Turning a coalbed methane project into a co-producing hydrocarbon project

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Abstract

Westgas obtained PPL 38 504 over the Greymouth Coalfield in the mid 1990s. In 1997 this was converted to PEP 38 508 and later extended to the south. Additional areas are now under application. PPL 38 504 was obtained based on the coalbed methane potential of coals within the Brunner and Paparoa coal measures. Reviews of data and analysis of field samples suggested that the area had the potential for hydrocarbons other than coalbed methane. This was confirmed with the drilling of Westgas-1 into the Brunner Coal Measures southeast of Dobson in 1996 which flowed gas [methane > ethane > propane > tr butane] to surface.

PEP 38 508 was applied for to evaluate the full hydrocarbon potential of the area. Subsequent operations included a reanalysis of Card Creek 1, reprocessing of seismic, the acquisition of high resolution seismic, field mapping, geochemical analyses, the drilling of the Westgas-2 and -3 stratigraphic wells, and reservoir/ production modeling.

Westgas-2 also flowed similar gas and logging indicated that gas was present over a 20 m zone of sandstones intercalated with the coal seams. Poor core recoveries of the coal resulted in only indicative gas yields of 10 m^3 of gas per tonne of coal. Westgas-3 was suspended above the production zone. In 1998 Westgas-2 was re-entered and re-completed as a test well. This initial testing indicated that the well had good production characteristics and the sandstone-coal reservoir could flow commercial quantities of gas.

New wells at Dobson and Rapahoe were drilled in 2001. The Dobson well again flowing gas from the sandstone-coal reservoir zone as well as a limited quantity of oil while the Rapahoe-1 did not flow gas to surface. The Rapahoe-1 well did, however, intersect coal seams with a gas yield of around 6 m^3 per tonne of coal. Cavitation of the coal seams in all three wells has recently been completed to enhance gas producibility from the coals.

Commercialisation is dependent on resolving production issues that are generally not faced by hydrocarbon producers. A critical issue is the presence of water in the reservoir. This is a feature of coalbed methane reservoirs and requires the installation of a pump to draw down the water column. In Rapahoe-1, water well pumps are being adapted while in the wells at Dobson progressive cavity pumps are being installed. Another issue is access to suitable rigs and ancillary equipment. Conventional oil rigs are overkill and while mineral rigs can be adapted they tend to be too small, of questionable quality and the operators unable to adapt to the higher health and safety requirements of the gasfield environment. Westgas is currently investigating options for obtaining a rig meeting the gap between existing oilfield and mineral rigs in New Zealand.

Introduction

Westgas Resources Ltd has spent several years investigating the potential of Petroleum Prospecting Permit 38 508 [formerly Petroleum Prospecting License 38 504] (Figure 1). The project was initiated by Ron Macdonald of Macdonald Investments Ltd [MIL] in 1994 and was joined by Solid Energy in 1997. Solid Energy subsequently withdrew from the joint venture as a result of exposure to foreign exchange losses. Resource Solutions is the operator for the permit on behalf of Westgas and is lead contractor for the project. Key advisors for the project include the Petroleum Division of CSIRO Australia, the Coalseam Gas Research Institute based at the University of North Queensland, the Institute of Geological and Nuclear Sci-ences, and Newman Energy Research.

Permit and location

Petroleum Exploration Permit PEP 38 508 covers 143 km^2 of the area within and south of the Greymouth Coalfield (Figure 2). PEP 38 508 was granted in Mid 1997 and replaced PPL 38 504 which covered the same area. In August 1999, Westgas applied for an extension of its permit to the north covering known oil seep areas in the Rewanui area and where Solid Energy was experiencing gas outbursts in the now closed Mt Davy Mine. We anticipate the granting of this extension and the associated relinquishment of an area in the south east of the permit shortly. Initial investigations at Rewanui were planned for this field season but must now be deferred until the 2002-2003 season.

Framework for Westgas investigations

The Westgas project is different from conventional petroleum permit operations. The initial premise for the project was that Coalbed Methane [CBM] gas is generated and remains within the high-rank coal seams, particularly in the eastern parts of the Greymouth Coalfield.

Initial exploration in PPL 38 504 indicated that potentially significant conventional gas and liquid hydrocarbons may exist within PPL 38 504 as well as CBM gas reservoirs.

Petroleum Exploration Permit PEP 38 508 was thus applied for on the basis that both sandstones and coals within the Brunner and Paparoa Coal Measures would be gas-bearing. Investigations since have therefore focused on both CBM and shallow conventional hydrocarbons. Co-production of CBM and conventional natural gas raises technological issues not typically addressed by either aCBM or natural gas operator.

Coalbed methane

All coal seams contain natural gas, principally methane (CH_4), but a range of criteria need to be established prior to proving economic extraction. These criteria include:

- overall gas content in terms of cubic metres of gas per tonne of coal
- the degree of gas saturation (i.e. has some of the gas within the coal been lost)
- the permeability of the coal (and hence the capacity of the coal reservior to flow gas)
- the coal's mechanical properties (governing the completion method adopted)
- the hydrogeological framework of the accessed formations.

MIL introduced CBM to New Zealand in the early 1980s assisted by NovaCorp which had been involved in such projects in Canada. NovaCorp identified Greymouth and the Ohai coalfield in Southland as having potential. The Greymouth area (Westgas) was considered to be the best prospect technically whereas the Ohai area had more clearly identified markets for the produced gas. Initial investigations were therefore focused on the Ohai area.

Considerable effort was put into the Ohai gas project (Southgas) but without success. The cause of the failure of Southgas was identified in a review undertaken in 1997-98 and work was then done to establish the parameters necessary to make the project work. Additionally, several important lessons were learnt which have been applied to Westgas. MIL recently decided to focus its resources on the Westgas project and thus surrendered its permit at Ohai.

Geological framework

The stratigraphic and structural setting of the region has been described in detail by others (Nathan et al 1986, Newman and Newman 1992, Matthews 1989, Purcell 1986, Thrasher et al 1996, Bishop 1991, Ward et al 1995, Boyd et al 1995 and Kamp et al 1991). Thus it is not necessary to describe the geological setting in great detail except where investigations suggest gaps in the database.

Stratigraphic sequence

Basement generally comprises metamorphosed sandstones and mudstones of the Greenland Group. Locally, a thin sequence of mid Cretaceous Hawkes Crag Breccia overlies basement. The Hawkes Crag Breccia is similar in character to the Jay Conglomerate, the lowermost formation of the Paparoa Group. Some authors regard the two as separate units while others lump the two together. The two are difficult to distinguish based on physical characteristics and the database does not allow for a definitive view. The data from Greymouth suggests that the Jay/Hawkes Crag represents a series of discontinuous units with one centred on the western

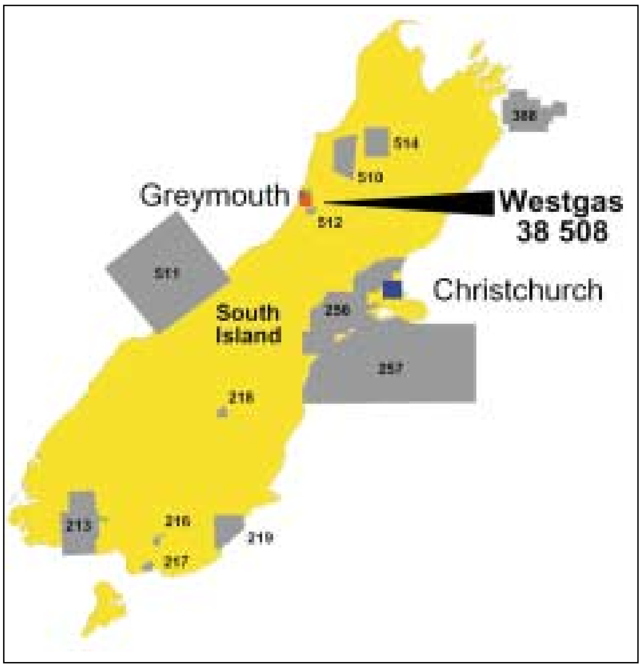

Figure 1: Map of the South Island showing the position of PEP 38 508 (Westgas) and other permits in the South Island.

