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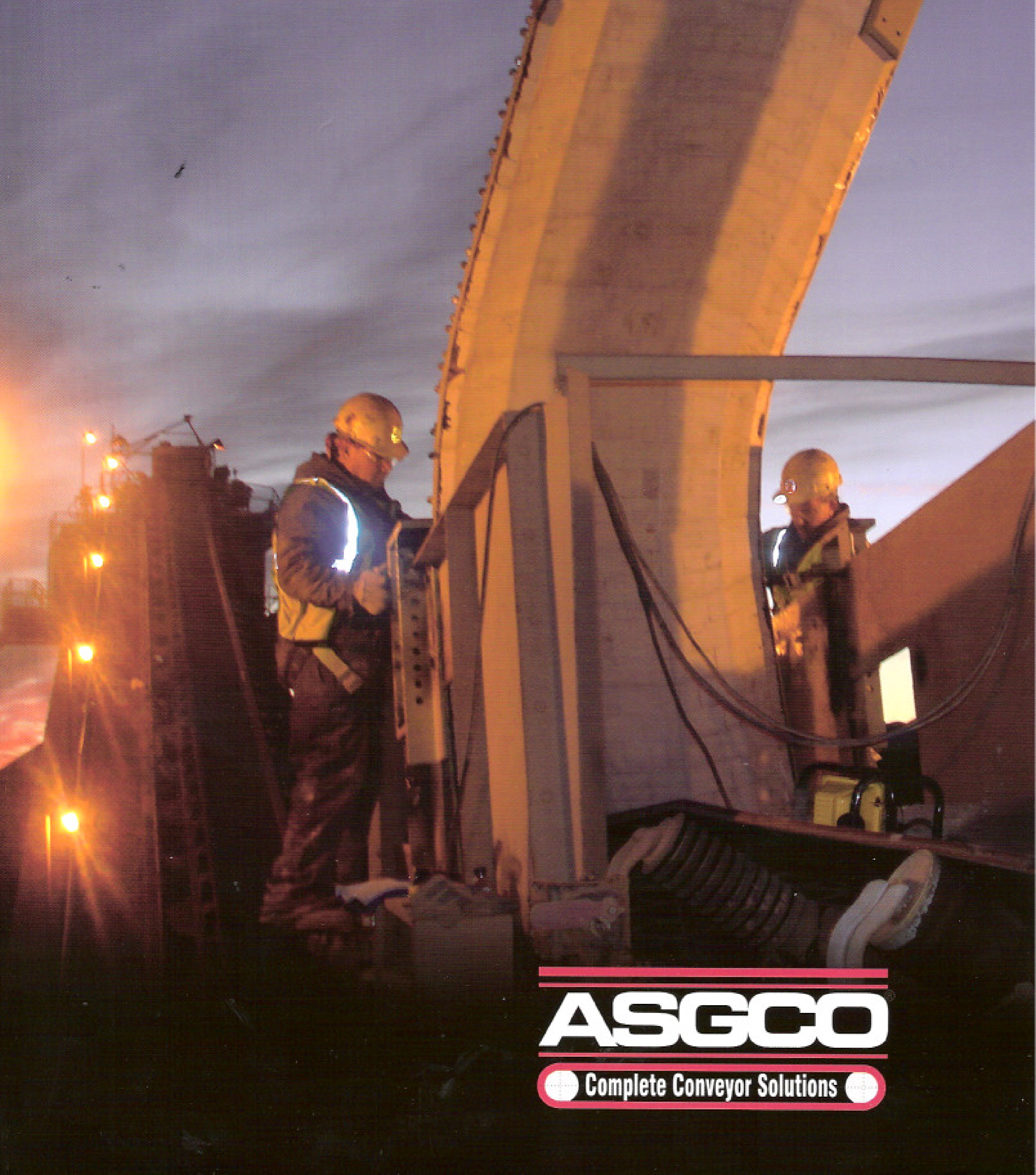

