AAPG Datapages/Search and Discovery Article #90234 © 2015 AAPG Asia Pacific Region, Geoscience Technology Workshop, Opportunities and Advancements in Coal Bed Methane in the Asia Pacific, February 12-13, 2015, Brisbane Australia

Evaluating Dynamic Behaviour of Complex In-Situ Gas Composition from a Coal Seam Reservoir – A Case Study from Fairview Early Permian East Coals

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Abstract

Gas compositions from CSG reservoirs typically have high methane concentration but significant amounts of carbon dioxide, nitrogen, and heavier hydrocarbons can be sorbed on coal. The degree at which these gases are attracted to the surface of the coal is known as the sorption affinity and it is proportional to the boiling point of each gas. Figure 1 shows the different boiling points of the gas species.

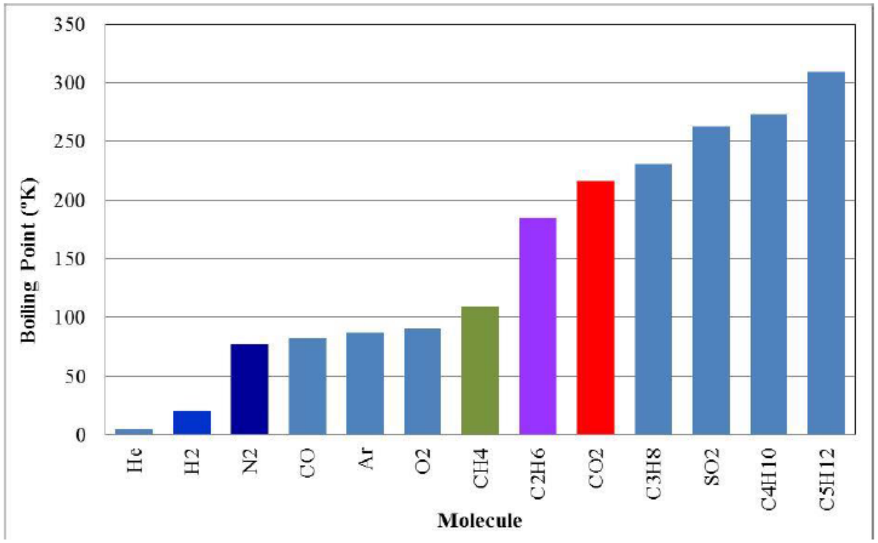

Figure 1. Boiling point of different gases (modified from Reference Kinetic diameters of selected gases, Break, 1973).

Santos is appraising more challenging plays including Early Permian Cattle Creek coals. These coals lie directly beneath the Bandanna coals in the Fairview field and are split into two main areas, East and West. The Early Permian East coals or Springwater play (focus point of this paper) typically occur at depths between 1,100 m and 1,800 m. The coals are characterised by low permeability, high gas content, relatively high concentration of ethane and heavier hydrocarbon components, and significant inerts concentration. Figure 2 summarizes the main reservoir features.

Cattle Creek Fm Reids Dome Beds | 339 km^2 | 1100 -1800 mGL | 20 core and Appraisal Wells

Risk	Factor	Comments
	Coal Extent	Well defined coal extents in most areas
	Coal Thickness	5 – 53 m
	Gas Content	10 – 15 m3/t (daf) (276 coal samples)
	Permeability	< 1 – 5 mD (28 DST/MDT in 13 wells)
	Gas Composition	0.2 – 12% CO2 | < 3% N2 | 2 – 14 % C2+
	De-watering	Low perm – water rate dependant on Perm
	Saturation	Gas saturation from 75% to max of 95%

Figure 2. Springwater play characteristics.

For this work, a detail review of the Early Permian East reservoir characteristics and a compositional history match of the main gas components (C_1H_4, C_2H_6, C_3H_8, CO_2, N_2) was performed in order to assist the compositional production forecast.

