NATURAL GAS FROM COAL, SOUTHGAS INVESTIGATIONS AT OHAI, NEW ZEALAND

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Methane is a natural inherent product of the coalification process along with carbon dioxide, nitrogen and water. Methane is generated in two phases; firstly, during early coalification through the decomposition of organic material and secondly, at higher temperatures during catagenic alteration of organic material. Analysis of gas from coal seams show that on average, these gases comprise in excess of 95% methane with traces of ethane and propane. Carbon dioxide and nitrogen generally comprise less than 3% of the gas mixture. Methane-rich gas from coal seams typically has a heating value of around 1000btu/scf.

New Zealand coalbed methane studies have concentrated on the Ohai Coalfield as a result of Southgas Resources Ltd investigations on the economic potential of the coalfield. The Ohai study has shown that the distribution and quantities of methane are similar to areas investigated overseas. Actual gas quantities, while not exceptionally high overall, are relatively high for coals of sub bituminous A to high volatile bituminous C rank. Although the cause of this has not been positively identified, the perhydrous nature of New Zealand Cretaceous Tertiary coals may be responsible at least in part. Other likely factors are the generally low ash content of the coal and the degree of cleating.

Geological investigations at Ohai have identified a coal resource of between 100 and 300 million tonnes of coal at a depth (between 350 and 450 m) and quality suitable for methane extraction. Production modelling of this deposit has been carried out using all known factors of relevance (overall coal quality, coal seam thickness, seam continuity, seam depth, gas content in cc/gm, etc), and solving for a range of permeability (K=0.1, 1.0 and 10). Single well production rates and cumulative production over a ten year well life were modelled for centre, and first and second offset wells in a five well pattern. The investigations show that at the average permeability expected at Ohai (K=1 to 3), coalbed gas production from Ohai could be economically viable. Distance to markets and the size of markets is identified as having a stronger influence on the economics of natural gas production from Ohai coalfield than exploration and production costs.

INTRODUCTION

The Southgas Coalbed methane project was established in 1984 to investigate the feasibility of extracting and marketing methane from coal seams in the Ohai Coalfield, Southland. Preliminary studies by consultants employed by Southgas at that time indicated the potential for 2 mmcfd of methane at 98-99% purity based on the (then) published coal reserves of 50 million tonnes. The same study identified a larger resource in the Greymouth Coalfield on the West Coast of the South Island, however, the Southland location was selected for initial development because a potential market already existed.

Since 1984, Southgas has drilled three slimline coal and gas evaluation wells, and put down two test production Virgin Coal Demethanation (VCD) wells. In addition, two test mine goaf (old mine workings) production wells were completed. Southgas hopes to complete up to five test production wells in the Ohai field over the next year followed by more extensive full production. Production from the initial test production programme is conservatively estimated at 250 000 scfd, while the full programme is initially targeted to cater for existing identified markets at a production rate 2 to 2.5 mmcfd. These figures are low in conventional oil field terms. It must be remembered, however, that the per well completion costs are relatively low (ca. $250 000). In addition, production projects are more geared to existing potential markets and do not reflect the maximum annual production potential of the field.

Methane from coal seams

The process of progressively transforming plant material through peat, lignite, bituminous coal to anthracite is known as coalification. As coalification continues, physical and chemical changes occur which are analogous to the increasing level of maturity recognised in kerogen-bearing petroleum source rocks of marine origin. Observations of these changes in maturity can be utilised in the same way as kerogen-bearing rocks to evaluate the methane potential of a coal sequence. The most useful indicators of maturity changes in coals are its calorific value, moisture content, volatile matter content, vitrinite reflectance, and fixed carbon content. All of these properties of coals are altered appreciably by the increased temperatures brought about by increased depth of burial. These coal properties are also affected by differences in coal type, that is, the composition of a coal reflects the composition of the original vegetation, the peat forming environment and probably the climate. Consequently, the precise determination of coal rank is difficult and can only approximate the thermal history of a coal.

Major products of the coalification process are methane (CH_4), carbon dioxide (CO_2) nitrogen (N_2) and water (H_2O). Methane is generated by two mechanisms during coalification (biogenic and thermogenic methane). During the early stages of coalification (≤50°C) methane is formed by the biogenic decomposition of organic material (marsh gas). As temperatures rise above 50°C, thermogenic methane generated by catagenic alteration of organic material occurs. Analysis of gas produced from coalbeds shows that, generally, these gases contain in excess of 95% methane with trace amounts of higher gases (for example, ethane and propane) and less than 3% each of nitrogen and carbon dioxide. Coalbed methane has a heating value of around 1000 Btu/scf at 95% purity.

Although actual figures vary considerably, the methane content of a coal is largely dependent on coal rank, with other features of the coal acting to either constrain or enhance the gas content over and above the base level. Generally, methane content increases as rank becomes higher and there is a corresponding increase in the proportion of higher hydrocarbons. This reflects rank-dependent chemical changes but also reflects rank related physical changes, in particular, the reduction in grain size and hence increased porosity with increased rank. These physical changes control the adsorptive capacity and thus the gas retentive capacity of the coal.