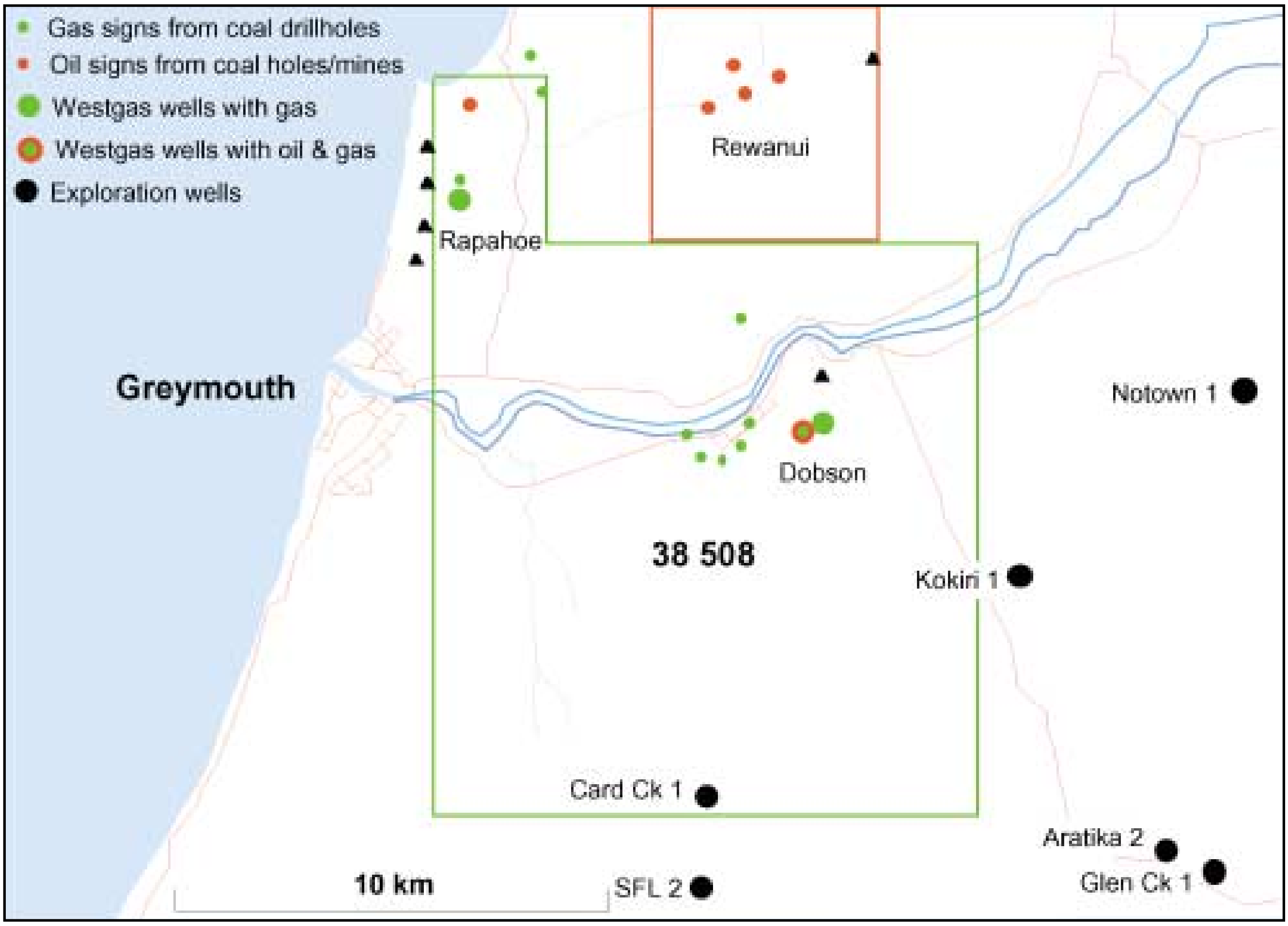

Figure 2: Location map of PEP 38 508, Greymouth, Westland showing gas wells, coal drillholes intersecting either gas or oil, and oil seeps.

and northwestern margins of the basin while a more widespread and possibly somewhat older equivalent unit is centred on the eastern side of the basin.

The Paparoa Group overlies the Greenland Group or Hawkes Crag Beccia and is a late Cretaceous to Paleocene coal measure sequence. Within the Paparoa Basin, the main part of the Paparoa Coal Measures comprises three coal bearing fluvatile formations separated by thick mudstone formations of lacustrine origin (Figure 3). The stratigraphic nomenclature of these rocks has become confused over time. At an operational level, however, the practice has been to regard the Ford, Morgan, Waiomo, Rewanui, Goldlight and Dunollie as formations within the Paparoa Group rather than members within a Paparoa Formation.

Within the Paparoa Basin, coal measure formations within the Paparoa Group are characterised by rapid lateral facies changes, variable unit thicknesses and abundant time breaks of uncertain duration (cf. Bowman et al, 1984). Coal seams of mineable thickness are located with the Morgan, Rewanui and Dunollie coal measures which formed along lake margins and adjacent flood plains due to lowering of basin level by increased tectonic activity. Accumulation of the Paparoa Coal Measures ended with the deposition of the Dunollie Formation.

The Dunollie Formation of the Paparoa Group is unconformably overlain by the Brunner Coal Measures within the central part of the basin but may be conformable or para-conformable elsewhere. Generally the Brunner consists of quartzose sandstone and conglomerate of variable thickness and coal. In both the east and western part of the basin, economic thicknesses of coal are known to occur. In localised areas where accelerated subsidence has occurred, formation thicknesses of up to 150 m occur. Carbonaceous mudstone and coal form up to 25% of the Brunner Coal Measures Formation (Nathan et al 1986). Typically Brunner seams are more lenticular than seams within the Paparoa Coal Measures.

Some workers (e.g. Nathan et al 1986) define two distinct Brunner Coal Measure sequences separated by a significant unconformity. This is unlikely, however, and it is considered that it more logical and consistent with drillhole data that these “lower Brunner Coal Measures” are in fact Dunollie Coal Measures.