The produced gas composition plays a key role from safety and economic evaluation of a project and its effect cannot be neglected. The production of CO_2 for example represents a potential issue from a corrosion of materials perspective (surface facilities and well completions). CO_2 treatment is capitally intensive and will have a major impact on project economics, therefore evolution of the gas composition with time is a key uncertainty that must be understood to allow for a fit for purpose, capital efficient project to be implemented.

Additionally the LNG plant has specific limits in terms of gas specification (inerts and heavier hydrocarbon components) that have to be met in order to operate safely and continuously. Understanding the multicomponent gas dynamic and its variation with reservoir depletion is key to ensuring an efficient downstream operation, evaluating the viability of different gas pre-treatment options or assessing blending capacity studies with additional gas available from a different reservoir.

The gas storage capacity of a particular coal is also a function of the gas itself (amongst other parameters as temperature, Coal Rank, ash and moisture content). Figure 3 shows an example of the resultant composite isotherm from a given gas composition.

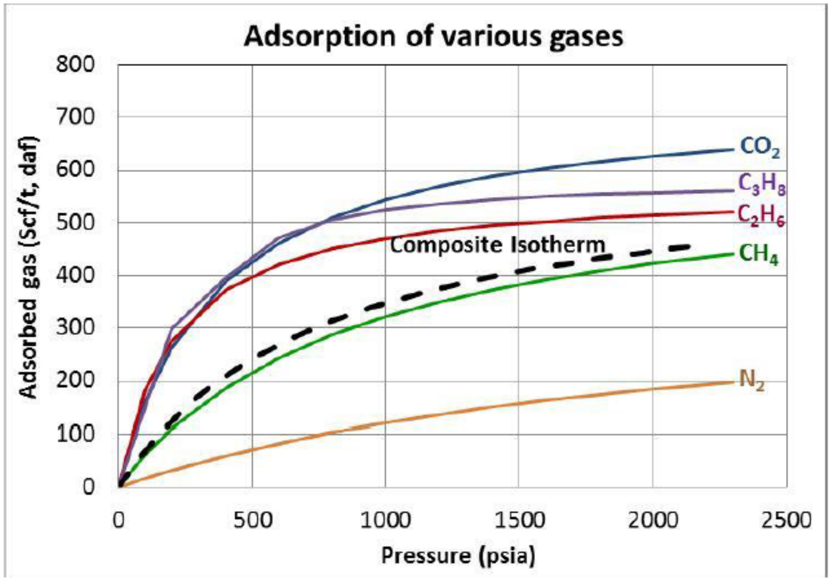

Figure 3. Adsorption of various gases and resultant composite isotherm.

In the case of having a coal seam gas reservoir with complex in-situ gas composition, a description of multicomponent gas sorption is needed in order to predict hydrocarbon gas-in-place, rates, and quantify reserves.

For this study, 2 different tools were used to model the adsorption/desorption behaviour of individual components (C1H4, C2H6, C3H8, CO2, N2) using the static and dynamic data available from the appraisal phase.

Tool 1: Spreadsheet developed in-house based on Extended Langmuir Isotherm (ELI) and coupled with material balance and discrete pressure stepping.

Description: ELI is the simplest model used to estimate multicomponent adsorption-desorption behaviour

$$\mathrm{Vi} = VLi \frac{bi * yi * p}{1 + \sum_{j=1}^{n} \mathrm{bj} * \mathrm{yj} * \mathrm{p}}$$

V_i = gas storage of component i, in-situ basis.
V_{Li} = pure component Langmuir volume.
b_i or b_j = pure component Langmuir pressure coefficient (1/PL)

y_i or y_j = mole fraction of component i or j in free gas phase
n= number of components in free gas phase.

In addition, the separation factor (or selectivity ratio) can be defined as:

$$\alpha = \frac{(x/y)_1}{(x/y)_2} = \frac{V_{L1} \times b_1}{V_{L2} \times b_2}$$

$$y_1 = \frac{x_1}{\alpha + (1-\alpha) \times x_1}$$

$$y_2 = 1 - y_1$$

X_1 or X_2 = mole fraction of a component in adsorbed phase (desorption test and compositional analysis). An example of the input parameters and outcomes from the simulation using the spreadsheet is shown in Table 1 and Figure 4 respectively.

