PS Coal Bed Methane Reservoir Simulation Study*

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Search and Discovery Article #80453 (2015)**
Posted June 30, 2015

*Adapted from poster presentation given at AAPG Asia Pacific Region, Geoscience Technology Workshop, Opportunities and Advancements in Coal Bed Methane in the Asia Pacific, Brisbane, Queensland, Australia, February 12-13, 2015

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Abstract

Coal-bed methane (CBM) production behaviour is difficult to predict or analyse due to its highly intricate reservoir characteristics. Gas production from CBM reservoirs is governed by complex interaction of diffusion from the matrix to fractures and two-phase gas and water flows through the fracture system to the production wells. The parameters that control the flow physics of these two systems are highly variable during the fluid production process. Generally CBM reservoir performance is evaluated using simulation software which requires experimental or/and field data to parametize the various governing equations that determine performance. Amongst the parameters that affect simulation outcomes, coal absolute permeability and relative permeability are key factors controlling CBM productivity. The absolute permeability of coal varies during production due to matrix shrinkage and geo-mechanical stress-strain effects, and may be highly anisotropic. Relative permeability controls water production during the dewatering stage and the shape of gas production curve. Very little is actually known about relative permeability in coal and although it may be interpreted as a physical phenomenon, the factors controlling it in coal remain largely unexplored. It is often the case that relative permeability is used as a fitting parameter in history matching studies.

History-matched relative permeability curves (Kr) for a coal often exhibit very different behaviour from laboratory-based curves, for reasons that remain largely unexplained. For practical predictive purposes, it is necessary to find methods to adjust or scale values of Kr from laboratory tests so that they are relevant to field applications. A simplified coal seam gas reservoir simulation was carried out to examine the relative significance of transport parameters on fluid production. The simulation is carried out using GEM from the CMG suite. This software has distinct functions permitting dual porosity and permeability for modelling fractured reservoirs, and simulates primary CBM production through models for gas sorption in the matrix system, gas diffusion through the matrix and two phase (gas and water) flow through the fracture systems.

The purpose of the study is not to replicate a realistic reservoir, rather to illustrate the sensitivity of production rate under different conditions. Most of the required data used in this study comes from the German Creek coal seam, Well-DR4, Bowen basin of Australia. Additional data elements of not available from this primary study are average values extracted from different literature studies or/and experimentally measured.

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Coal Bed Methane Reservoir Simulation Study

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Project Summary

In coal reservoir simulation, absolute permeability and relative permeability are key factors controlling CBM productivity. The absolute permeability of coal changes during production due to matrix shrinkage and geo-mechanical stress-strain relaxations, and is usually highly anisotropic.

Relative permeability controls water production during the dewatering stage and the shape of gas production curve. Little is actually known about relative permeability in coal and although it may be interpreted as a physical phenomenon, the factors controlling it in coal remain largely unexplored.

Project Objectives and Significance

A sensitivity analysis is conducted using GEM & CMOST from the CMG software suite:

- Using laboratory relative perm curves, varying other reservoir parameters within tightly constrained limits (Table 2). This illustrates effects of other important coal properties on CBM productivity, and that adequate history match cannot be obtained without also adjusting the relative permeability curve.
- Altering the laboratory relative perm curve (Fig-d-1) in a methodical way to provide amended relative perm curves (Fig 3). This systematically analyses of the effects of shape and magnitude parameters of Kr on production profile.

$$K_{rw} = \frac{K^{o}_{rw} S_i^{L_w}}{S_i^{L_w} + E_w (1-S_i)^{T_w}} \qquad K_{rg} = \frac{K^{o}_{rg}(1-S_i)^{L_g}}{(1-S_i)^{L_g} + E_g S_i^{T_g}}$$

Where: g and w are gas and water phases, respectively,
Kr is modified relative permeability curve,
Si is initial saturation,
$K_r o$ is end point of initial relative permeability,
L, T and E control the bottom, top and lateral position of the Kr curves (CMG 2011).

- Approximate ranges of variables may be useful for history matching and optimisation assessments.

