Practices and Pitfalls in Estimating Coalbed Methane Resources and Reserves*

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Search and Discovery Article #80011 (2008)
Posted October 29, 2008

*Adapted from oral presentation at AAPG Annual Convention, San Antonio, TX, April 20-23, 2008

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Abstract

The estimation of coalbed methane (CBM) resources and reserves is a complex process due to the layered, fractured, and heterogeneous nature of these reservoirs. CBM resource estimation begins by quantifying variations in areal extent, thickness, gas content, and coal density. These then serve as input for determining the gas resource using probabilistic techniques. During this process, it is important to avoid pitfalls such as generating a resource range that is too narrow or failing to include non-coal lithologies. It is also important to realize, based on numerous examples, that resource estimates are commonly a poor predictor of gas production potential. CBM reserves depend upon demonstrated production which is typically characterized by a dewatering and ramp-up period prior to attaining peak gas rates. Core and log data obtained from appraisal wells provide the gas content and isotherm data necessary to make the first estimates of gas-in-place and potential recovery. This information can be used to initialize screening-level numerical simulation models to understand the critical factors controlling gas production and recommend pilot well types and spacing. Once economic rates are achieved, production forecasts can be generated and compared with gas-in-place estimates to ensure that the reserves numbers are reasonable. After the reservoir is dewatered, material balance and decline curve analyses can be used to estimate reserves in a manner similar to conventional reservoirs. Throughout this process, as shown by several case studies, care must be taken to avoid common technical and managerial pitfalls that result in erroneous reserves estimates and bad decisions regarding which projects to develop or divest.

Practices and Pitfalls in Estimating Coalbed Methane Resources and Reserves

Creties Jenkins
DeGolyer and MacNaughton

Notes by Presenter: The title of my talk today is Practices and Pitfalls in Estimating Coalbed Methane Resources and Reserves. And while the topic of resources and reserves might not be at the top of your list if you're focused on trying to keep a rig busy or prove up a new lease, the topic is of critical importance because…

Reserves are the Basis of Corporate Value

- Over 150 publicly-owned U.S. oil and gas producers file reserves data
- Their total reported oil and gas reserves are valued at over $3 trillion
- Proved reserves account of over 70 percent of their total market value
- Inaccurate estimates cause serious problems
  - Reserve write-downs
  - Poor planning and managerial decisions

From B.G. Dharan, “Improving the Relevance and Reliability of Oil and Gas Reserves Disclosures,” Presented to U.S. House Committee on Financial Services

Notes by Presenter: Reserves are the basis of value for oil and gas corporations.

In the U.S., over 150 publically-traded companies file resources and reserves data, and their total reported reserves are valued at over 3 trillion dollars. This accounts for about 70% of their total market value.

And if you don't get the reserves numbers right, you can have some serious problems. We're all aware that several large companies suffered proven reserve write-downs over the past few years, but in addition to this, inaccurate estimates can cause companies to focus on the wrong fields and the wrong projects, resulting in significantly poorer financial performance.