Methane is retained in coals in one of three states; as adsorbed molecules on the organic surfaces, as free gas within the pores or fractures, and dissolved in ground water associated with the seam. The main factors involved in methane content and retention other than rank are coal type (vitrinite and exinite rich coals yield more gas than inertinite rich coals), cleat development (increased permeability), and ash levels (muddier coals will have lower gas yields due to reduced porosity).

The United States experience

The presence of methane in coal seams has been known since miners first went underground to mine coal. The study of coalbed methane was initiated in the United States of America as well as in some European countries (in particular Hungary) with the intent of reducing the hazard to miners and improving mine safety. As such most early US research into demethanation was carried out in relatively shallow mineable coalbeds.

Early studies in the US were carried out by the Pittsburg Mining and Safety Research Centre of the US Bureau of Mines, and focussed on the mechanisms of gas retention and release, gas flows through coalbeds, mine ventilation, and degasification both in advance of and during mining. The emphasis in these studies was on shallow (less than 2500 ft deep) coalbeds economically mineable with existing technology. Many of the techniques now employed on a routine basis during VCD work were developed during this programme.

Following the oil crisis of the early 1970s, this hazard to mining was recognised as a potential energy resource. The US Department of Energy established the Unconventional Gas Recovery Program to address the evaluation and potential production of methane from coalbed reservoirs. The Methane Recovery from Coalbeds Project was set up to identify the magnitude and distribution of the US coalbed methane resource, prove its productivity, and generate private sector interest in its production and utilisation.

Thirteen major US coal basins were analysed for methane potential between 1979 and 1982 and the results stimulated significant interest from the oil and gas industry. Commercial gas production is now occurring in several of these basins, in particular, the Warrior, San Juan and Piceance Basins. Good summaries of the United States experience with VCD technology can be seen in the topical reports to the Gas Research Institute (c.f. Kelso et al., 1988) and in the proceedings of the recent Coalbed Methane Symposium's (c.f. University of Alabama 1989 Proceedings of the Coalbed Methane Symposium, April 1989).

Coalbed methane in New Zealand

While methane from coal seams is a well known hazard in New Zealand coal mines, little work had been carried out to investigate the economic extraction of methane from coals prior to the Southgas project. Greymouth and Ohai Coalfields (Fig. 1) have been identified as having the best potential for methane extraction. Greymouth satisfies most geological criteria but is too far from potential markets to consider a viable proposition at the time of writing. Aratika Coalfield, situated just north of Lake Brunner, contains coal of the same rank as at Ohai and may be equally prospective, although the methane potential of the coalfield has not been investigated. The overall level of knowledge of Aratika Coalfield is low in comparison to the other coalfields.

Coals from Ohai Coalfield are of relatively low rank compared to the coals in the United States where most coalbed methane investigations have been carried out. Several factors suggest, however, that overseas criteria may not

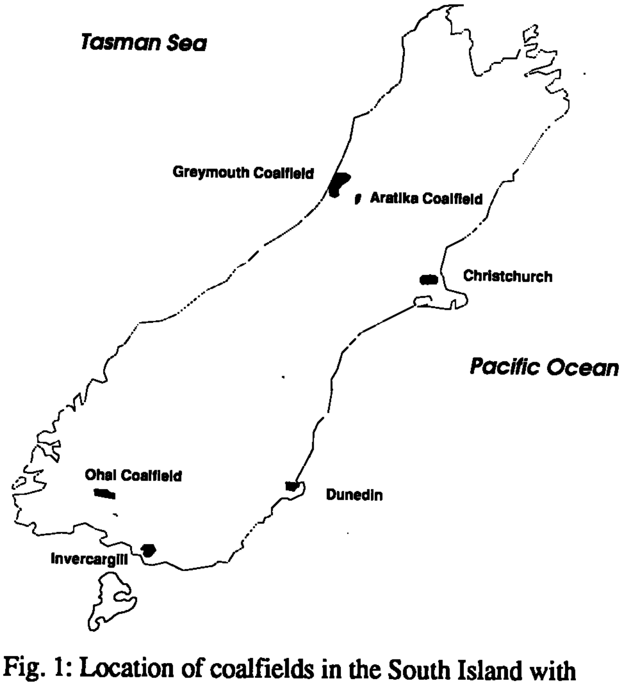

Fig. 1: Location of coalfields in the South Island with methane drainage potential.

apply well in New Zealand. Firstly, the coals are rich in hydrogen (perhydrous) compared with United States coal. Secondly, shallow gas had already been encountered in coalfield drilling. Thirdly, high methane flows were experienced in Morley Mine necessitating special control and suggesting that methane drainage could benefit local coal mining operations.

OHAI COALFIELD

Location

The Ohai Coalfield is located 77 km northwest of the City of Invercargill (Fig. 2) and covers approximately 100 km^2; the townships of Ohai and Nightcaps lie within the coalfield. The coalfield occupies a broad elongate west-northwest trending depression between the Takitimu Ranges in the north and the Twinlaw Range to the south. The topography of the area is characterised by dissected terraces and low undulating hills. Small meandering streams occupy the valley floors.