Methodology

Table 1. Reservoir parameters "Base-Case"

Length (30grids)	1020m	Coal density	1400 kg/m^3
Width (30grids)	1020m	Coal compressibility	1.45E-07 (1/kPa)
Thickness (10grids)	2.8 m	Reservoir pressure	4000 kPa
Reservoir depth	400 m	Reservoir Temperature	30 ºC
φ (Matrix)	0.1	CH4 mole fraction	1
φ (Fracture)	0.005	Langmuir volume constant	20.8 m^3/t
Kh	7.8 (mD)	Langmuir pressure constant	1178 kPa
Kv	2.32 (mD)	Coal diffusion coefficient	2×10^{-8} (cm^2/s)
Cleat spacing	0.008m	Initial gas content (m^3/t)	15.6
Poisson Ratio	0.35	Equil.Pres.@ gas content	3578 kPa
Skin	0	Young's modulus	2000 MPa
Min BHP	200 kPa g	Strain at infinite pressure	0.0088
Max water prod	200 m^3/d	Palmar Mansoori exponent	3

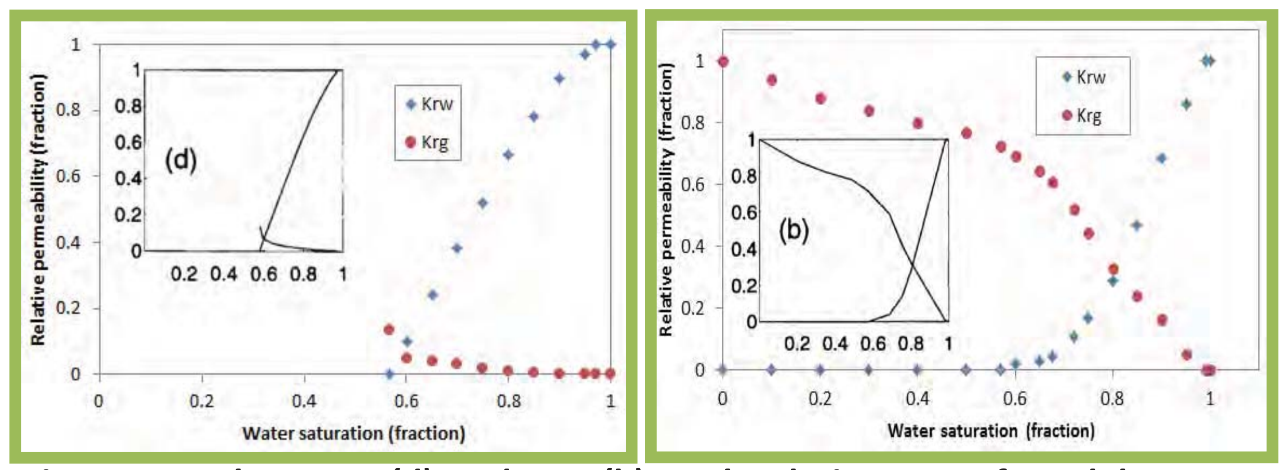

*Figure. 1. Laboratory (d) and HM (b) Coal Relative Perm from laboratory; Well DR4, GC coal seam, Bowen basin (*Meaney and Paterson 1996*)*

Simulation Strategy

- Fig 4 first column uses the lab rel perm curves along with the properties in Table 2, giving 45 solutions. None fit well.
- Fig 4 mid column uses set reservoir values (Table 2) and varies relative permeability, giving 16 solutions. Fits are barely acceptable
- Fig 4 last column allows both properties and rel perm curves to vary. A good fit is obtained.

Table 2. Reservoir parameters "Base-Case"

Property	Mean	Maximum	Minimum
Kh	7.8 mD	13	4.7
Kv	2.32 mD	4.32	1.25
ϕf	0.005	0.01	0.001
Fracture spacing	0.008m	0.012	0.004
Poisson Ratio	0.35	0.39	0.30
Young's modulus	2000 MPa	2050	1950
Strain	0.0088	0.0098	0.0078

