Coalbed methane potential in the Waikato Coalfield of New Zealand:
A comparison with developed basins in the United States

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Abstract

Coalbed methane (CBM) has become a significant energy source in the United States. CBM wells have been drilled in many basins in the U.S., and five basins have substantial CBM development. In this paper we compare key success factors for CBM development in basins in the US with historical and new data from the Waikato coalfields. Four of the most successful and active coal seam gas areas in the US exhibit a variable mix of thickness, depth, permeability, and gas content. We compare key indicators of success with publicly and newly available test data from the Waikato coalfield. Over 7000 bores in the Waikato Coal Measures give a high degree of control over some key success factors. Available data also provides direction for developing the most prospective areas of the Waikato. This paper identifies new coal desorption test data from drilling activity in 2003, adsorption curves and other data indicating that the Waikato coalfields may contain up to 750 PJ of new gas reserves. Development of this resource will depend on determining the right combination of drilling and production technology coupled with sufficient gas market demand that will allow producers to move from testing to full scale production.

Introduction

Production of coal bed methane during 2000 has risen to 7% of the entire domestic gas production in the USA according to US Energy Information Administration data and represents 9% of proved US dry-gas reserves. Methane production from coal beds in the San Juan, Powder River, Raton and Uintah basins has grown rapidly since 1980. Development has been spurred by a combination of gas price, tax incentives, technical understanding and new production methodologies that have combined to make this resource one of the fastest growing segments of domestic production and reserve additions. Much of the data required to move the Waikato coalfields from rank wildcat through a multi-well pilot stage is available as a result of the extensive work completed by the government in assessing the coal resource in the region during the 1970's and 80's.

In order to take advantage of this publically available data it is important to understand some basic concepts of methane storage in coal. Gas is stored in coal beds in three forms; as free gas in pore spaces and fractures, as gas dissolved in water, and as gas adsorbed to the surfaces of organic components. (Mavor and Nelson, 1997) Gas directly adsorbed onto coal provides the greatest storage volume of all three mechanisms. Adsorbed gas adheres to coal at the molecular level and is liberated only by through a reduction in reservoir pressure. This adsorption is adequately described by the Langmiur isotherm (McClennan et. al., 1995). Since most coal deposits are water saturated they require reduction of hydraulic pressure in order to liberate the gas. The high degree of faulting in the Waikato coalfields may reduce the potential for lateral recharge and speed the pilot production test phase. Successful application of techniques developed in other basins suggest that the use of multiple well production pods utilizing either five spot or twelve spot patterns will provide the best test for commercial viability of the Waikato coalfields and provide a much needed supply of gas to augment the rapidly declining availability of methane from other sources.

Base requirements

Based on our experience in U.S. CBM development as well as knowledged gleaned from published papers, the minimum base requirements for economically viable production from accumulations of CBM are (1) the coal must be buried as least 60 metres; (2) the coal must be sealed to trap the gas; (3) the coal must be sufficiently permeable; (4) gas content must be sufficient; and (5) coals must be sufficiently thick. Burial to a minimum depth is required for thermal maturation of the coal and to establish hydrostatic pressures sufficient

