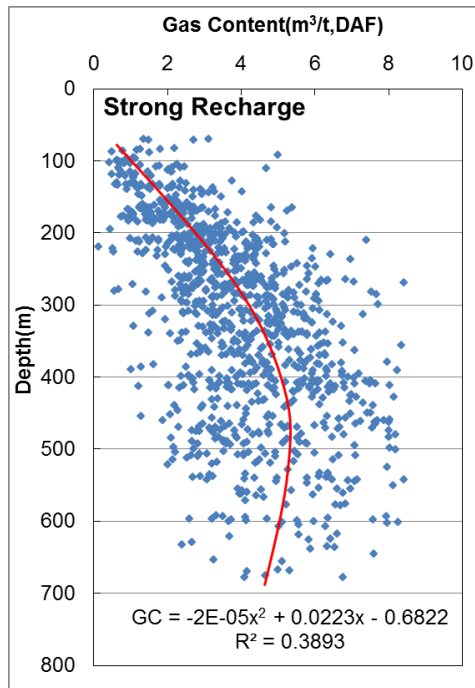
- **Gas content analysis based on water recharge**
 - Three hydrogeologic regions
 - Different GC vs. Depth trends in three regions



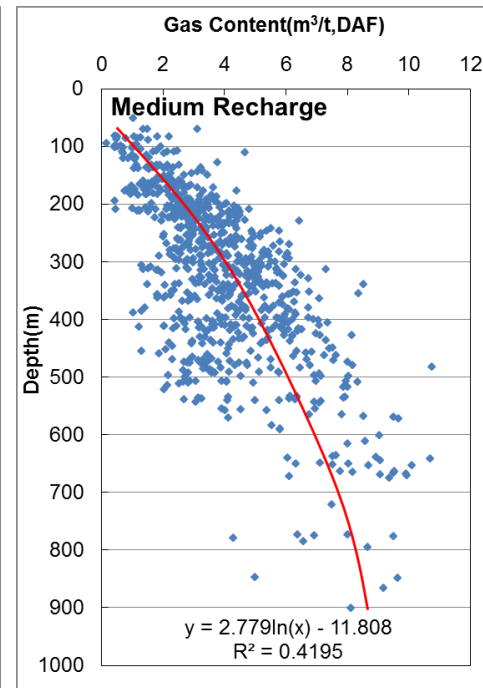
Drainage Systems in eastern Surat Basin



Hydrogeologic regions in eastern Surat Basin



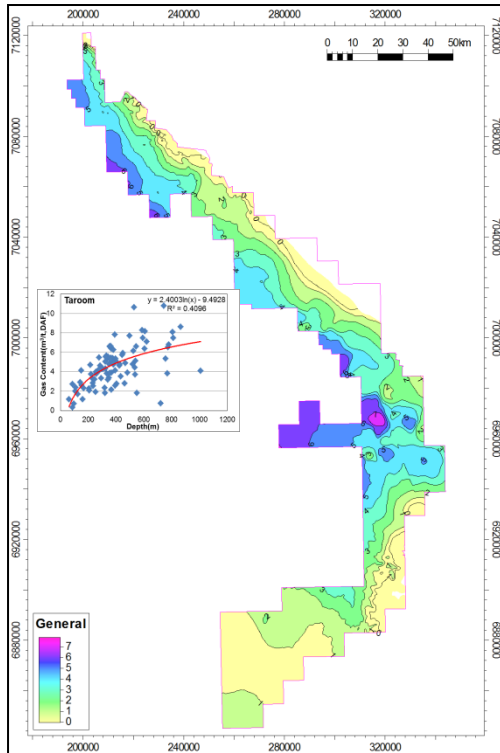
GC vs. Depth crossplots in different hydrogeologic regions



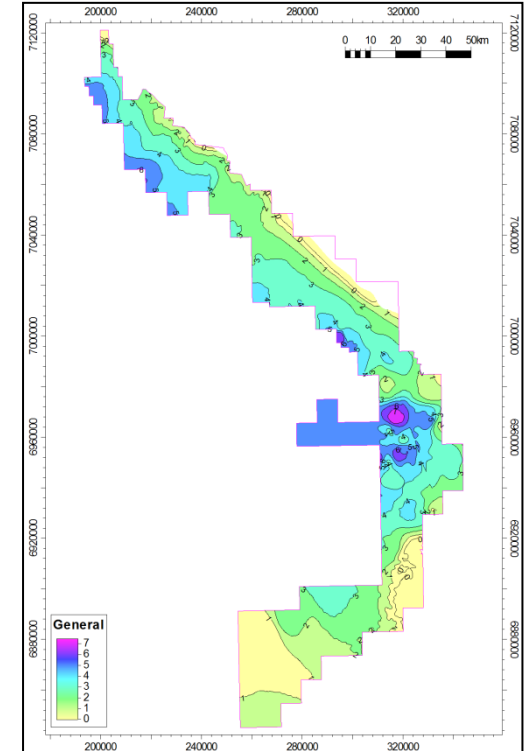
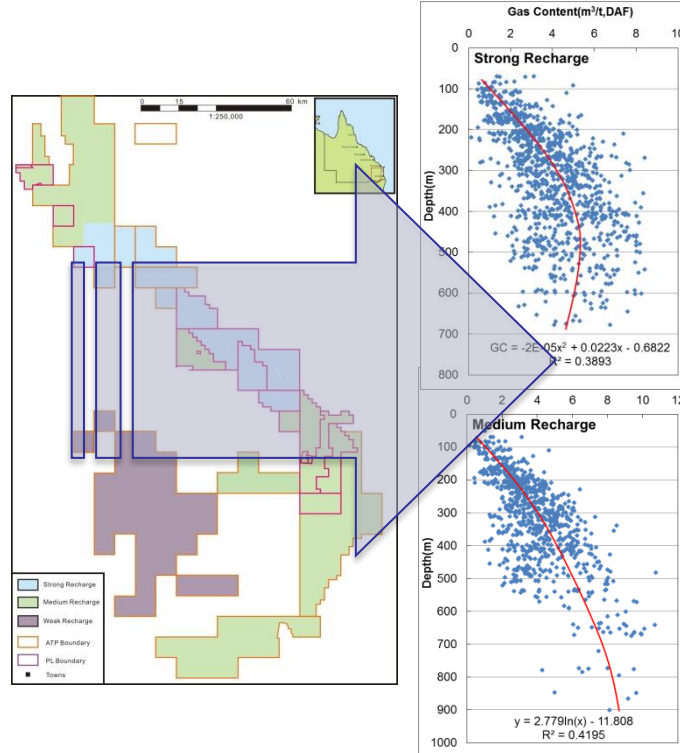
Property Modeling Improvement

Gas Content Modeling

- Gas content modeling based on GC vs. Depth trends in 3 hydrogeologic regions
 - Different GC vs. Depth trend in each region



Original contour map of gas content of Taroom CM



New contour map of gas content of Taroom CM21

Summary

- Gas content vs. depth crossplots show an increasing-decreasing trend with the inflection points in accordance with Tangalooma Sandstone in eastern Surat Basin.
- Secondary biogenic gas generation and surface water recharge can explain the GC vs. depth trend.
- Classification of hydrogeologic regions can enhance the reliability of gas content modeling.



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Thanks for Your Attention

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