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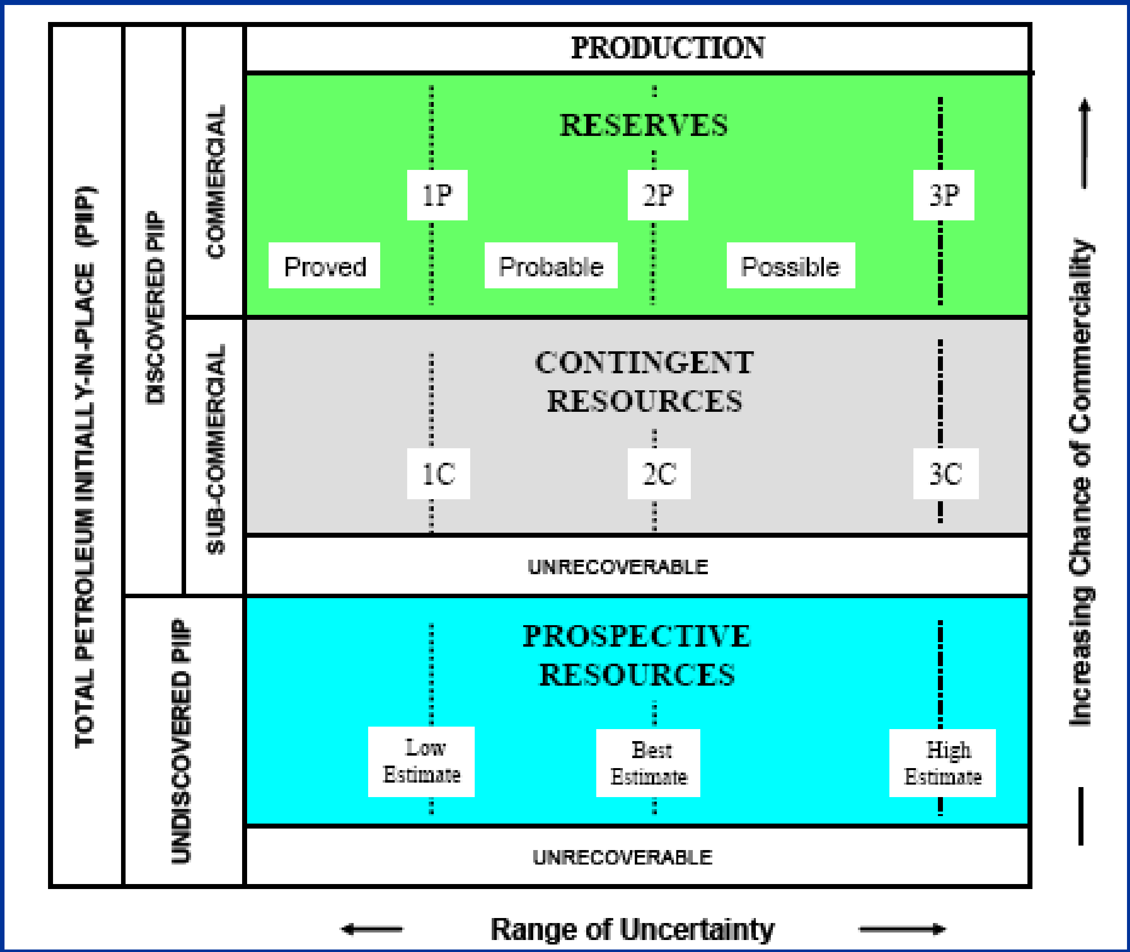
PRMS: Classification Framework



From "Petroleum Resources Management System", 2007, document at www.spe.org

Notes by Presenter: To help companies do a better job of quantifying their resources and reserves, the AAPG, along with the SPE/WPC/SPEE, has developed the Petroleum Resources Management System, or PRMS. It consists of a classification framework composed of…

PROSPECTIVE RESOURCES which are are potentially recoverable hydrocarbons from undiscovered accumulations CONTINGENT RESOURCES which are potentially recoverable hydrocarbons from known accumulations, but there are one or more contingencies that keep these from being classified as reserves.

RESERVES which are hydrocarbons anticipated to be commercially recoverable from known accumulations.

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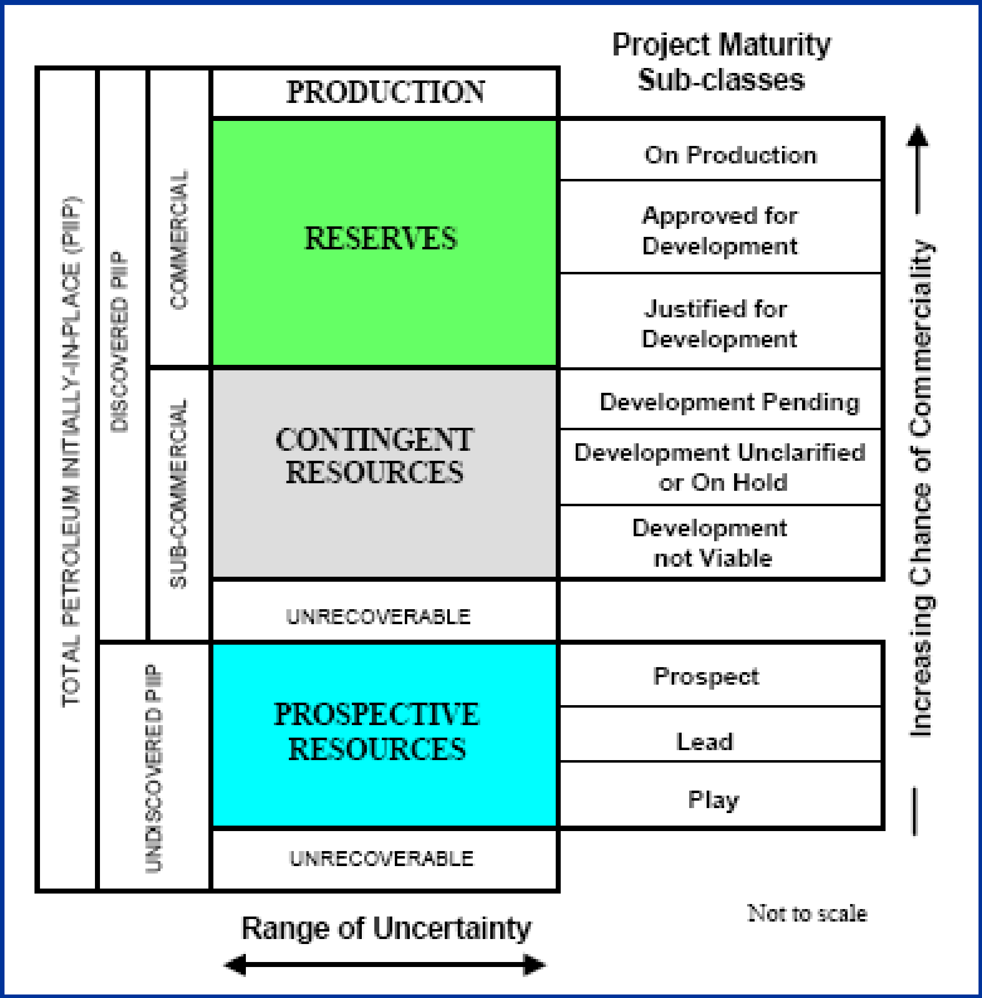
PRMS: Project Maturity Subclasses