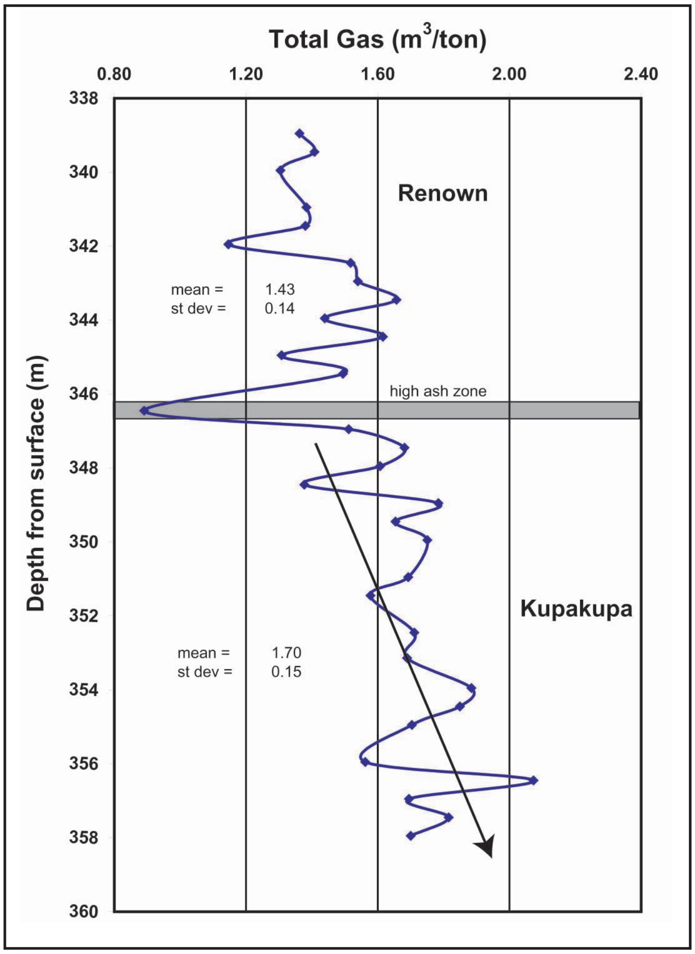

Figure 1: Total gas from TW1 drill hole.

to adsorb methane onto coals. The coal must be sealed to allow pressurization of the coals to promote adsorption and to prevent methane from escaping as it is produced. The coal must be sufficiently permeable to allow both dewatering and corresponding pressure reduction to liberate adsorbed gas to facilitate production. The combination of permeability, gas content in the coal, and coal thickness must be sufficient to allow both the accumulation of commercial quantities of gas and the production of that gas at commercially viable rates (Nuccio, 2000; Hill et. al., 2000).

Coals at suitable depth and sufficient thickness to provide commercial accumulations have been clearly identified in the Waikato coalfields from the Coal Resources Survey. Published work has established that the coal is present at significant thickness ‑below 500 m. (Edbrooke, 1987; Edbrooke et al., 1994). The coal resources assessment was directed at establishing the resource base of coal that can be mined with current technology. Drill hole data deeper than about 500 m is scarce as the mining limit was and still is thought to be about 450 m. This lack of control on deeper resources could present an upside in methane resource estimates for the Waikato coalfield. We have examined most of the drilling records and lithologic logs for the 7,000 wells in the Waikato coalfield to confirm coal thickness, overburden depths, and coal ranks described in Edbrooke et al. (1994).

The Waikato Coal Measures are sealed by the overlying fine grained transgressive marine sequence of the upper Te Kuiti Group (King, et. al. 1999). In particular, the tidal flat mudstones of the Glen Afton Claystone of the Mangakotuku Formation provide an impermeable seal for the coals. Lateral seals are created by pinchouts of the coal seams and numerous high angle normal faults that cross the Waikato Basin (Edbrooke et al., 1994; Sherwood et al., 1977). The Waikato region is one of the least seismically active areas in modern New Zealand, and shows little evidence of recent syntectonic sedimentation (Walcott, 1984). The lack of recent seismicity in the region reduces the chance that recent faulting has breached previously sealed coals. Finally, gas in the Huntly coal mines and reports of free gas to surface during drilling activities provides prima facie evidence for effective seals to the Waikato coals (Paul Frandi, personal communication; Fowke, 1987; Roger Gregg, personal communication).

Data on the gas content in coals in the Waikato coalfield is sparse. Reports of methane in the Huntly district coal mines, mine methane explosions, and the free gas encountered while drilling cited above all provide qualitative evidence for gas in the coals. There have been 4 papers qualitatively documenting gas in the coals (Crosdale, 1998; Beamish and Vance, 1990; 2 undergraduate student studies at the University of Auckland, no longer available).

The data cited above indicate the basic conditions for commercially viable CBM production are present in the Waikato coalfield. Qualitative indicators have been met in the Waikato and by definition in the successful producing basins in the following tables. The benefit of multiple well pilots to induce interference became apparent in 1990 (Seidle, 2000) during testing of pilot pods of five closely spaced wells in the San Juan Basin. Anadarko reports that (Miller, 2000) extensive review of five well and 12 or 16 well pods in the Uintah Basin (Helper Field) favors designs that include a higher number of internal wells which allow for faster pressure reduction.

Huntly Coalfield gas properties

In-ground gas resources cannot be estimated without some exploration drilling to establish gas contents and saturation. In conjunction with a seismic tie well programme conducted by Solid Energy, a complete coal core for desorption was taken in mid 2003. The coal core comprised both the Renown as well as the Kupakupa coal seams separated by a 20 cm high-ash zone. Total coal thickness was approximately 20 m. Gas contents in the coal ranged from about 1.15 m^3/tonne to a maximum of 2.07 m^3/tonne. The Kupakupa coal in general had higher gas contents and there was an observed increase in gas with depth (Fig. 1).