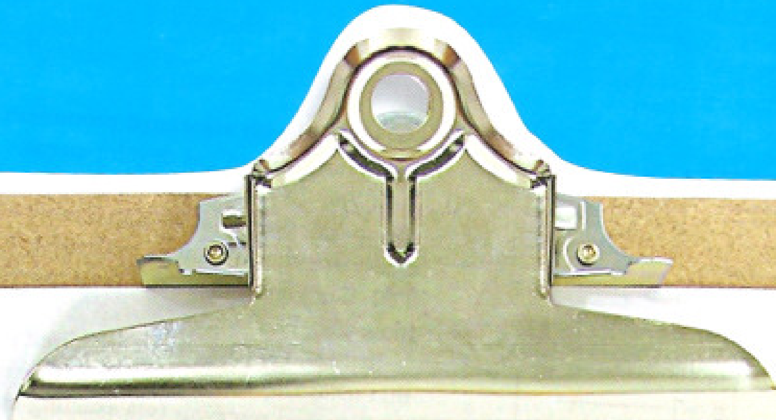

CBM challenges

Dr John M. Pope, GST–WellDog, US, discusses the challenge of reservoir heterogeneity to CBM development.

In the mid-1990s, the Powder River Basin became home to the fastest growing coalbed methane (CBM) development in the world. That growth was accompanied by significant uncertainty about the location of the gas, how much water would have to be removed to produce it, and how many wells should be drilled to accomplish that removal. Those concerns were exacerbated by the land rush and speculation, with associated promotion, that typically drives new oil and gas developments.

In 1999, in response to the concerns, The Blue Sky Group Inc., began to develop a sensor capable of measuring the amount of methane in a CBM well. In 2001, that venture was spun out to create WellDog Inc. (now GST-WellDog).

In 2004, WellDog commercialised a technical service that measures the partial pressure of methane in an undisturbed reservoir (via exacting measurement of the solution gas in an undisturbed reservoir), thereby providing the critical desorption pressure and gas content of methane in the coal. The initial service was executed via a downhole wireline tool. Further technical developments now allow the company to perform the service at the wellhead, for reservoirs being actively dewatered, using fluid brought to the surface from the reservoir via existing pumps and tubing.

Over the past five years, WellDog has been hired to evaluate hundreds of CBM reservoirs in all of the major basins in North America. Those basins included mature producing basins, such as the San Juan and the Raton, as well as emerging basins, including Powder River, Green River, Piceance, Cherokee, Uinta and Alberta Plains. The resulting data have enabled the company to map how gas distributes laterally in a typical coal seam, as well as how gas distributes vertically between typical coal seams under various conditions.

Recently, the company has become increasingly interested in comparing the natural distributions of gas in coals to the distributions predicted by conventional wisdom in the industry, and to the drilling and completion strategies employed by development

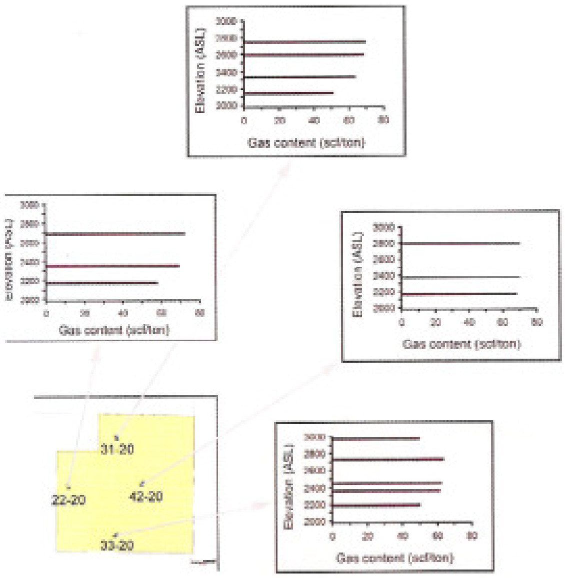

Figure 1. Graphs of coal gas content vs. coal seam depth, in feet above sea level, at four locations in a 320 acre field.