The district is sparsely populated (Ohai 676 people and Nightcaps 460 people) and the two towns exist to serve the local mining operations and to a lesser extent the surrounding farms. A decline in the mining industry over the last 20 years has resulted in a significant decline in population. The major population centre in the region is Invercargill which has a population of 49 000. Main service centres for the coalfield are the towns of Winton and Otautau. Bluff, situated 30 km south of Invercargill, is a deep water port and is linked to Ohai by rail. The Tiwai Point Aluminium Smelter is the only industrial complex of significant size in the region. Mining at Ohai Coalfield began near Nightcaps in 1879 reaching a peak production of 100 000 tonnes in 1916. Subsequent production has been concentrated on the Ohai area and a peak of 320 000 tonnes were produced in the early 1960s with production declining slowly since.

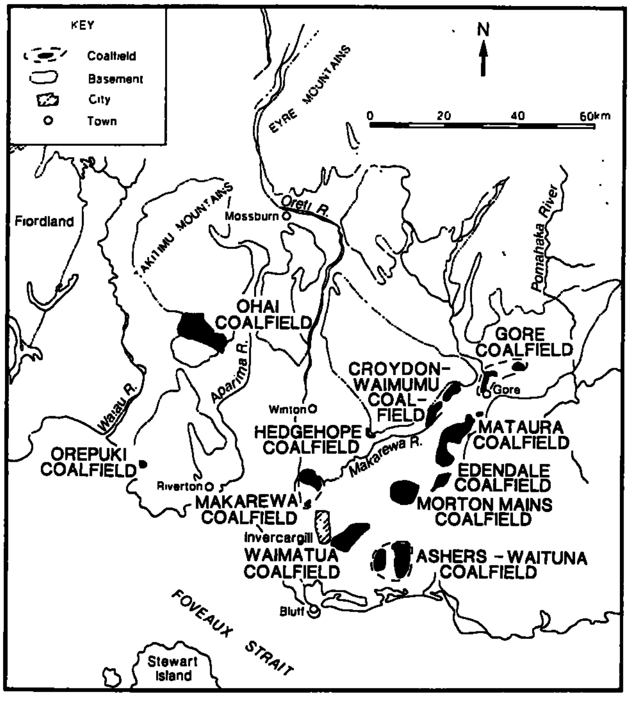

Fig. 2: Location of Ohai Coalfield.

Exploration

A major phase of coalfield exploration was initiated by State Coal Mines in 1983 but was terminated when State Coal Mines was corporatised in 1987. The New Zealand Coal Resources Survey (Mines Division) carried out gravity and seismic surveys from 1983 and initiated a major survey of the eastern half of the coalfield in 1985, culminating with the production of a major exploration report in 1987 (Bowman, Brodie and Garlick, 1987). Methane gas evaluations were initiated in 1983 by State Coal Mines and in the following year by Southgas.

Geological setting

Ohai Coalfield occupies a northwest-southeast oriented fault controlled depression situated between the Takitimu Range to the north and the Twinlaw Range to the south. The coalfield contains up to perhaps 2000 m of Upper Cretaceous and Tertiary sediments unconformably overlying Lower Permian and Mesozoic Basement. The coal measure sequence of Upper Cretaceous to Eocene age ranges in thickness from 0 to 500+ m and is at the base of a thick marine sequence. The coal measure sequence outcrops around the north eastern margin of the basin but is buried beneath increasing thicknesses of Mid to Upper Tertiary sediments to the south and southwest.

Thick coal deposits are confined to the sandstone and coal dominated Morley Coal Measures, the uppermost formation in the Cretaceous Ohai Group. The formation is characterised by rapid facies and thickness changes. The formation reaches around 200 m in thickness. The Morley Coal Measures are underlain by up to 160 m of New Brighton Conglomerate which are in turn underlain by up to 50 m of Wairio Formation coal measures and conglomerate/breccia. Thin but gassy coal seams have been intersected in the upper Dail Member of the Wairio Formation (Cave, in press). This Cretaceous coal measure section is the approximate genetic correlative of the Paparoa and Pakawau Groups of Nelson-Westland.

The Ohai Group is unconformably overlain by the Nightcaps Group of Eocene age. Sub economic coal deposits occur within the mud dominated Beaumont Coal Measures, the lowest formation in the Nightcaps Group. The formation reaches 120 m in the Ohai Coalfield but thicker correlatives occur in the Waiau Basin to the west. The Beaumont Coal Measures are overlain by the Orauea Mudstone, a 450+ m thick homogeneous mudstone sequence. Correlatives of the Orauea Mudstone occur widely in the Waiau Basin and also the Winton Basin to the east. The Orauea Mudstone is overlain by a thick pile of middle and upper Tertiary marine mudstones and limestones to the south and west.

Formation thicknesses and structural trends indicate that the Cretaceous-Eocene sequence occupies a number of distinct sedimentary basins (Ohai, Mossbank and Nightcaps Basins) separated by basement highs (Bluebottle and Moretown Highs). This strata also obscures much of a basement high which defined the western limit to the Ohai depositional basin in Cretaceous time. Thin scattered remnants of Cretaceous coal measure sediments in the Productus Creek area indicate that the coalfield was originally more extensive towards the north.