The adsorption isotherm for the core (Fig. 2) indicates that at this depth the reservoir is about 45% saturated with gas. Coal beds of subbituminous B in rank and lower are often undersaturated (Stricker and Flores, 2002). At depths less than 400 m it is possible that there is not enough pressure to maintain full saturation, however reports of gas bubbling to surface during coring operations in the Ohinewai area at depths of 100 m seem to indicate that saturated conditions are possible at shallow depths. Gas in the Waikato coalfields is probably a mixture of biogenically and thermogenically derived gas. Isotopic analysis of the gas is needed to determine the relative importance of each fraction. In the immediate area of the TW1 core the slope of the total gas vs. depth line indicates that with even modest increases in depths full saturation of the reservoir is likely to exist.

Although the amount of new data collected so far is small, the results are encouraging, especially when compared with other major coalbed methane basins.

Comparison of key indicators in select US Basins with available data from the Waikato Coalfields

Thickness

The thickness and number of seams in the Waikato coalfields compare favorably with other economic coalbed methane plays. Coals between 2 and 30 meters with one to three seams in the Huntly and Ohinewai sectors of the Waikato Coalfield compares favorably to economic basins in the United States (Table 1) that have large areas with a total coal thickness of between 4 and 43 meters and up to 11 individual seams. Most operators would agree that maximizing the number of meters of total coal and minimizing the absolute number of individual seams decreases cost and complexity in developing economic projects. As a result of the technical complexity of multi-seam completions many wells are produced from one horizon while preserving additional seams for later in the life of the well bore.

Gas content

Gas content is typically measured in units of gas per unit of coal. This measure disguises the importance of units of gas that can be effectively drained by a given well bore. Basins such as the Powder River with relatively low gas content can produce economic quantities of gas because of greater overall seam thickness and high permeability. Conversely, basins such as the Uintah with modest coal thickness overcome that measure through higher gas content per unit of coal. The overall thickness of portions of the Waikato coalfields combined with gas content measurements from initial desorbtion and adsorption results indicate that the Waikato has the potential to access gas at rates per well that compare favorably with some of the most active and economic basins of the US (Table 1).

Permeability

Permeability is a significant factor in determining commercial viability of CBM projects. Basins can have very high gas contents and sufficient coal thickness to contain vast gas reserves in place, but because of low permeability the gas is uneconomic to produce at current levels of completion technology. The Piceance Basin of western Colorado is an example of such a basin . Conversely, basins with very low gas content can be commercially viable if the coal thickness is sufficient to contain large quantities of gas and the coal permeability is high (Hill et. al., 2000; Nelson, 2000). Permeability to some extent exists in all coals and can be improved by artificial stimulation such as hydraulic fracturing.

Permeability is a measure of a coal, acting as a storage vessel or reservoir, to transmit fluids such as water or gas. Since conventional vertical wells drain an ever larger circle of gas over time, measurements of permeability are one way to gauge the ability of a given well bore to drain gas. The success of horizontal wells drilled in low permeability coals using complex patterns show significant drainage occurring inside of 12 months and illustrates the importance of improved communication from the well bore to the far-field reservoir. This type of horizontal drainage holes have been used to degas coals in advance of mining activity. Gas is liberated more quickly and migrates along the path of least resistance.

Table 1: Key basin factors from the USA compared with the Waikato coalfield

	San Juan [1]	Raton[1]	Powder River[1]	Uintah[2]	Waikato
Pilot name	Cedar Hill	Spanish Peak	Rawhide Butte		
Field name				Drunkards Wash	
Coal seams	Fruitland	Vermejo	Wyodak	Ferron	Renown, Kupakupa, Te Kuiti
Coal age	L. Cretaceous	L. Cretaceous	Palaocene	Cretaceous	Eocene
Coal rank	high-vol A bit	med & low-vol bit	subbituminous	high-vol B bit[4]	subbituminous
Number of wells	3	4	13	498	
Well spacing, acres	320	103	20 to 40	160	
Number of coal seams	1	5 to 11	1	4	1 to 3
Depth, meters	854[3]	450	122	785	60 to 550+
Net coal thickness, meters	6.1	4.6 to 10.1	42.7	6.1	2 to 30
Gas content, cc/g	13.6[5]	11.1	0.7	11.4	1.15 to 2.07
Langmuir volume (VL) cc/g	24.76	39.82	2.34		12.46
Langmuir pressure, Mpa	4.18	8.28	2.47		4.1
Reservoir pressure, Mpa	10.34	3.03	1.03	6.89	-
Permeability, md	25	25	100	15 est	1 to 40
Porosity, %	1	1?	10	na	
Production time, months	4	36	24		
Response time, months	2.6	24	na		

[1]Seidle, 2000 with data compiled from various sources; [2]Lamarre et al., 2003; [3]Ambrose and Ayers, 1991; [4]Miller, 2003; [5]GRI, 1999

In some respects, high permeability streaks and hydraulic fracturing are both systems that mimic transport freeways. Fracture systems can act to reduce far-field pressures, allowing desorption to begin, free gas to migrate and water to be removed from the system.