From "Petroleum Resources Management System", 2007, document at www.spe.org

Notes by Presenter: The way in which this classification system is supposed to work is shown here. Projects begin life as a play for which leads and prospects are generated. Prospective resources are assigned to these. Then, when a well is drilled, and potentially economic quantities of oil or gas are discovered, the project matures into contingent resources.

Finally, when hydrocarbons can be shown to be economically recoverable under a given development plan, they are classified as reserves.

Treatment of Unconventional Projects

"… there typically is a need for increased sampling density to define uncertainty of in-place volumes, variations in quality of reservoir and hydrocarbons, and their detailed spatial distribution…"

"… successful pilots or operating projects in the subject reservoir or successful projects in analogous reservoirs may be required to establish a distribution of recovery efficiencies for non-conventional accumulations."

From "Petroleum Resources Management System", 2007, document at www.spe.org

Notes by Presenter: This classification system is supposed to be applied to both conventional and unconventional accumulations, like CBM. But, as the guidelines state, there is typically a need for increased sampling, which means more wells, in order to quantify the gas-in-place and the variations in reservoir properties. It may also be necessary to establish pilot projects in order to determine whether gas can be economically recovered, and what kinds of recovery efficiencies can be achieved.

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Conventional vs. CBM: Key Differences

- **Conventional**
  - Discrete accumulation
  - Free gas saturation
  - Must be at critical gas saturation for gas to flow
  - Darcy flow
  - Gas peak at production start
  - Low to moderate permeability variation

- **CBM**
  - Continuous accumulation
  - Sorbed gas content
  - Must be at critical desorption pressure for gas to flow
  - Diffusion + Darcy flow
  - Ramps up to gas peak with time
  - High to extreme permeability variation

Notes by Presenter: The primary reason for this "extra work" is the complexity of these reservoirs compared to conventional reservoirs. Coals contain a continuous accumulation of gas that is sorbed to the surface area of the organic matter. As water is produced from the coals, the pressure drops below the critical desorption pressure, at which point gas diffuses from the matrix and moves under Darcy flow through fractures to the wellbore. Because most CBM reservoirs are undersaturated with respect to gas, they require a significant period of dewatering, which can lead to delayed gas production and poor economics. The gas rate then ramps up to a peak with time that is controlled to a large extent by the coal permeability, which can be highly variable. Wells that are only a few hundred meters apart may have absolute permeabilities that differ by two or three orders of magnitude. CBM wells also exhibit strong directional permeabilities, which may be 20 times higher in the face cleat direction than in the butt cleat direction. Finally, because the coal shrinks as gas is produced, the absolute permeability can increase by a factor of 3 or 4 times over a period of several years.

CBM Resource Estimation Techniques

- **Field analogs**
  - Based on parameter similarities
- **Volumetric methods**
  - Area * Thickness * Gas Content * Coal Density
- **Probabilistic methods**
  - To quantify resource uncertainty

Notes by Presenter: So given these significant differences between conventional and CBM reservoirs, how do we go about estimating their resources and reserves?

Let's look first at CBM resources, which are commonly estimated using three different techniques—field analogs, volumetric methods, and probabilistic methods.