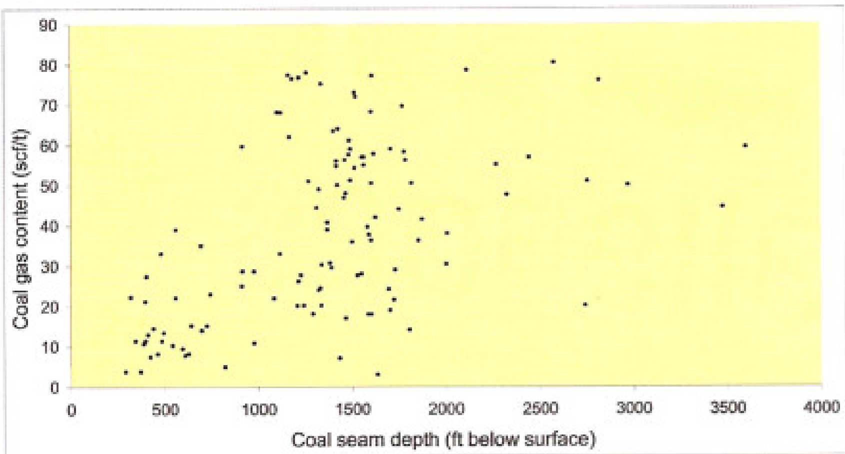

Figure 2. Graph of coal gas content vs. coal seam depth measured in 120 wells completed in 17 coal seams in the Powder River Basin, Wyoming, US.

Table 1. Gas-in-place and water-in-place calculations, and associated economic projections, for a multizone completion pilot in the Powder River Basin.

	GIP (million ft^3)	WIP (bbls)	Gas value (at US$ 3/thousand ft^3)	Water handling costs (at US$ 0.30/ bbl)	Projected net production income (US$)
Canyon-stringer 2	292	335,442	876,000	100,633	775,367
Canyon-stringer 1	522	433,902	1,566,000	130,171	1,435,829
Canyon	985	840,149	2,955,000	252,045	2,702,955
Cook-stringer 2	363	433,691	1,089,000	130,107	958,893
Cook-stringer 1	544	655,522	1,632,000	196,657	1,435,343
Cook	934	1,194,002	2,802,000	358,201	2,443,799
Wall	1429	9,352,501	4,287,000	2,805,750	1,481,250
Total	5069	13,245,209	15,207,000	3,973,563	11,233,437
Selective completions					
Canyon-all	1799	1,609,493	5,397,000	482,848	4,914,152
Cook-all	1841	2,283,215	5,523,000	684,965	4,838,036
Wall	1429	9,352,501	4,287,000	2,805,750	1,481,250

companies as a result. These comparisons reveal significant discrepancies between the expectations and strategies of the CBM industry and the reservoir reality.

Conventional wisdom

Methane is produced as a byproduct of the biogenic and thermogenic coalification processes. In general, coal rank, coal gas capacity and coal gas content increase with increasing coalification. This suggests that deeper and higher rank coals will contain more gas.

After its production, methane is held within the coal pores and cleats by hydrostatic pressure. Because hydrostatic pressure generally increases with increasing depth, this also suggests that deeper coals will contain more gas.

Gas contents are typically assumed to vary somewhat across a basin. Most producers assume that if a core sample gas desorption test shows good gas at one location in a township (23,040 acres), the coal in the rest of that township will contain similar levels of gas. Similarly, many producers will test the gas content in one or two zones of a multizone completion, assuming that the untested two to six zones will show similar gas levels.

When gas prices are high, the production inefficiencies that result from these assumptions are paid for with shareholder profits. When gas prices are low, the resulting inefficiencies can cause companies to fail or to exit the CBM development business.

Reservoir reality

While conventional wisdom can act as a general guide to choosing basins and coal types to develop, it does not offer much help when making the practical decisions of where to drill or which coal seams to complete (or which coal seams to degas before mining). Careful, detailed reservoir evaluation reveals that CBM reservoirs are typically defined by lateral and vertical "sweet spots" of high gas content and producible gas pressures.

For example, Figure 1 shows methane gas content vs. depth at four locations across 320 acres for a package of coals that range in depth from 1000 to 2000 ft below surface. The coals were evaluated vertically, across the package, and laterally, across 320 acres. In this case, the top zone contained more gas (and less water) than the bottom zone.

Figure 2 shows a plot of gas content against coal seam depth for a significant section of WellDog's database on the Powder River Basin. Obviously, correlation of coal seam depth to gas content (for coals of similar rank) remains elusive.

Similarly, lateral distribution of gas in a typical coal does not occur via a gradual gradient, but varies widely and in a non-linear fashion. In many cases, gas distribution appears to depend strongly on substructure in the coal, and not on general trends in depth or location in a basin.