Limited slug test data gathered by RDT in conjunction with Solid Energy using a modification of the method described by Koenig (1987) reveal that coals in the area tested have zones of high permeability, usually associated with fractures and significant sections of low permeability associated with the low bulk permeability of the coal matrix. Visual inspection reveals intervals in both the Kupakupa and Renown with significant fracturing while other areas appear not to have the advantage of fracturing to aid in draining gas. High permeability associated with fractures in the coal may permit the production of economic quantities of gas without requiring the use of artificial stimulation or horizontal well bores.

Rank

Economic basins have been developed with coals and mudstones throughout the full spectrum of rank from high volatile bituminous to sub-bitimunious coals. Even lignite has been shown to have associated methane, though their storage capacity tends to be low. Coal rank in the Waikato coalfields is in the middle of the range of the basins reviewed for this paper.

Vitrinite reflectance

Vitrinite reflectance is a measure of thermal maturity in coal. Coals exhibiting vitrinite reflectance (% Ro) below 0.60% (Nuncio et al., 2000) primarily generate methane biogenically, where thermogenic methane generation predominates in coals with Ro greater than 0.60%. Table 1 illustrates that coals over a wide range of % Ro are capable of being developed into economic coalbed methane plays. Numerous samples and various reports show that the Waikato coals range in Ro from 0.34 to 0.53%. It should be noted that vitrinite reflectance is more predictive of the type of gas generation mechanism, than the ability of the coal to either generate or store gas in commercial quantities.

Economics

The impact of economics on the viability, timing and pace of development cannot be ignored as it has played a central role in the development of drilling and completion technology, field development and ultimate success in all production areas. Gas production from the Phillips 3-18 (Fruitland Coal) as early as 1953 (Seidle 2000) and later pilot work in 1990 was clearly necessary to prove the technical merits of coal seam gas production. Gas prices in the early 1990's resided in a range from below $1.00 US to as high as $2.25 US (as reported in the gas price tracking publication INSIDE FERC) with annual average prices in 1991 of $1.26 and $1.65 in 1992. Tax incentives in the form of the Section 29 tax credit increased the potential economic value of gas produced from wells by an approximately 50%. This incentive coupled with modestly increasing gas prices boosted economic performance in the San Juan Basin into a range that caught the attention of the producer community and have driven the basin to be the largest commercial coal seam gas producer in the world. It is interesting to note that once the Section 29 tax credit expired in 1993 the annual rate of CBM drilling fell dramatically from an annual rate of 500 per year to a low of 100 before rebounding again as the absolute value of gas, along with improved understanding of the mechanics of CSG production once again drove producers to drill additional wells (Hill et al., 2000). The timing of large scale development of the Raton Basin was hampered for a period due to lack of pipeline take away capacity, effectively causing economic shut-in. Similarly, large areas of the Powder River Basin remain undeveloped as regulatory processes required for permitting and drilling wells on Federal lands were (and are) reviewed and completed.

Natural gas prices in New Zealand have been largely set under long term contracts at levels well below thresholds required to interest producers seeking additional deliverability and reserves. Recent reviews of available gas supplies have changed the perception that gas was readily available and caused prices to rise and reportedly shortening the supply terms offered by vendors. Actions by Methanex, as reported in the popular press, to write off their remaining investment in NZ is just one serious indication of the severity of the gas supply problem.

Development of coal seam gas in the Waikato Basin will undoubtedly follow a similar pattern of technical feasibility being established in a series of steps followed by pilot programs and commercial development when price supports that activity. Success in developing this resource will depend on careful evaluation of the technical merits of the basin, but also the economic factors required to bring production on line in a commercially reasonable manner.

In short, the gas must be there, we as an industry must be able to coax it out of the ground, and the market must need the gas enough to make it profitable to develop the resource.