Directly overlying the Brunner is the Island Sandstone, a homogenous, fine, calcareous, nearshore marine sand. This formation is in turn conformably overlain by the dark brown to grey, weakly carbonaceous Kaiata Mudstone. Outcrop and drillhole data from south of Greymouth shows that a coarse grained conglomeratic unit, the Omotumotu Member, is

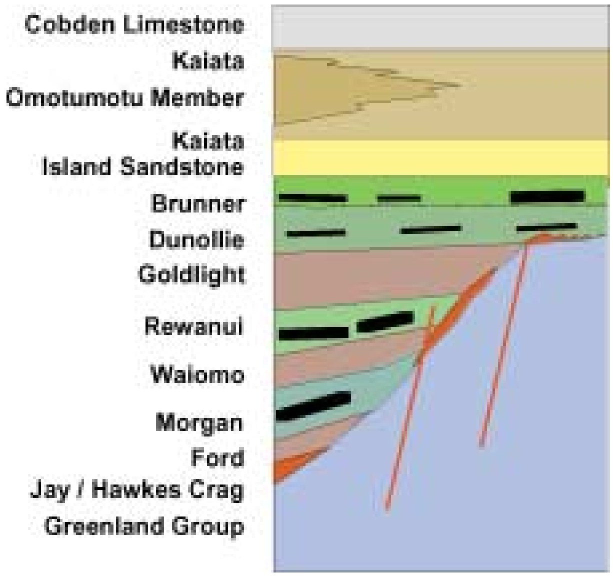

Figure 3: Composite column through the Stratigraphic sequence of the Paparoa Basin.

complexly interfingered with the Kaiata. In the south of the permit area, the Kaiata Mudstone is in turn overlain by the Cobden Limestone but these rocks have been removed in the core of the Brunner-Mt Davy anticline within the Greymouth Coalfield.

Basin development

PEP 38 508 is located within the Paparoa "Trough" or basin, which in turn is part of the Westland basin (Figure 4). The Paparoa Basin comprises an elongate, structurally controlled basin 180 km long and 20 km wide. The Cretaceous to Eocene coal measure sequence was not, however, entirely laid down in a structurally controlled basin. In reality, there are several distinct structurally controlled basins (Greymouth, Pike, Karoro and the much younger Grey Valley Basin to the east). These are separated by uplifted areas and more gently subsiding platforms receiving thin but laterally extensive influxes of sediment.

Additionally, the fault angle depression depositional framework favoured by some authors for the Cretaceous-Paleocene sequence is considered too simplistic. Westgas investigations instead suggests that a series of pull-apart basins developed in response to a post-Morgan Formation (Paparoa Coal Measures) switch from a northwest to NNE oriented structural grain.

The strata within the Westland Basin proper comprise firstly a thin and intermittently present veneer of breccia overlain by the Upper Cretaceous to Paleocene Paparoa Coal Measures (~ Pakawau Coal Measures of the Taranaki Basin). Structurally controlled basin-fill Paparoa sedimentation waned in the Paleocene and the Dunollie Coal Measures at the top of the Paparoa sequence was laid down in a regionally transgressive setting across the subsiding Omotu platform.

An erosive hiatus between the Dunollie Coal Measures and Brunner Coal Measures (Eocene) occurring in the centre of

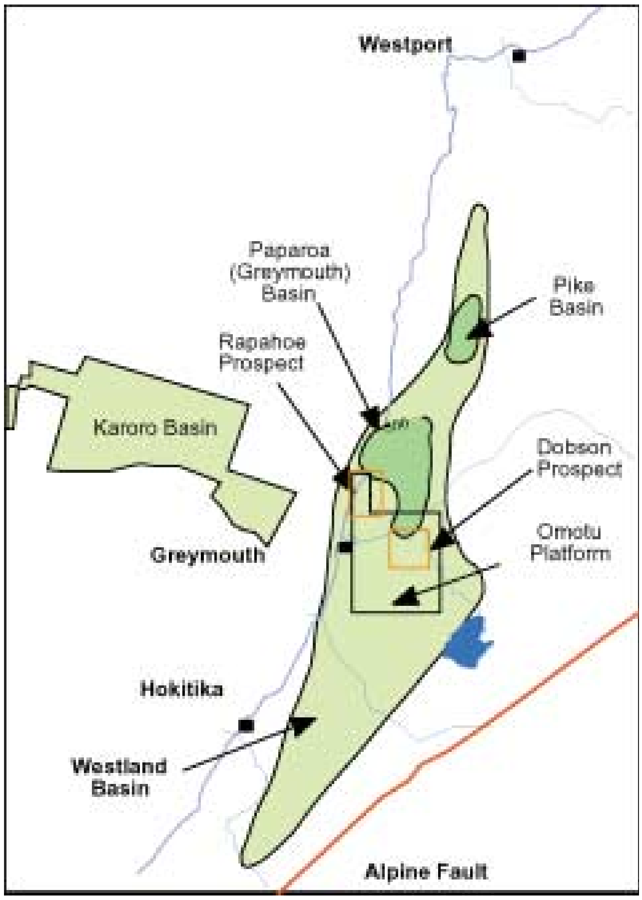

Figure 4: The Westland Basin during the Late Cretaceous-Paleocene coinciding with the deposition of the Paparoa Coal Measures (after Nathan et al 1986) showing the permit area and the Dobson and Rapahoe prospects.

the Paparoa Basin and other localised depocentres such as at Pike River but it is less evident elsewhere. At Dobson, for example, there is no obvious break between the Brunner and Dunollie formations.

Basin eversion

A major structural feature known as the Grey Valley fault zone is located approximately five kilometres east of the Dobson mine area and defines the eastern margin of the Paparoa Basin. This fault now separates the Paparoa Basin from the Grey Valley Basin which is situtated further east. The Grey Valley fault zone has been generally considered a major hinge controlling deposition during the Upper Cretaceous (Figure 5).

The Grey Valley Basin was a partially emergent platform during the deposition of the Paparoa Coal Measures. During this time the land surface must have had a subdued character since there is little evidence of the repeated influxes of coarse sediment into the Greymouth Basin that characterised the northwestern margin. Thus movement on the fault may have been less vigorous than that on the faults further west with sedimentation keeping pace with the rate of subsidence. Indeed Westgas work at Dobson indicates that another approximately east-west oriented fault zone parallel to the Grey River strongly influenced sedimentation in this area.