The coalfield is not complexly deformed in comparison with the Greymouth Coalfield, but geologic structure is still a significant constraint to mining. East-west to northeast-southwest oriented normal faults and a second set of northwest-southeast oriented normal faults dominate the structure, and postdate a phase of folding in the early Tertiary which gave rise to the Ohai Anticline and other folds. Cleat development, important for methane retention, is strongly controlled by structure. Gravity and field studies suggest that the Twinlaw fault which forms the southern boundary of the coalfield is a major recent thrust.

Coal resources

The Ohai Coalfield is subdivided into a number of exploration sectors. Some of these (Wairaki, Screens, South Screens, Swampy Creek and Three West) lie within the area being mined Coal Corporation. Five additional sectors were defined during Coal Resources Survey exploration (Nightcaps, Gorge Creek, Wairio, Mossbank and Moretown), but only one of these (Moretown) contains significant deep coal. One further sector (Orauea) has since been defined. The Coalfield contains a significant coal resource ranging in rank from sub bituminous C at Nightcaps to bituminous C in the Moretown and Orauea sectors. Much of the area currently mined by Coal Corp is of sub bituminous A rank.

In-ground coal resources for the Ohai coalfield are 5.06 million tonnes (measured), 124.42 million tonnes (indicated), 50.38 million tonnes (inferred), and 100-300 million tonnes (hypothetical). These measured, indicated and inferred resource figures assume several cut-off criteria which essentially mean that seams of 1m or less are not regarded (Anckorn et al., 1986). These cut-offs are important with respect to mining but do not apply for methane drainage which can regard the entire seam as the resource. It is assumed here that only the Moretown and Orauea sectors are available for methane drainage since coal located in other sectors is either too shallow to be considered a methane resource or is too close to current mine workings and has suffered varying degrees of loss due to drainage through mine workings. The Moretown sector contains 88.84 million tonnes of indicated coal (with cut-offs applied) but contains between 97 and 106 million tonnes of coal when considering the total resource (Table 1). A total of 197 (97+100) to 406 (106+300) million tonnes of coal may thus be available in the Moretown and Orauea sectors for methane drainage.

Methane

Methane has long been recognised to be a special problem in the Ohai Coalfield (c.f. Bowen, 1964) but became especially evident when mine development in the SW Dip section of Morley Mine was constrained by high gas flows from the southern part of the section. It appears that the methane was derived from a fault structure situated immediately to the south of the developed workings. Gas flows were also a problem in coal exploration drilling carried out by State Coal Mines and later by the New Zealand Coal Resources Survey with very high gas flows occurring in several wells (e.g. 330, 341, 343, 371). More minor gas flows were noted routinely from many drillholes put down in the area. Significant quantities of untested traces of condensate were found in porous sandstone cores from the roof of the No. 2 seam in DH's 341 and 343.

Sector	Measured	Indicated	Inferred	Hypothetical	Total
Swampy Creek	0.00	5.46	1.36	*	6.82
Screens	0.00	3.86	0.00	*	3.86
South Screens	0.00	6.69	11.48	*	18.17
Three West	1.55	15.64	21.14	*	38.33
Wairaki	3.51	3.93	0.81	*	8.25
Moretown	0.00	88.84	0.07	*	88.91
Wairio	0.00	0.00	0.30	*	0.30
Nightcaps	0.00	0.00	6.60	*	6.60
Mossbank	0.00	0.00	5.90	*	5.90
Morleyvale	0.00	0.00	2.72	*	2.72
Orauea	0.00	0.00	0.00	100 – 300	0.00
Ohai Coalfield	**5.06**	**124.42**	**50.38**	**100 – 300**	**179.86**

Table 1: Coal Resources of the Ohai Coalfield

Gas desorption testing was carried out on a routine basis by State Coal Mines and the New Zealand Coal Resources Survey. Gas values recorded range from a low of 1cc/gm up to a maximum of 6.32 cc/gm (Fig. 3). Low gas values were recorded at shallow depths and in instances where loss of gas to the surface via fault planes is possible. The gas values recorded from the Morley Formation in the Moretown Sector (ranging from 1.77cc/gm up to 6.32cc/gm) more clearly represent the true gas content of the coal. The low values here are clearly related to shallow depth poor quality coal samples and more typical clean, low ash coals gave significantly higher values. An important feature of the gas values indicated in Fig. 3 is the strong positive relationship between depth and gas content. A polynomial regression line fitted to the gas desorption data indicates that gas contents of 5cc/gm should be obtained from depths of 350 m or more. Extrapolation of the curve to a depth of 600 m indicates that gas yields of over 8cc/gm may be obtained.

Gas quality in the Ohai Coalfield is high with few contaminants. Methane represented 95 to 98% of the gas with lesser nitrogen and water, and traces of ethane and propane. A sample taken from a pipeline in the SW Dip of Morley Mine most closely represents the actual in-ground gas composition having only traces of gases other than methane. Samples taken by Nova Corp during the Southgas Phase 1 study have reduced purities as a result of contamination from air. The Nova samples were measured from gas desorption canisters that had been desorbing gas for around one month and mixing of the gases within the canister with the atmosphere had probably occurred.