Component	Mole fraction of a component in adsorbed phase	VL (Scf/ton)	PL (psi)	b (1/psi)	$\alpha = \frac{(V_L*b)_{C1}}{(V_L*b)_{Comp}}$	Mole fraction of a component in free phase
C_1H_4	0.774	382	672	0.0015	1	0.862
C_2H_6	0.111	508	154	0.0065	0.1723	0.021
N_2	0.026	294	1615	0.0115	3.1226	0.091
CO_2	0.089	664	305	0.0033	0.2611	0.026

Table 1. Input parameters for compositional simulation.

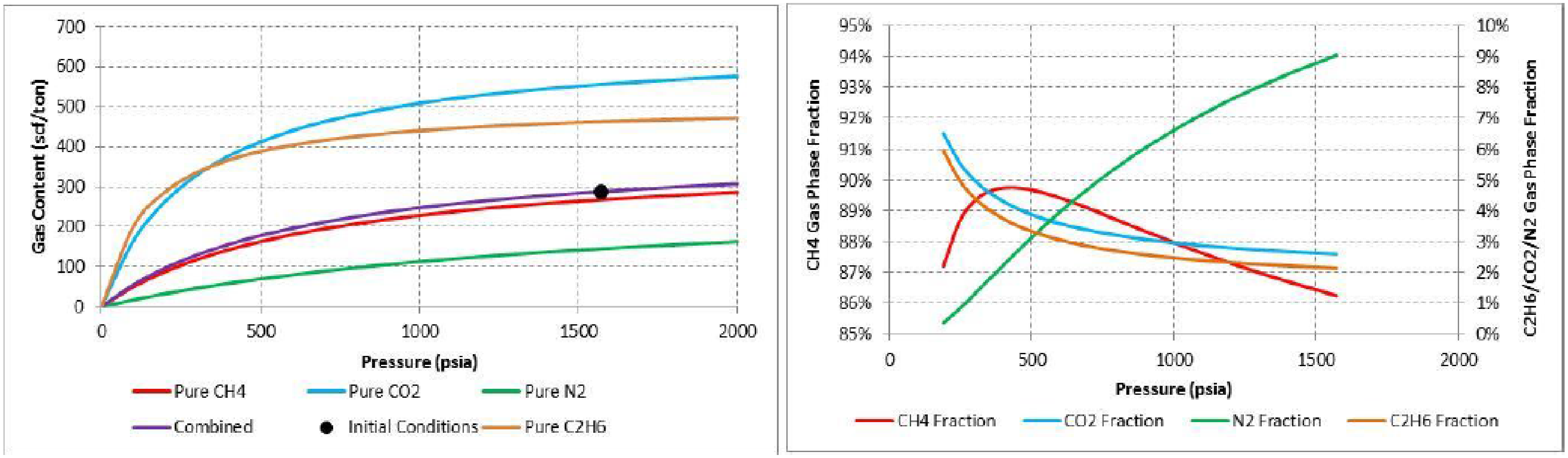

Figure 4. Gas content and gas composition evolution with depletion.

Tool 2: Eclipse^{TM} compositional single well model. Description:

- Single well model in Eclipse 300.
- In-situ Gas Content and gas composition per layer based on desorption test.
- Isotherms by components based on adsorption test.
- Diffusion coefficient per component based on desorption test and molecule sizes.
- Water, gas and bottom hole flowing pressure history matching.
- Production forecasting.

From this work, it was concluded that:

- Gas composition will tend to evolve with depletion as a function of initial composition, coal characteristic (sorption affinity) and development strategy.
- Estimated heating values of the produced gas can be significantly different from that estimated with in-situ gas composition.
- For given CO_2 and C_2H_6 in-situ concentrations (sorbed phase), the initial concentration of each component in free gas phase is significantly lower however it can vary up to 75% depending on the corresponding isotherms.
- Periodical wellhead gas sampling and accurate production data from appraisal wells is key to be able to build a suitable tool to track gas concentration evolution with depletion.