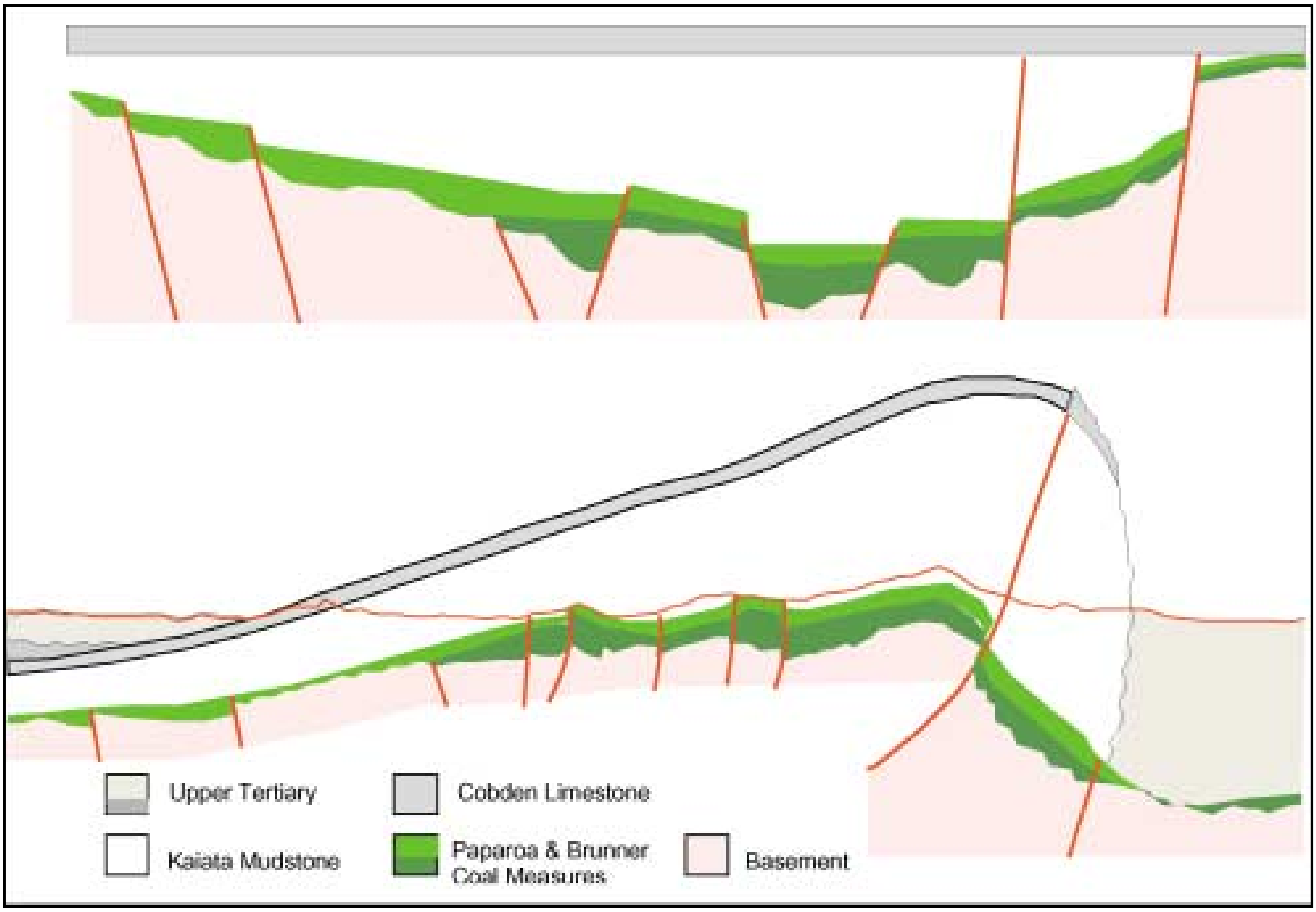

Figure 5: East west cross section through the Paparoa Basin showing the basin at its post-Oligiocene maximum burial (top) and the present day configuration of the Brunner-Mt Davy Anticline (bottom).

In the Paleocene the zone of weakness marked by the Grey Valley Fault locked up as the extensional regime that characterised the Cretaceous waned and was replaced with a regional subsidence trend. This allowed the Grey Valley platform to gradually subside and a veneer of the Dunollie Coal Measures was then deposited across the area. Whereas the Paparoa Basin has an almost continuous depositional record from the Cretaceous to the Oligocene, the deposition of the Dunollie represents the initiation of regional basin development further east. Later during the Miocene to Pliocene, subsidence and sediment accumulation was much greater in the Grey Valley Basin than elsewhere with maximum submergence of the basin in the Late Oligocene (Nathan, et al 1986).

The Grey Valley Fault became active following deposition of the Cobden Limestone, resulting in the eversion of the basin. The basin axis is now at least approximately represented by the crest of the asymmetric Brunner - Mt Davy Anticline. The steep eastern anticlinal limb forms the eastern edge of the Grey Valley Basin. In contrast the western limb of the Brunner - Mt. Davy Anticline is less steep and has with low to medium amplitude second and third order folds that mimic the form of the main fold.

Investigations to date

Westgas has undertaken the following investigations:

- initial data review and compilation
- prospect targeting within the permit
- reprocessing and reinterpretation of high resolution seismic lines acquired by the NZCRS in 1984
- the drilling of three HQ stratigraphic wells and associated testing in the Dobson prospect
- undertaking a high resolution seismic survey in the Dobson-Kaiata area.

Initial data review

The review lead to a revision of the projects work programme as initially presented to Crown Minerals in the permit application (Barry and Cave 1994). It recommended that vitrinite reflectance variation be analysed to assist targeting of areas for investigation. This was because a variation in reflectance characteristics between the older Paparoa and younger Brunner target horizons was identified. It also recommended that a stratigraphic drillhole be put down south of Dobson to establish the coal measure distribution of this area and that up to 10 km of high resolution seismic data be acquired to assist in the targeting of additional drillholes.

Prospect targeting

Implicit in the review was that there was at least two distinct hydrocarbon prospects in the permit. These were the Dobson and Rapahoe prospects centred around known gas and oil seeps/indications. MIL accepted the recommendation to undertake further investigations at Dobson in the southeastern part of the coalfield and work was initiated to identify a suitable site for drilling (Figure 6).

Seismic reprocessing

In addition to drilling a stratigraphic well, several 1984 era high resolution seismic lines in the Rapahoe area in the northwest of the coalfield were reprocessed. This seismic was originally acquired by the New Zealand Coal Resources Survey but the results were poor. At the time it was inferred that this was due to difficult ground conditions. Thus it was important to determine whether or not difficult ground conditions was going to be a problem prior to undertaking a new seismic survey at Dobson. The re-processing established that meaningful data had been obtained in the original survey and suggested that seismic surveying could be successful (Cave 1999a).

Westgas-1

The Westgas-1 well was put down to assess the natural gas potential of the Brunner Coal Measures at Dobson. This area was selected because several early holes put down in the area for coal mining purposes showed signs of both gaseous and light liquid hydrocarbons (e.g. Gage and Wellman 1944, Bowman, 1984) [see Figure 2].

The sequence intersected in Westgas-1 was close to that anticipated in the well prognosis and established:

- continuity of coal south east of Dobson.
- gassy Brunner Coal Measure coals and associated Brunner sands. There was also some gas and condensate-cut water from the Island Sandstone
- poor recovery of coal cores suggesting that the coals were friable indicating good permeability.

The well was not suitable to maintain for further testing and as a consequence the well was plugged and abandoned.

Acquisition of seismic data

In late 1996, IGNS was contracted to provide up to 9 km of high resolution seismic data passing through the Westgas-1 area (Melhuish 1997). It was intended to use the data to site the Westgas-2 and -3 wells. The seismic profiles demonstrated continuous pronounced reflectors interpreted as coal seams. The profiles did not show the expected reversal of dip at the eastern end of the line associated with the crest of the Brunner-Mt Davy Anticline. Consequently, Westgas-3 was sited at the end of the line which should have been on the crest of the anticline. When the well was drilled, it was found that seismic processing had not identified the anticlinal axis.

Reprocessing of the line established that the anticlinal crest was to the west of the well (Waghorn 1997). Dips in drill core were around 60° E suggesting that the well was on the steep eastern limb of the anticline and would intersect the target formation at a depth beyond the safe capacity of the rig. Drilling was thus terminated.

Westgas-2

The Westgas-2 well is located west of Westgas-1 and drilled as an HQ slimhole stratigraphic well (Figure 7) [See Cave 1999b]. The well had the objective of confirming coal continuity, obtaining samples for gas desorption, and adsorption and geochemical testing, It also had the objective of obtaining reservior pressure data, obtaining coal seam permeability data, assessing risk factors associated with an artesioning zone within the Island Sandstone, and assessing gas producibility of the area. The following formations were intersected.