For example, Figure 3a shows how gas is distributed across three sections (1920 acres) in a sub-bituminous coal residing at about 1000 ft below surface. In general, the gas content is concentrated in the northeast of this field. A significant decrease (about 44%) in gas content is observed between that location and the westernmost coal. An even larger decrease (about 60%) is observed between that location and the southeast portion of the same section, less than a kilometre away.

It is interesting to compare this variation in gas content to the variation in the mean seam elevation of the coal in this area, as shown in Figure 3b. Surprisingly, the highest gas content in this field does not occur at the deepest coal, in the west, or in the shallowest coal, in the east, but near what appears to be a slight discontinuity in the coal depth in section 13. Similar discontinuities in coal seam depth in section 15, in the west, do not show similar discontinuities in gas, however.

In another example illustrating lateral gas distribution, Figure 4a shows gas content measured in a circa 2000 acre field containing a sub-bituminous coal seam located about 1200 ft below surface. This field exhibits a significant southwest-northeast discontinuity in the gas distribution. Southeast of this discontinuity, gas contents range from 50 – 80 standard ft^3/t.

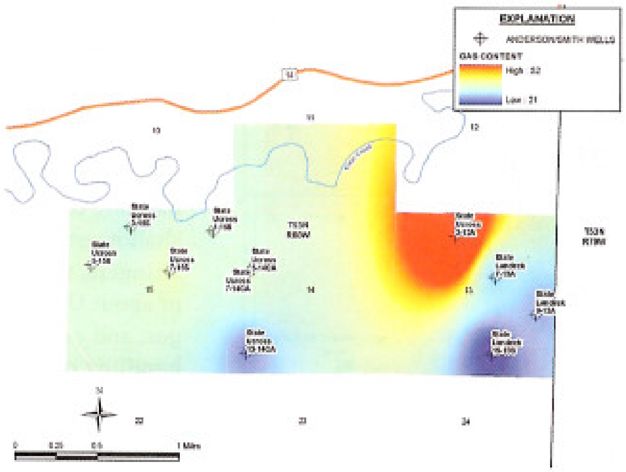

Figure 3a. Isopach of coal gas content for the Smith/Anderson coal seam across about 2000 acres in the Powder River Basin.

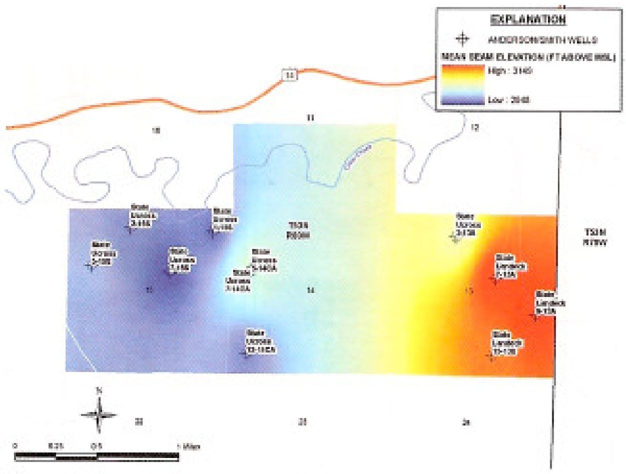

Figure 3b. Isopach of mean seam elevation (in feet above sea level) for the Smith/Anderson coal seam across about 2000 acres in the Powder River Basin.

Northwest of this discontinuity, gas contents range from just 7 – 40 standard ft^3/t. From the peak location to the lowest location, gas content decreases by 90% over just 2 miles.

Figure 4b shows the hydrostatic pressure measured in this field, and Figure 4c shows the mean coal seam elevation in the field. A discontinuity is also observed in these isopachs at the same location, including an unusual circa 500 ft westward increase in coal seam elevation – counter to the basin's east-west dip, suggesting that the northwest and southeast portions of this field are not in hydrologic communication. In fact, they appear to be acting as discrete reservoirs with very different properties. These observations may be explained – or at least supported – by the presence of a river which travels roughly in line with the discontinuity, suggesting that geologic faulting may be the source of the reservoir gas distribution.