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Field Analogs

Parameter	Prospect	Drunkard's Wash
Area (sq miles)	2000	200
Gas content (scf/t)	150-700	200-500 (400)
Coal Thickness (ft)	30-70	4-48 (24)
Ash content (wt %)	5-25	15
Gas saturation (%)	30-100	100
Permeability (md)	0.5-112 md	5-20 md
Coal rank	High volatile A	High volatile B

Notes by Presenter: Field analogs are often used to get some idea of whether the resource parameters associated with a prospect are similar to those of a commercial property like the Drunkard's Wash Field in Utah.

The biggest problem with this approach is that the prospect parameters are generally associated with just a few wells, and it is common for the parameter range to be much larger than that of the commercial field.

In the example shown here, IF the prospect really has an average gas content of 700 scf/ton, a thickness of 70 feet, an ash content of 5 percent, is 100% saturated with gas, and has 100+ md of permeability, not only will it be better than Drunkard's Wash, it's also going to be the best coalbed methane reservoir the world has ever seen. On the other hand, if two or three of these parameters are at the other end of the range, then the project won't even be commercial.

So from my experience, field analogs are useful for getting people excited about the commercial potential of a prospect, but they are no substitute for the data collection and analysis needed to make an good estimate of resources and reserves in the prospect itself.

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Volumetric Method

- Areal extent
  - From wireline logs, cores, seismic
- Thickness
  - From wireline logs, cores, mudlogs
- Gas content
  - From cores, cuttings, and/or logs
- Density
  - From cores, cuttings, and/or logs

Notes by Presenter: The second, and most commonly used method, is the volumetric method. It consists of using a combination of log, core, cuttings, and sometimes seismic data to determine the areal extent, thickness, gas content, and the average density of a coal seam. Multiplying these four parameters together yields the volumetric gas in-place.

Let's take a closer look at each of these four parameters to see what we can learn about their variability.

Areal Variability

- Individual seams may thicken or be cut-out
- Coal “package” is usually persistent

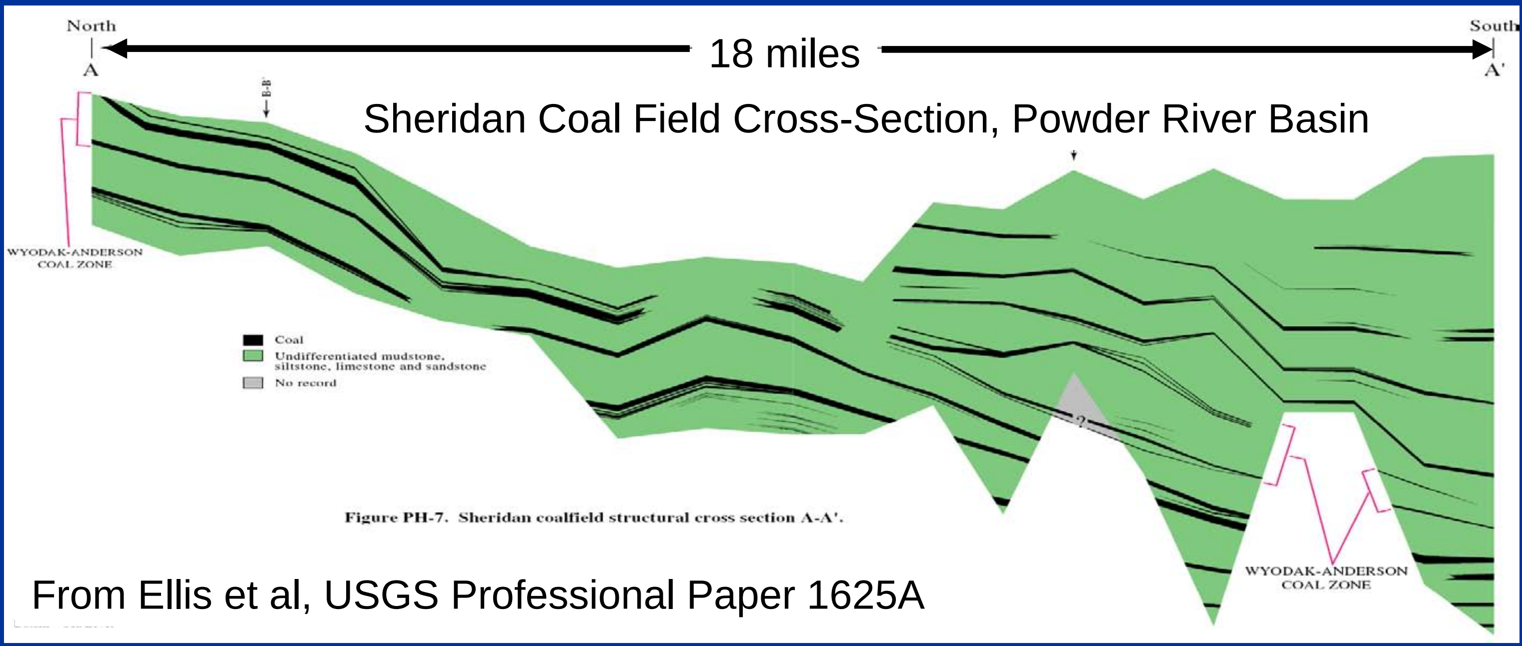


Figure PH-7. Sheridan coalfield structural cross section A-A'.