Formation	Depth	Thickness
Kaiata Mudstone	0 - 273	273
Island Sandstone	273 - 383.52	110.52
Brunner Coal Measures	383.52 - 456	72.48
Paparoa Coal Measures	456 - 553.75	97.75
EOH (Paparoa CM)	553.75	

Table 1. Stratigraphic Summary for Westgas-2.

Minor gas was observed within the Kaiata Mudstone at 264 m, gas-cut water was noted within the Island Sandstone at 350 m and significant gas was observed between 383 and 420 m within the Brunner. Several other minor gas zones were also noted within the Paparoa Coal Measures in lower parts of the well. A kerosene smell was noted in core at 418.5 m in the Brunner while at 496 m a light oily fluid was observed being expelled from pore spaces within muddy sands within the Paparoa. Other minor signs of light fluid being expelled were observed at 530 and 540 m within the lower Paparoa Coal Measures.

Desorption tests gave gas contents of between 8 m^3 /tonne and 10 m^3 /tonne. The poor quality cores obtained indicates that these values were regarded as minima. Coal samples were tested for adsorption isotherms and a reasonable match between the desorption and adsorption data suggests that the coals are fully gas saturated. The gas bled off during desorption testing was analysed for gas composition with methane dominate at +90%, ethane at +5%, propane +2% plus traces of higher gases.

Because of the presence of fluids and gas from the sandstones overlying the main coal seam, conventional hydrocarbon analyses such as RockEval were undertaken along with VFR and tests oriented towards the coals (Newman 1997). These tests suggested firstly that the materials tested have suppressed reflectances resulting from perhydrous composition while Tmax was consistent with the reflectance of about 1.00% Ro max. Relatively high TOCs and hydrogen indices suggested that some of the coal measure sediments were potentially significant hydrocarbon sources as well as the coals themselves. These analyses thus confirmed the assessment of the well during drilling and logging.

The well was then re-entered and recompleted as a bare foot test production well. The main objective of the testing programme was to assess seam permeability, reservior pressure and gas producibility. The difficulty in obtaining coal samples to allow the direct measurement of permeability and the characteristics of those coal cores obtained suggested that the permeabilities were relatively high but this could not be measured.

Because the coal seams are over pressured, the principal test therefore employed flow rate and pressure build up data to assess permeability. The data suggests a radial composite reservior with a lower permeability zone of around 8 mD around the wellbore increasing to 24 mD further out into the formation. The indications of a lower permeability zone close to the well bore may indicate formation damage but in this instance it is thought to be more likely due to gas blockage close to the well bore arising from the earlier testing. The producibility analysis indicated that a larger diameter test production well would flow economic quantities of gas.

Dobson production well

The Dobson well [interim well name] was drilled west of the Westgas-2 well in 2001. Dobson was drilled as a 6" production well to the top of the production zone and then cased with the production zone and "rat hole" completed bare foot below. The sequence in Dobson was as expected in the prognosis although slightly deeper due to strata dips being in excess of 35°. A number of drilling difficulties were experienced and the production zone was fully cored to facilitate progress. An upside was the recovery of oil saturated core in the first core run and visable discharging of gas from

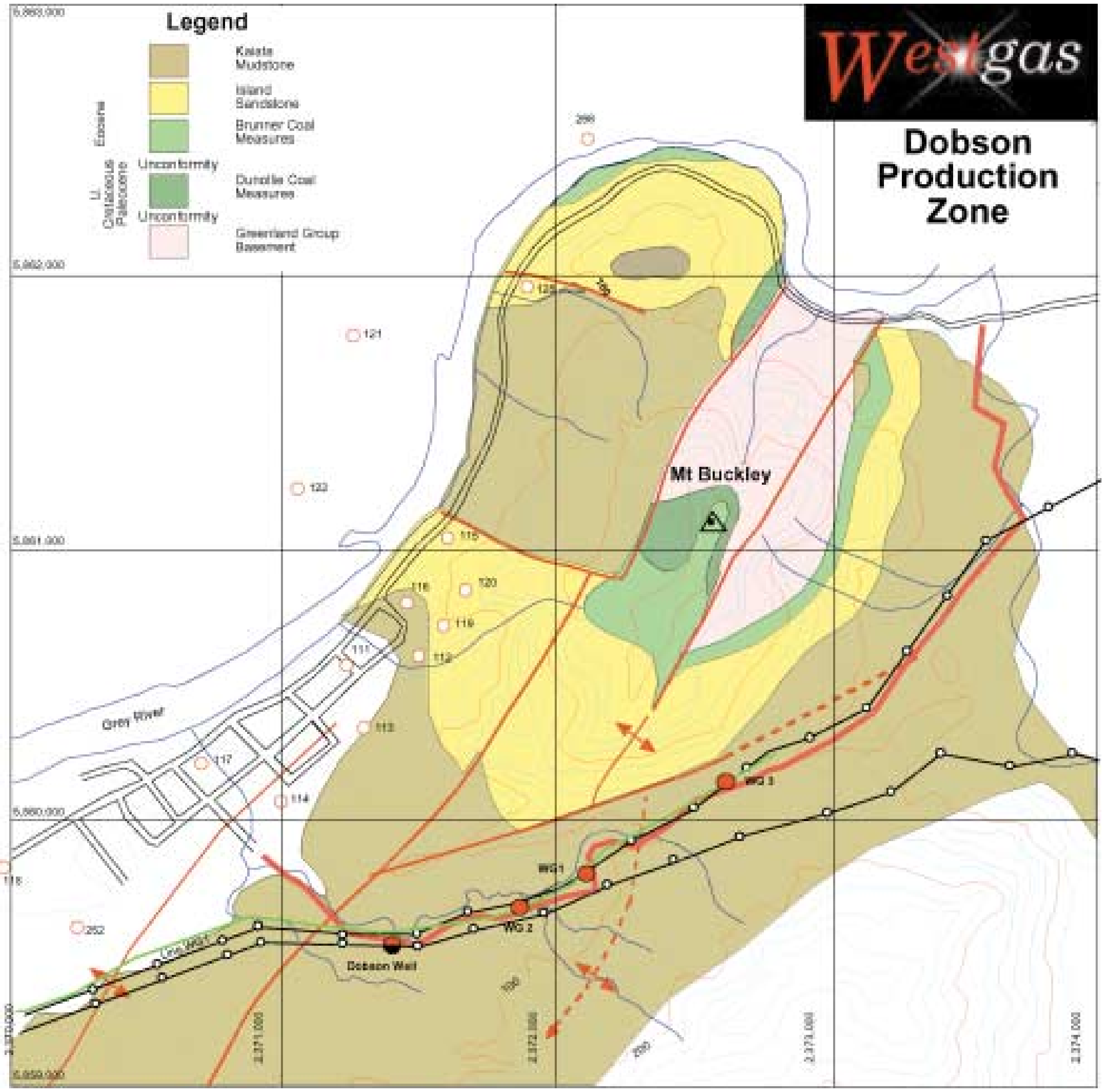

Figure 6: Location map of the Dobson prospect showing the geological setting of the area topography roads and well locations.

sandstone cores between the oil zone and the top of the main Brunner coal seam. Brunner coal cores also discharged gas when removed from the well.

Rapahoe-1

The Rapahoe-1 well is Westgas Resources Ltd's first well outside of the Dobson prospect. Our intentions had been to drill this area after getting the Dobson discovery into production. Inflexible work programme commitments, however, required us to divert resources from the Dobson development programme to drill the Rapahoe prospect. The Rapahoe area was of interest because of the results of two coal holes drilled in the early 1980s (Figure 8).