Summary

We have presented data establishing that the conditions for commercially viable coalbed methane development are all present in the Waikato coalfields. The primary attributes necessary for CBM development, coal thickness, depth, gas content, and permeability all compare favorably with established developed CBM plays in the United States. Specifically,

- Historic and new data indicates methane present in Waikato coal seams
- New data shows these levels to be commercially viable
- Permeability is within the range of other economic CBM plays
- Flows from individual wells need to be established through a pilot well programme, but early indications from the data are favorable.
- Using Langmuir volume (Fig. 2) and coal reserves estimates, an upper limit of 750 PJ of gas in place is possible.

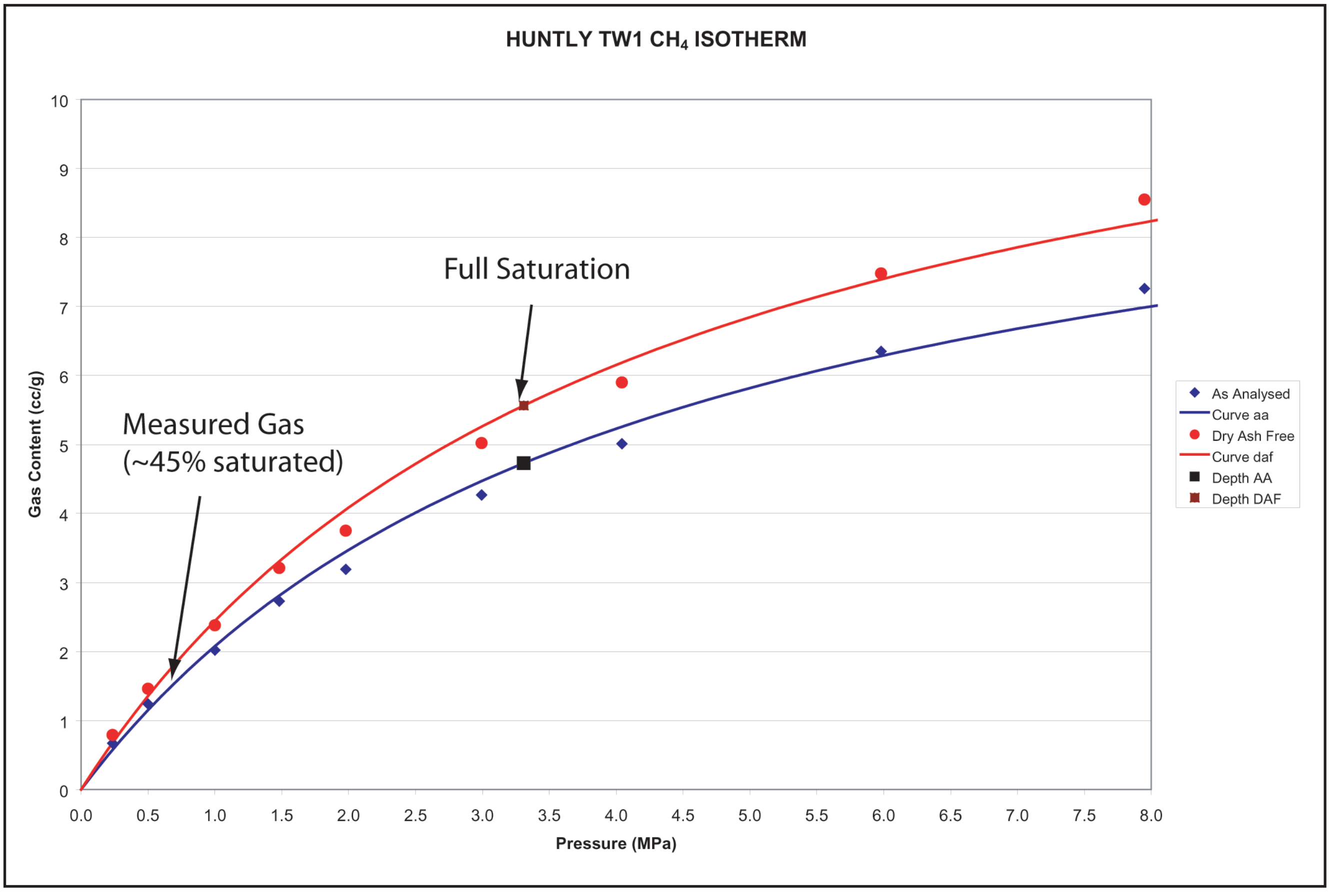

Figure 2: Adsorption isotherm data forTW1 drill hole showing gas content at full saturation and the measured value.

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