SOUTHGAS EXPLORATION PROGRAMME

Coal and gas resources

The first phase of exploration involved the drilling of 3 slimline cored stratigraphic drillholes (SG-E1-84, SG-E2-84, and SG-E3-84) west and south of existing NZ State Coal

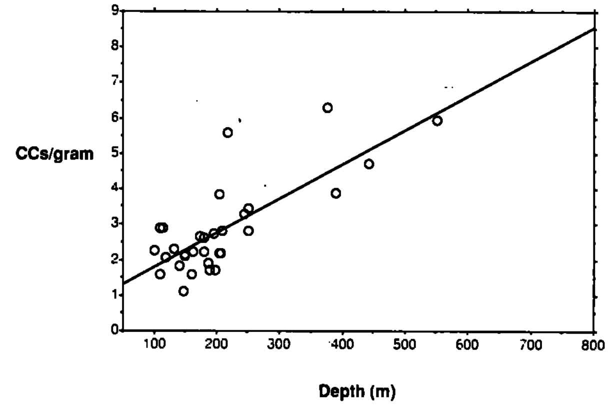

Fig. 3: The methane content of Ohai coals related to depth below surface (a regression curve has been fitted to extrapolate probable gas yield at greater depths.

Mines (now Coal Corp) mine workings. Drilling was carried out using conventional coalfield wireline drillrigs to the base of the Morley Formation. These drillholes intersected two main seams and numerous minor seams. Total coal thickness ranged from 41 m in E1 up to 48 m in E3.

Analysis of the methane content of the seams by the desorption method indicated gas quantities averaging 5cc per gram of coal in E1 and 2, and 3cc per gm in E3. These values are lower than the theoretical gas content of Ohai coals calculated by the *Kim method* at 8cc per gm. It was assumed that actual gas values measured were lower than the theoretical content because of loss of gas into adjacent mine workings and the transfer of free gas into surrounding permeable strata.

Coal resource evaluations based on the extrapolation from explored areas suggests that at least 100 million tonnes (Mt) of coal would be available for demethanation and that up to 500 Mt may possibly be present in unexplored areas. Using the theoretical methane content of 8cc/gm of coal, it was concluded that up to 2 million cubic feet per day over ten years could be available for production.

Initial test production programme

Following the initial resource evaluation programme, two virgin coal demethanation VCD test production wells (TP 1 and TP 2) were put down beyond E2 and E3 respectively to test the production potential of Ohai coals. TP1 was designed to test the gas production of a 44 m thick section of structurally unaffected coal while TP 2 was designed to test the production from a structurally disturbed area.

The TP1 well was completed to 436 m with a 215.9mm production hole drilled from 165 m to T.D. Pre-slotted casing on site was set at the bottom of the hole and backed off at 159 metres, with the slots targeted to locate adjacent to seams and other gas prone horizons. TP2 was completed to 460 m with the production casing set from 210 m to T.D.

Both TP1 and TP2 were subject to a limited permeability test by injecting water at a specific rate and measuring penetration of the formation; it was concluded that TP2 had a higher relative permeability than TP1. Objections from the local coal mines operator precluded the hydraulic fracturing of the wells although both wells were located well away from existing mining operations. Submersible pumps were installed in both wells to dewater the strata adjacent to the well.

Gas production

The maximum production for TP1 during the initial pumping phase was 603 m^3 per day (21 300 scfd) achieved 2.5 hours after pumping began. Production then gradually declined until it reached a rate of 181 m^3 per day on the 3rd day and continued to decline gradually for remainder of the month. The maximum production for TP2 was 306 m^3 per day (10 800 scfd) during the initial pumping phase and thereafter declined similarly to TP1 (Fig. 4). The poor gas production rates result from the prohibition on hydraulic stimulation of the wells. Experience with the Unconventional Gas Recovery programme in the United States suggests that production increases of the order of 10 to 100 times can be achieved by stimulating the production wells. Consequently a fraced well at Ohai is projected to produce from a minimum of around 20 000 to a maximum of 200 000 scfd.

An average production of around 60 000 scfd is likely. High gas production from naturally stimulated zones due to faulting comparable to those adjacent to Morley Mine and in some coal exploration drillholes (c.f. Coal DH 341) could result in high gas yields at reduced well completion costs. To test the potential gas production from naturally stimulated zones, the TP4 well was drilled into the SW Dip section of Morley Mine to intersect gas from the mine goaf and ultimately draining from a major fault zone beyond the mine. Regular gas flows of around 150 000 scfd were recorded at the TP4 wellhead but commercial production from the well could not be carried out, again due to constraints imposed by the mine operator.

Future VCD work

Results to date indicate that the coalfield has a significant methane gas potential. It has also been identified that the major constraints on development are not related to the nature and extent of the gas resource but are due to the potential conflicts between coal mining operations and gas extraction programmes. Southgas has distanced itself from the coal mine operators because of these potential conflicts and is concentrating future activities away from active mines to ensure that such constraints do not apply in the future. These areas, the Moretown and Orauea Sectors have the additional advantage of higher coal rank than the areas where the previous test production programme was carried out, and the gas content of the coal will be correspondingly higher.