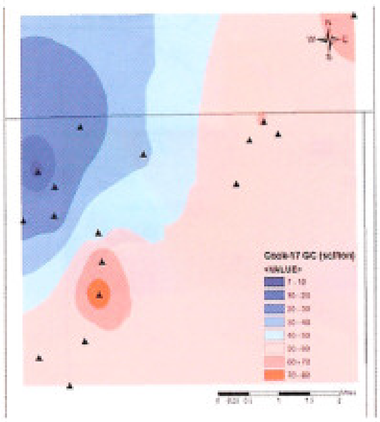

Figure 4a. Isopach of coal gas content for the Cook coal seam across about 2000 acres in the Powder River Basin.

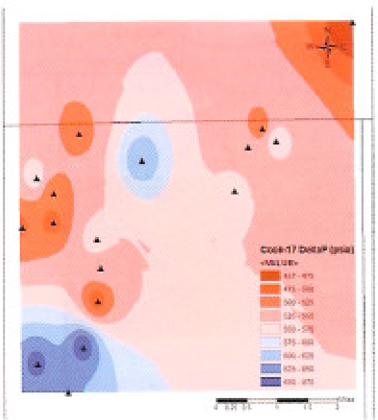

Figure 4b. Isopach of drawdown required to produce gas from the Cook coal seam across about 2000 acres in the Powder River Basin.

Impact on development

It is disconcerting to observe these levels of reservoir heterogeneity over such short lateral and vertical distances in coals of similar rank. When considering the homogeneous drilling and production methods typically employed by the industry, the impact of reservoir heterogeneity on development economics cannot be ignored.

For example, the simple gas-in-place and water-in-place calculations in Table 1, determined for the multizone targets shown in Figure 1, illustrate how completion decisions will impact development economics in this field. Completing all zones, a typical strategy would result in production of about US$ 16 million worth of gas, but at a price of US$ 4.5 million in water handing costs. Completing just the shallowest two coals, and their stringers, would result in production of about US$ 10.5 million worth of gas, and only US$ 2 million in water handling costs.

Similarly, development of the entire field shown in Figure 3 would result in production of US$ 5.7 million worth of gas, and cost US$ 1.9 million in water handling. Production of just the peak gas location in that field would produce US$ 1.1 million worth of gas and cost only US$ 130,000 in water handling.

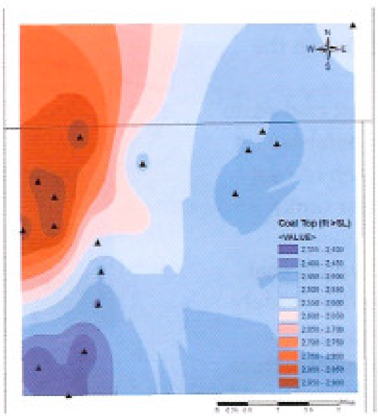

Figure 4c. Isopach of coal top elevation (in feet above sea level) for the Cook coal seam across about 2000 acres in the Powder River Basin.

Is heterogeneous development practical?

When considering adjusting development strategies in response to the heterogeneous reservoir, important issues must be considered. These issues range from the technical (can the producer effectively dewater only a portion of the field?) to procedural (when a producer has drilled and cased a well, it is going to produce that well), regulatory (the gas commission requires installation of infrastructure before drilling – and testing – so most of the investment is made) and strategic (the asset auditors use general numbers for reserves calculations, so heterogeneous gas distribution does not matter to the balance sheet).

The technical considerations are simple to address. For example, heterogeneity in gas distribution implies poor gas and water transport between the various portions of the field and/or between vertical zones. This poor transport indicates that discrete production of water, and thus of gas, in the field and/or between seams is possible given appropriate reservoir access. Targeted production of sweet spots in CBM should therefore utilise higher drilling density in sweet spots and horizontal drilling to quickly and effectively isolate and produce that gas.

The procedural, cultural and regulatory issues that result from the expectations created by conventional wisdom are similarly easy to address, but perhaps more difficult to change. For companies interested in producing gas, however, the increases in production profit attainable by heterogeneous development justify the cultural and operational adjustments required to execute it. The resulting reductions in overall operational size and environmental impacts should allow the industry to grow responsibly and quickly.