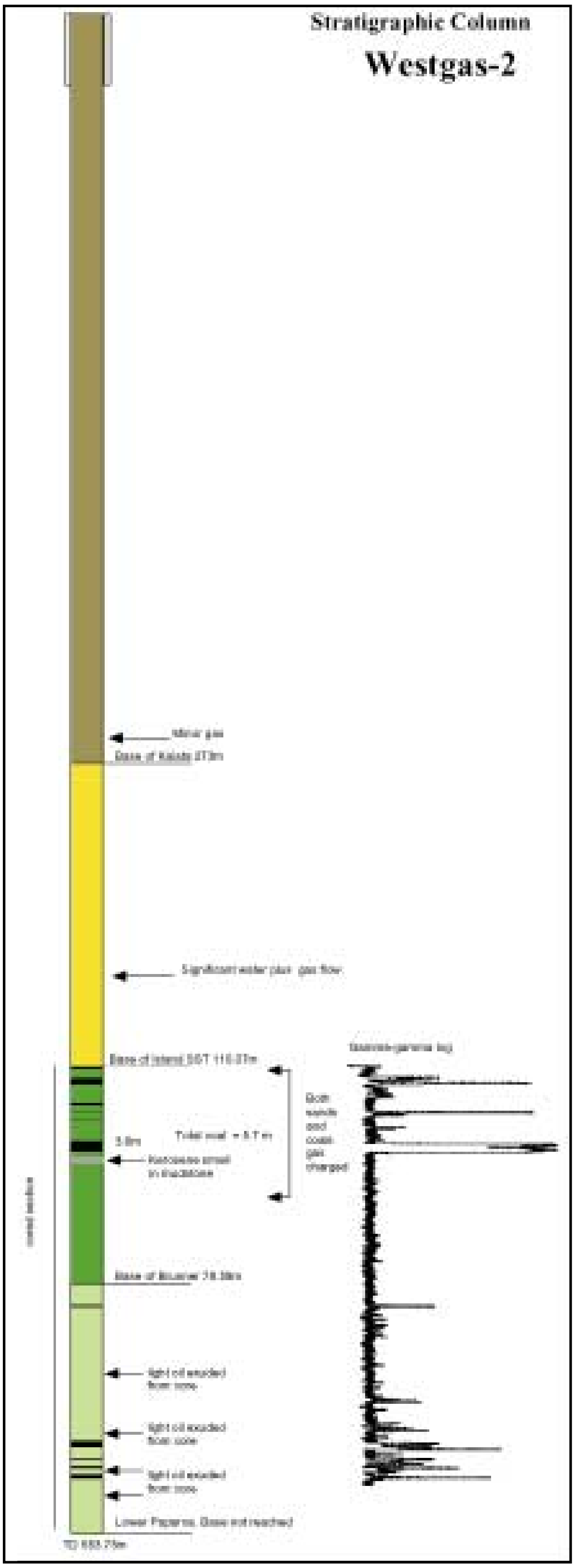

Figure 7: Stratigraphic column for Westgas 2.

NZCRS-652 discharged gas as soon as the Brunner Coal measures were intersected and was temporarily abandoned until control measures could be put in place to plug the well. Similarly NZCRS-653 flowed oil to the surface from a zone 20 m into the Brunner Coal Measures and was also not completed through to its intended TD. To facilitate siting of Rapahoe-1, a 5+ km high resolution seismic line was shot across the area by GNS. The results were good despite difficult ground conditions in places.

Unexpected site problems included a cannabis crop adjacent to the line and the arrest of one of the local seismic crew responsible for the crop! Rapahoe-1 was located around 500 m southwest of NZCRS 652 and drilled through the Brunner Coal Measures intersecting two seams. As was the case with Dobson, the well was drilled as a 6" production well and completed bare foot.

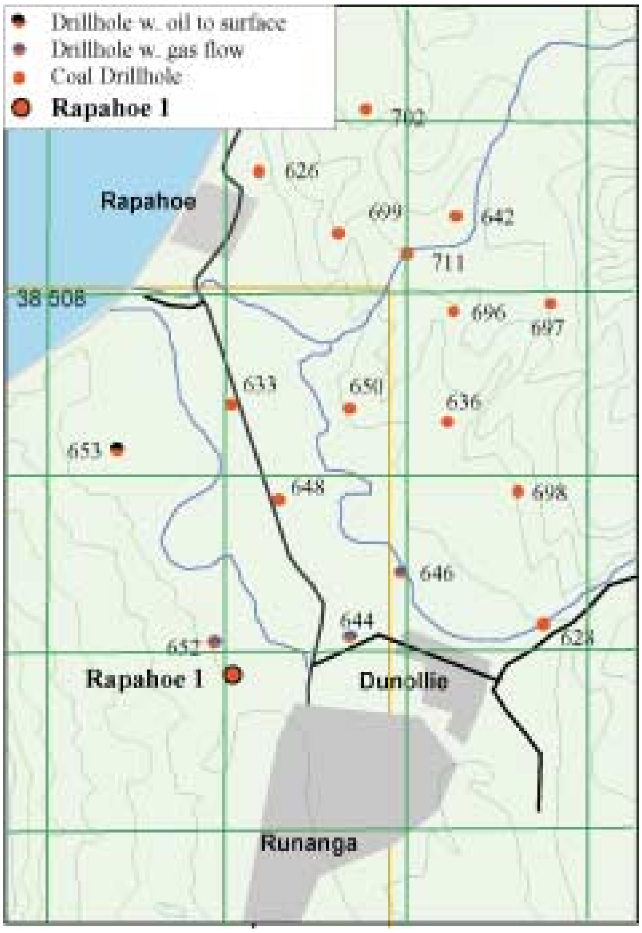

Figure 8: Map of the Rapahoe area showing the location of Rapahoe 1, DH 652 and 653 and other coal holes with hydrocarbon shows.

Well stimulation and production

A feature of any well where the coal seam is a producing zone is the need to stimulate the coal to enhance permeability and producibility. In the Southgas project hydraulic fracturing had been used to stimulate the coal seams. The treatment was too aggressive, however, resulting in severe formation damage and collapsed casing which meant that the production zone could not be accessed. A cavity stimulation technique was considered more suitable for the Westgas wells at Dobson and it was felt that either hydraulic fracturing or cavity completion may work in Rapahoe-1.

One advantage of employing a cavity completion is that it can remove formation damage resulting from drill muds caking the well bore. One risk factor requiring consideration for Westgas not encountered by "conventional" CBM operators was the need to ensure that the gas-bearing sandstones associated with the seams were not damaged by the treatment.

The normal method for cavitating coal seams was developed in the United States. The technique involves the repeated injection of air or air/fluid mixtures into the seam under considerable pressure (1,500 psi and up to 3,000 scf/minute) and the subsequent opening of a surface value causing a rapid and violent reduction in pressure. Up to 20 injections are normally performed and the resulting cavity can have a radius of more than 2 m. The process is time consuming with treatments taking up to 20 days per well. There are difficulties in using this technique in New Zealand due to the high cost of mobilising equipment and personnel.

For Westgas, operating near to houses in the case of Rapahoe-1, and high voltage power lines in the case of the Dobson wells also precluded use of such an aggressive technique. Because the wells at Dobson also produce gas from the sands associated with the coal seam the risk of formation damage from the method was also too high.