Production modelling

The data acquired by Southgas to date has been used to model gas production using the COMET program and based on gas production from a central well in a five-spot well pattern over a ten year production period. Three scenarios were initially modelled using absolute cleat permeability of 0.1, 1.0 and 10.0 md (Table 2). The five well pattern is a conventional VCD gas well configuration with 300 m (1000 ft) between a central well (quarter well) and two offset wells (half wells) representing an overall well spacing of 9.3 hectares (23 acres) (Fig. 5). Based on a conservatively modelled gas content of 142 scf per coal tonne (c.f. 4cc/gm) and with the initial pressure equal to desorption pressure at 568 psia, an adsorption isotherm was constructed (Fig. 6). This plot showed that the Ohai coal has a steeper slope compared with a more typical U.S.A coal (Rock Creek) because of the lower gas content. Despite the modelled low gas content, the overall COMET model runs suggested that economic quantities of gas at permeability between 1.0 and 10.0 md may be produced at Ohai. The favourable production result is largely due to the great thickness of coal (average thickness of 20 m). Empirical data suggests that average actual cleat permeability for Ohai will be around 3.0

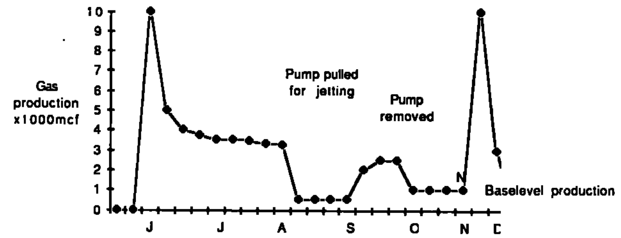

Fig. 4: Initial and baselevel gas production from the Southgas TP 2 well, Ohai.

SW	KRW	KRG
0.0	0.0	1.0
0.50	0.0	0.75
0.55	0.005	0.71
0.60	0.01	0.63
0.65	0.02	0.53
0.70	0.05	0.40
0.75	0.10	0.25
0.80	0.18	0.10
0.85	0.30	0.0
0.90	0.45	0.0
0.95	0.69	0.0
1.0	1.0	0.0

Gas-water Relative Permeability Curve for Ohai production modeling runs

Table 2: Gas-water relative permeability curve data used to model production.

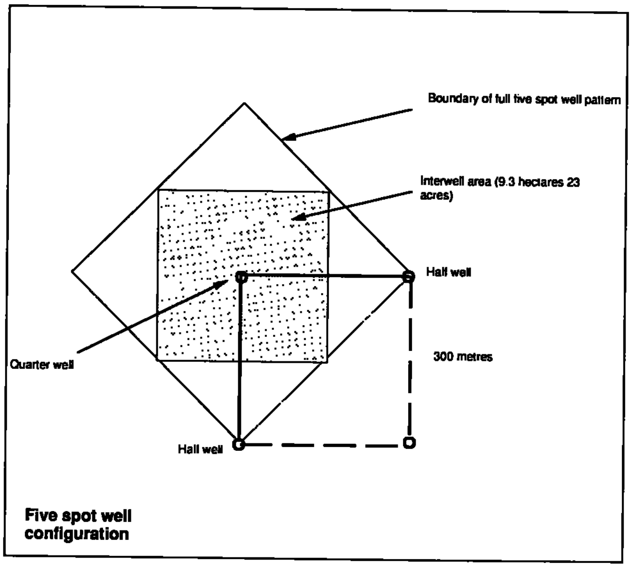

Fig. 5: Conventional VCD five well pattern.

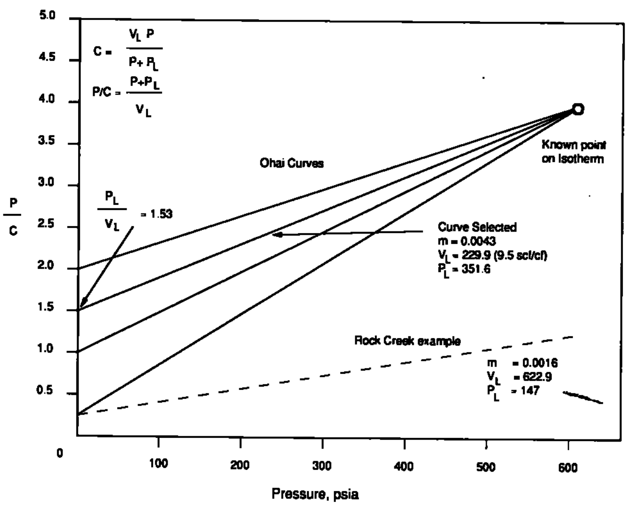

Fig. 6: Ohai Adsorption Isotherm.

md and the COMET model was subsequently run to model gas production at this level of permeability.

The overall results of the models indicate that single well average daily production in a five well test pattern could range from 43 – 550 mcfd at year one down to 21 – 200 mcfd at year ten depending on the level of cleat permeability (Fig. 7a). On a single well average cumulative production for a 5 well test pattern, production in year one would range from 0.05 – 0.55mmcfd in year one to 0.2 –2.6 mmcfd by year ten (Fig. 7b). Single well daily production and ten year cumulative production at a permeability of 3.0 md are given in Figs. 7c and 7d. Total field daily production and ten year cumulative production for a five well test programme are given in Figs. 7e and 7f.