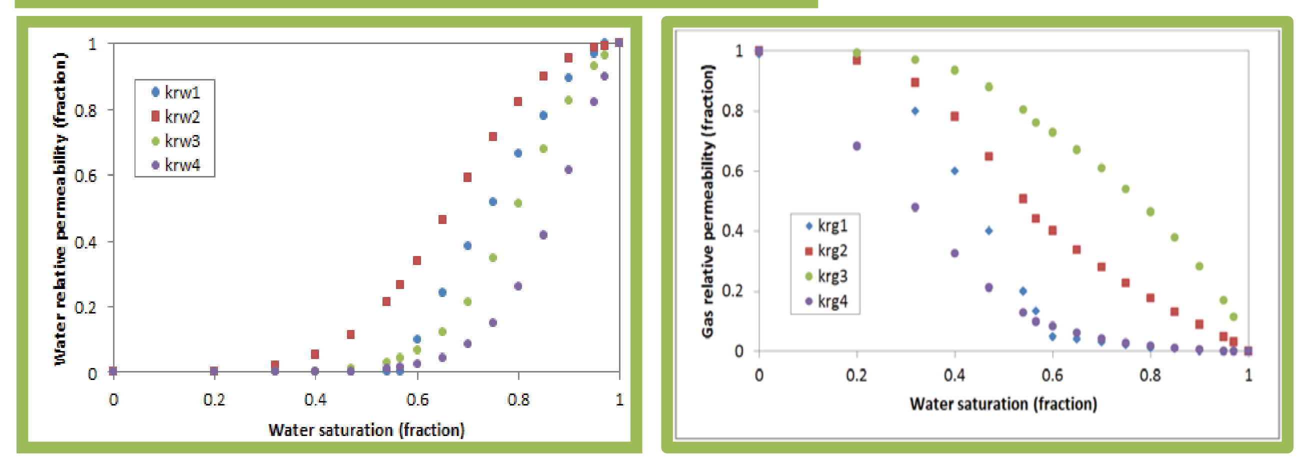

Figure. 3. various gas and water relative permeability curves

Initial Outcomes

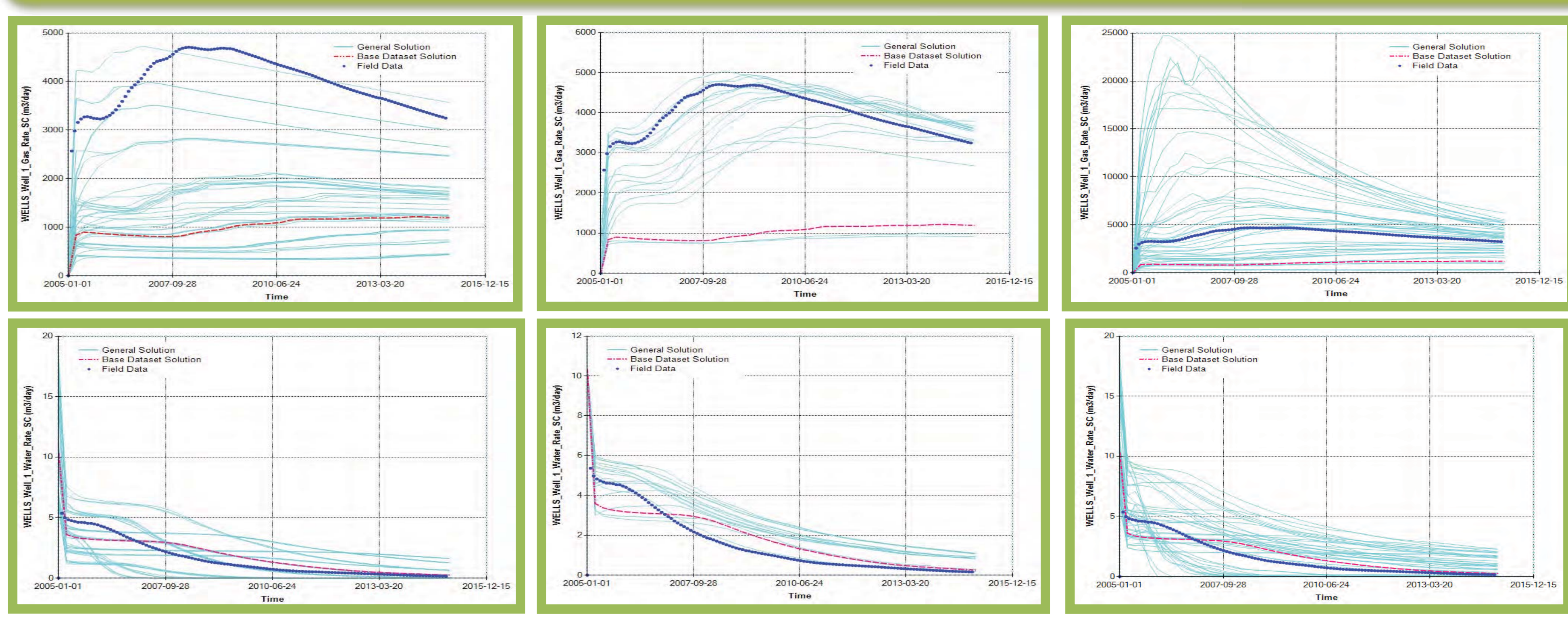

Figure. 4. Simulation of the case scenarios

- Relative permeability is a key determinant of gas and water production.
- Laboratory relative perms for coal, as currently measured, cannot be used to fit field production.
- Adjusting relative perm to obtain history matches makes reservoir modelling an elaborate curve fitting exercise, without an independently verifiable basis.
- Current rel perm measurement or prediction tools are severely deficient.

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