To test the susceptability of the coal seams to cavitation, a jetting tool was fabricated and run into both the Rapahoe and Dobson wells on an HQ drill string prior to demobilising the drilling rig. Despite inadequate pump capacity and leaky joints, the treatment successfully excavated the seams resulting in cavities of around 20 cm radius.

Cavity completions

Faced with a desirable technique which we could not use because of its aggressive nature, Westgas Resources decided that the best option was to design and build a cavity completion module in-house. The basis for the design is a coiled tubing unit with a range of jetting tool configurations (Figure 9). The coiled tubing unit allowed us to place the jetting tool precisely against the seam thus avoiding unwanted damage to the adjacent sandstones. Pump capacity was supplied by a Tasman Oil Tools unit capable of delivering in excess of 600 litres per minute at 1500 psi. The treatment thus required the injection of far less fluid than that normally required by cavity completions.

Despite the relative lack of injection volume, the technique worked well and successfully excavated the seam. The method had some unanticipated additional benefits over the conventional method. This was firstly because the maintenance of a flowing connection between the formation and the surface allowed the well to self-clean removing the need for a post cavitation workover. It also allowed for the capture of the caviated coal so that the volumes being removed could be readily measured and the success of the treatment assessed.

Pumping

In both the Dobson and Rapahoe-1 wells, water production from the formation is an issue. The Dobson well has a wellhead pressure of around 110 psi about half of which is delivered by a water flow of about 20 litres per minute. Rapahoe-1 on the other hand is normally pressured and does not flow either gas or water to surface.

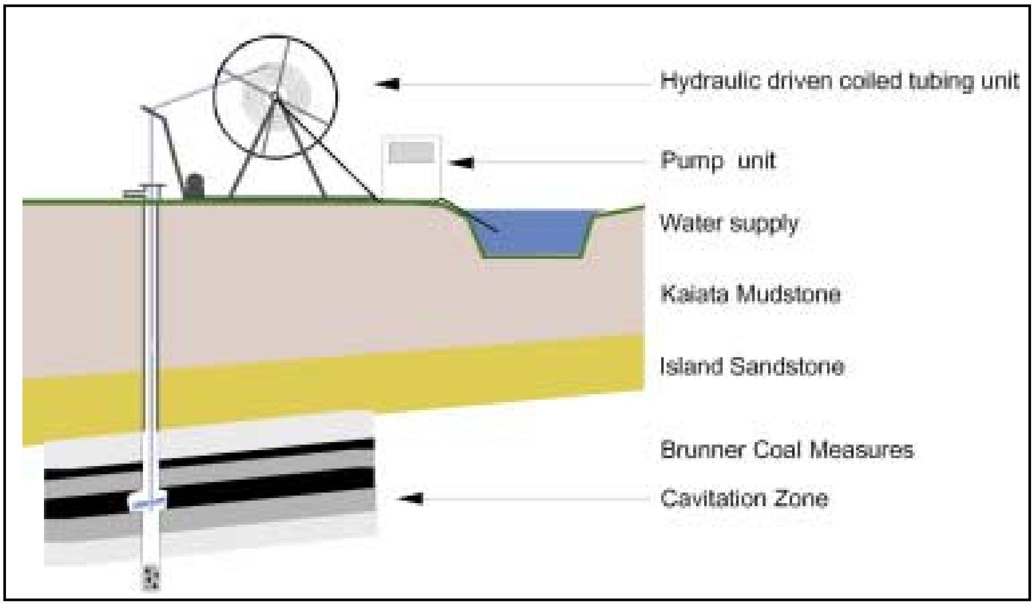

Figure 9: Schematic diagram of the cavity completion set up.

This water is a normal feature in CBM wells but an impediment to the production of conventional gas. Addressing this problem necessitates artificially lifting the water and separating the gas from the water. In the Westgas-2 well, a Jensen beam pump was trialled which successfully separated the gas from the water and lowered the water table. The pump suffered from two problems that precluded its use to produce commercial gas from the well. A critical problem was the lack of annulus in this well. Consequently, gas block constrained flow and made it difficult to balance pump rates and gas flow rates. Another problem with this pump was that it was over specified for the job and much of the cost involved with running the pump was associated with the energy requirements of slowing down the downstroke of the counterweights.

As part of the cavitation programme, the gas pressure evident in the Dobson well was used to assist drawdown of the well by a low head surface pump. It was found, however, that because the water and gas pressures in the well were effectively balanced, this technique, while low cost, did not have the pumping efficiency required to adequately draw down the well.

The decision has thus been made to use progressive cavity (PC) pumps in the Dobson well (Figure 10). Progressive cavity pumps are being increasing used in CBM wells instead of jack pumps and were considered by Westgas in 1997. At that time, uncertainty about the pumps' reliability, lack of suitable units outside the US and Canada, and the associated lack of infrastructural support ruled out their use. Now, however, the expansion of CBM operations in Australia and the advances in pump design means that the problems associated with their use have been over come. We anticipate installation of a PC pump in the Dobson well in April.

In the case of Rapahoe-1, Westgas is undertaking further experiments using water well sucker rod pumps coupled with the downhole pump unit and gas separator from a Jensen oilfield beam pump. Water well pumps work on the same principal as oilfield beam pumps but have lower lift capacities. They also work in smaller diameter wells, have a reputation for reliability and a low capital and operating cost.

Determining drawdown depth

Achieve sustainable flow from the wells does not require complete withdrawl of water from the well, merely the lowering of the water table to a depth that allows gas to flow at a rate balanced to demand requirments. Gas flow was initiated at a drawdown of 76 metres in the 1998 test programme in the Westgas-2 well (Casey 1998) but the optimum drawdown depth is likely to be somewhat greater than that.

An experiment was run on the Rapahoe-1 well as part of the cavity completion programme to establish the depth at which sustainable gas flow was initiated and to optimise the pump placement depth. This was done by coupling a compressor to the coiled tubing unit to displace the water from the upper part of the well. This showed that gas flow was initiated at a depth of around 80 to 90 m and once the water depth was lowered to 150 to 160 m the gas pressure was enough to vigorously eject the remaining water from the well (Figure 11). It must be noted that it was only once cavitation was completed and the drawdown experiment run that Westgas determined that the Rapahoe-1 well would produce gas. Final drawdown depths in both Rapahoe and Dobson wells will be determined by empirical trialling when the pumps are installed.

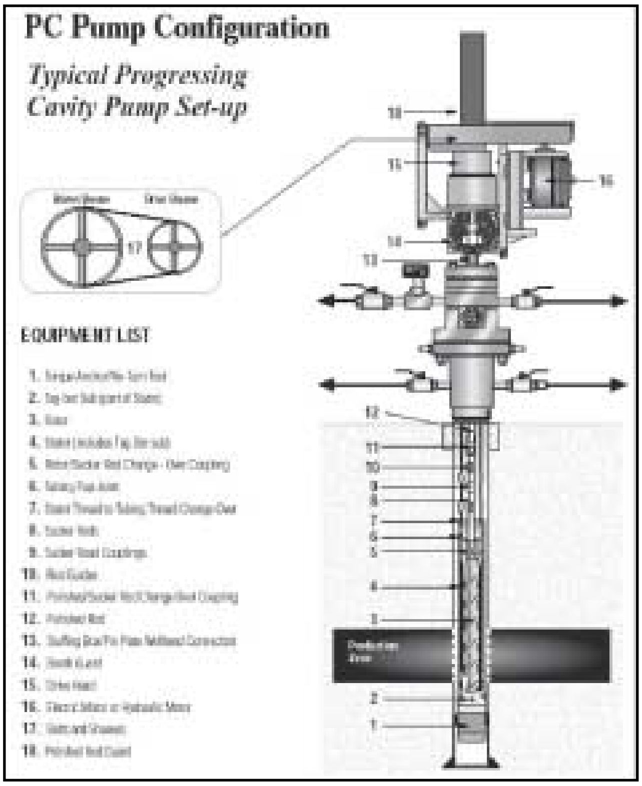

Figure 10a: Schematic diagram of a standard progressive cavity pump installation.