Based on the gas production modelling, a five well pattern test site suitable for hydraulic fracturing has been identified in the Moretown Sector within the Southgas project area. Southgas hopes to carry out a full test in this area in the near future.

Markets and transport

Southgas commissioned an independent investigation of the market potential for Ohai natural gas which established that a major potential consumer for the gas was NZAS's aluminium smelter at Tiwai Point. Additional markets among the domestic, commercial, and industrial users in and around Invercargill, Dunedin and Queenstown were also identified. Transportation scenarios ranging from tube trailer transport to a dedicated pipeline. It was identified that a dedicated pipeline is the preferred transportation option but has high upfront capital costs. Tube trailer transport is clearly more expensive and would result in short term relatively high gas prices. Road transport does, however, have the advantage of greater flexibility for moving the smaller volumes of gas that would be produced at the initial stages of the project and would allow smaller markets that would otherwise be unable to use natural gas as an energy source to be supplied.

Production well configuration

The production modelling suggests that a simple initial well configuration employing a small number of wells (ca. nine wells) would satisfy the existing identified market demand for the gas as well as providing an onsite energy source. Fill in drilling to offset central well production decline over a ten year production period would be required. Sufficient coal resources have been identified in the Moretown Sector over at least a 20 year production period.

Drilling costs

While actual well cost is less of a consideration in overall gas price than the cost of transport, the need to employ full oilfield equipment adds unnecessary cost to the project. The area Southgas is investigating has been explored and a number of coal drillholes put down through the target zone. These earlier drillholes could be produced far more cheaply because they were drilling for coal under the Coal Mines Act. The need to employ equipment such as blow out preventers for low pressure gas makes VCD exploration in New Zealand relatively expensive compared with the U.S.A. Coalbed methane extraction is a new technology for New Zealand and the regulatory regime has not yet caught up. Such a new set of regulations will need to be considered if VCD is to become a viable long term energy industry in New Zealand.

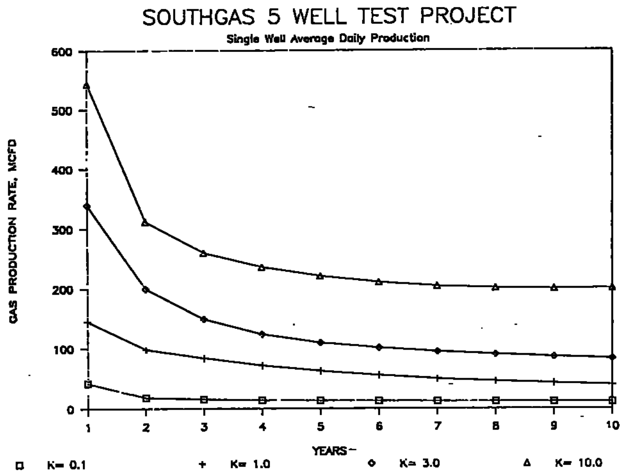

Fig. 7a: Single well average (averaged for the centre and first and second offset wells in a five well pattern) daily production over a ten year production period, solved for predicted permeability rates.

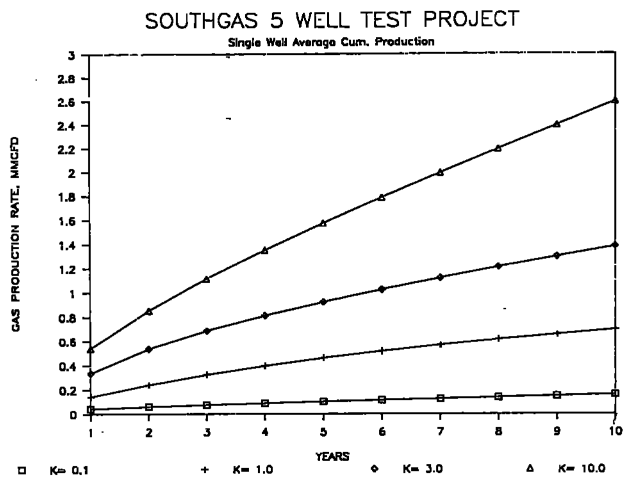

Fig. 7b: Single well average cumulative gas production over a ten year period, solved for predicted permeability.

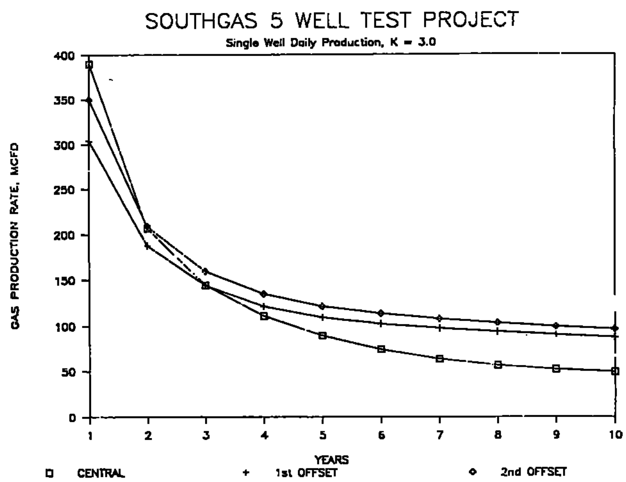

Fig. 7c: Single well daily production for central, first offset and second offset wells in a five well pattern over a ten year period, solved for a permeability of 3.0md.

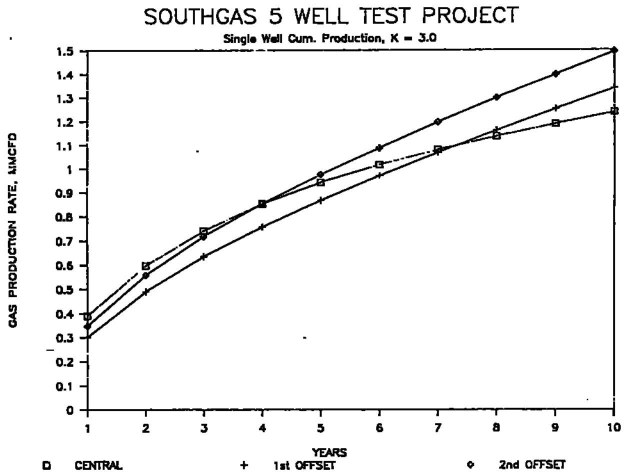

Fig. 7d: Single well cumulative production for central, first offset and second offset wells in a five well pattern over a ten year period at a permeability of 3.0md.

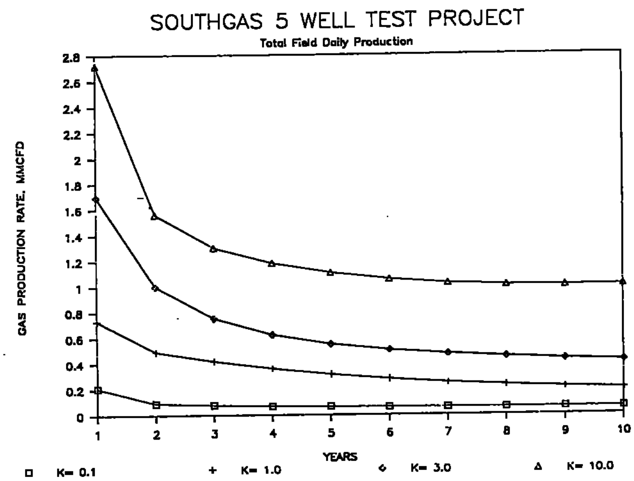

Fig. 7e: Total field daily production for a five well test programme over a ten year production period.

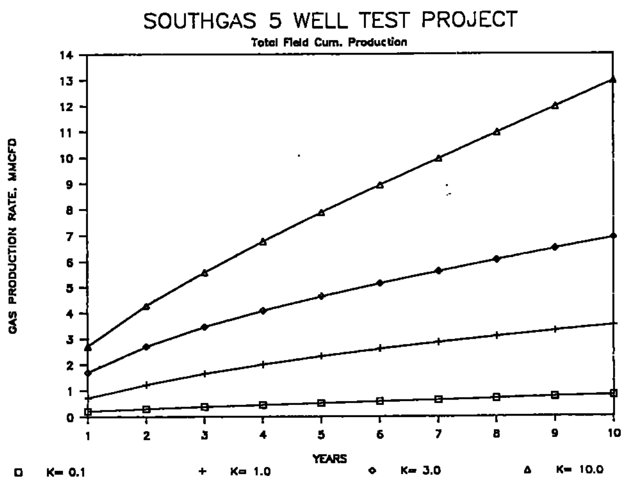

Fig. 7f: Total field cumulative production for a five well test programme over a ten year production period.

CONCLUSIONS

Coalbed methane is an unconventional energy source in New Zealand although it is a technique that is becoming more readily accepted in the U.S.A.

Methane from coal seams is a well known hazard in New Zealand coal mines, but little work has been carried out to investigate the economic extraction of methane from coals until the formation of the Southgas project.

The Moretown sector contains 88.84 million tonnes of indicated coal (with cut-offs applied) but contains between 97 and 106 million tonnes of coal when considering the total resource. A total of 197 (97+100) to 406 (106+300) million tonnes of coal may thus be available in the Moretown and Orauea sectors for methane drainage.

The gas values recorded from the Morley Formation in the Moretown Sector range from 1.77cc/gm up to 6.32cc/gm with the low values related to shallow sample depth or poor quality coal samples. More typical clean, low ash coals having significantly higher values. An important feature of the gas values is the strong positive relationship between depth and gas content.

The feasibility study carried out at Ohai suggests that natural gas can be economically produced from the coalfield. A relatively small number of cheap wells could be put down to produce a target production of 2 mmcfd over at least a ten year production period and fill in drilling could allow production to be extended for 20 years. Additional coal resources of higher rank and at a greater are inferred to occur in the Orauea Sector. These resources could provide a gas resource beyond a 20 year period.

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