Figure 10b: Photograph showing a progressive cavity pump wellhead installation in Australia comparable to that being installed in the Dobson well.

Production modelling

Reservoir modeling of the CBM component of the Westgas-2 well was undertaken by CSIRO petroleum using data from the 1998 test production programme and provides an indication of the production capacity for the Dobson prospect (Meaney et al 1998).

The per well production rates for a full production well based on the established permeability of 24 mD are tabulated below (Table 2) along with the energy output this represents in MJ per day. The resulting production profiles are also figured below (Figures 12 and 13). The modeling indicated that a properly constructed and stimulated production well should produce commercially viable quantities of gas. The results from the current production wells at Dobson are consistent with the CSIRO production model with the conventional gas from the zone overlying the coal seams providing a production upside.

Figure 11: Photograph showing the vigorous ejection of water from the Rapahoe 1 well after water level was drawn down to 160m.

Completion	Pre-stimulation	Post-stimulation
Permeability	24mD	24mD
Maximum rate m/d	2,900	37,611
Maximum rate ft/d	102.412	1,328,220
MJ/day	109,117.44	1,415,185.5

Table 2. Production rates for a single well based on 24mD permeability under pre- and post-stimulation settings.

Prospect definition and future exploration

The Westgas investigations have shown that the existing wells in the Dobson prospect are located on a second order anticlinal fold on the western limb of the Brunner- Mt Davy Anticline. Maturation studies undertaken (Newman 1997) confirmed our assessment that the sequence provided a hydrocarbon source while the presence of the second order folds have acted as efficient traps. Some workers (e.g., Nathan et al 1986) have concluded that the timing of basin eversion has been a problem. All of the field evidence points to the retention of hydrocarbons within the basin, however, and our assessment is that pre-eversion structural complexities have facilitated hydrocarbon entrapment.

Recent seismic acquisition west of the existing wells has identified a similar structure with a pronounced flat spot reflector. This structure has been designated Forsters Farm and we hope to drill the structure in the next field season.

What has become clear from the Westgas investigations is that the second order folds developed on the limb of the Brunner - Mt Davy Anticline represent potential conventional hydrocarbon targets and future efforts will be focussed on the identification of additional structures.

The Rapahoe prospect on the other hand is primarily a CBM prospect despite the present of oil in NZCRS 653. Further seismic acquisition is required across the NZCRS 653 site before additional drilling north of Rapahoe-1 is considered. Depending on final flow rates from Rapahoe-1, a five spot

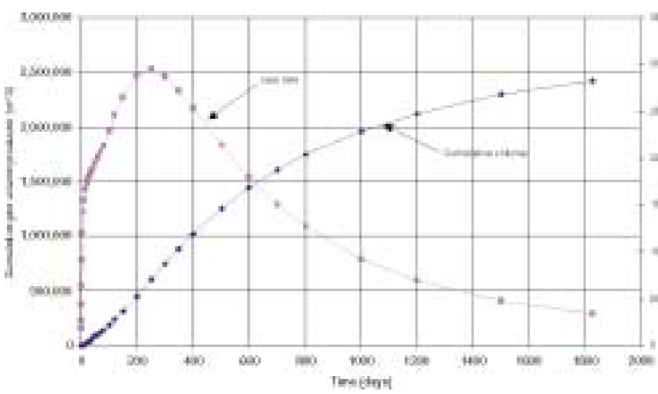

Figure 12: Chart showing per well pre stimulation gas production at 24 MD permeability.

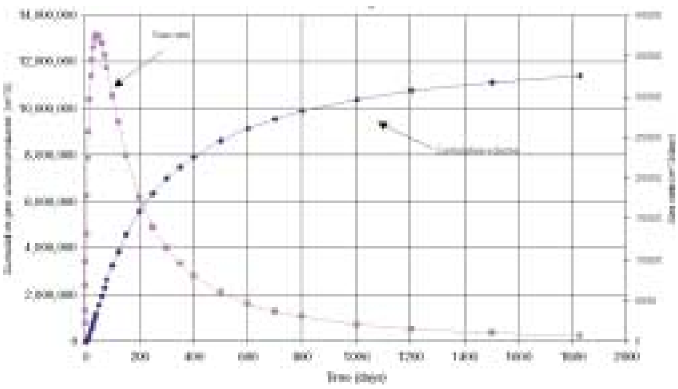

Figure 13: Chart showing per well post-stimulation gas production at 24 MD.

pattern of low-cost production wells will be drilled adjacent to Rapahoe-1 to maximise yield from the CBM reservior.

The Mt Davy area is of particular interest because of the gas-outburst problems experienced in the now closed Mt Davy Mine. The presence of liquids encountered while constructing the “stone drive” for the Mt Davy Mine and the oil seeps associated with the Liverpool, and Spark and Party mines also points to at least localised hydrocarbon entrapment. One of Solid Energy’s coal exploration holes at the mouth of the Mt Davy Mine encountered a gas pocket capable of evacuating the drill column. We treat the records of such coal holes with caution, however, as a lack of annulus and the habit of drilling with water and no mud weight clearly exacerbates such blow-outs.

A final area of interest is to the south of the area where Card Creek-1 and SFL-2 were drilled by previous operators. A detailed analysis of the Card Creek 1 well has been undertaken which suggests that the thick coals in the well could represent excellent coalbed methane reservoirs. Our modelling indicates that the Island Sandstone which produced gas-cut water in Card Creek-1 thickens to the north. Re-entry into Card Creek-1 for further testing is one option as is the identification of a suitable low environmental impact site between Card Creek-1 and Dobson. As the land in this area is administered by the Department of Conservation a considerable amount of work will be required to assure them that any drilling will be low impact.

Our policy of small-footprint low-impact drilling has allowed us to operate in areas where use of a conventional rig would not be possible. After the drilling of Westgas-2, however, we decided to abandon the use of mineral rigs due to the lack of well maintained rigs and the low level of competence of mineral rig drill crews. This is even though Westgas uses a service permit holder to manage all field operations and owns its own well control equipment. In the end we were obliged to again employ such rigs for the drilling of the Rapahoe-1 and the Dobson wells but this was due to the inflexibility in administering work programme commitments. We expect to overcome these issues by obtaining a rig capable of handling the drilling of production sized holes to depths of up to 1500 m. We intend to maintain our policy of low footprint, low impact drilling even when a larger rig is employed for future wells.

Conclusions

Over the next few months, Westgas Resources anticipates bringing the Rapahoe-1 and Dobson wells into full production. Investigations into the economic viability of small-scale power generation embedded in the local grid have been completed as has a study into the resource consent and land use issues associated with such a project. Longer term we anticipate applying for mining permits covering Rapahoe and Dobson/Fosters Farm and undertaking additional exploration centred on Mt Davy and Card Creek.

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