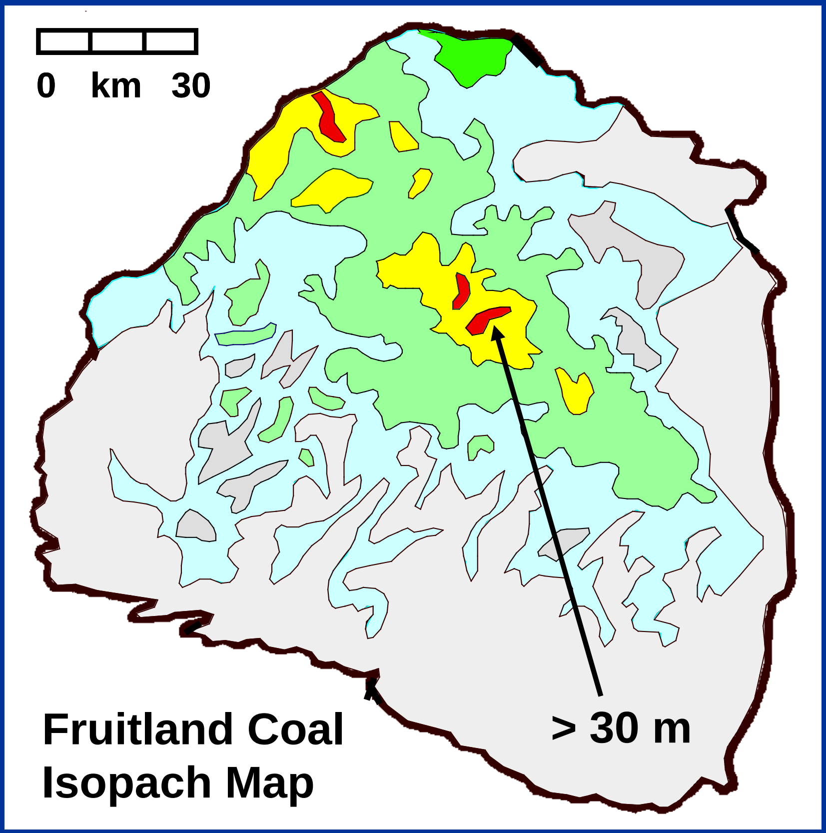
From Ellis et al, USGS Professional Paper 1625A

Notes by Presenter: The first parameter, areal extent, is likely to be the least variable parameter.

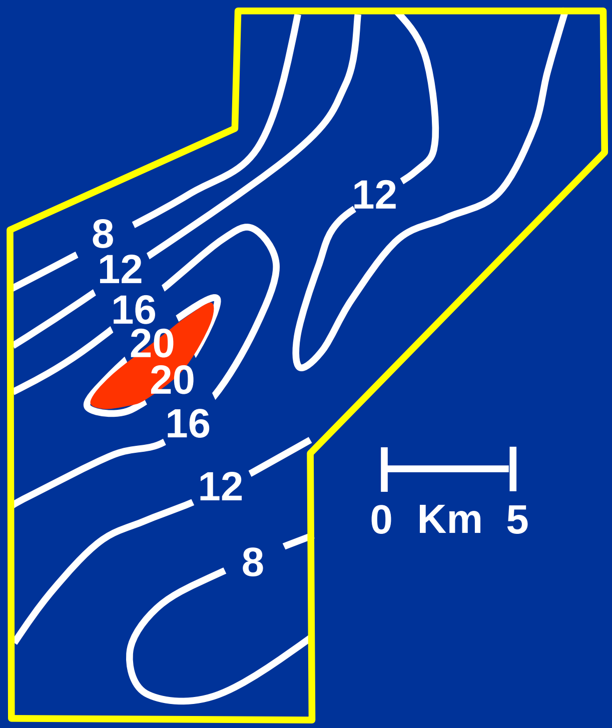
This is because nearly all CBM prospects contain a “package” of coal seams as shown in this 18 mile long cross-section through the Sheridan Coal Field in the Powder River Basin of Wyoming.

Even if individual seams are absent in some locations, there is generally still enough coal in the other seams to result in a sufficient cumulative thickness for economic gas production.

Thickness Variability



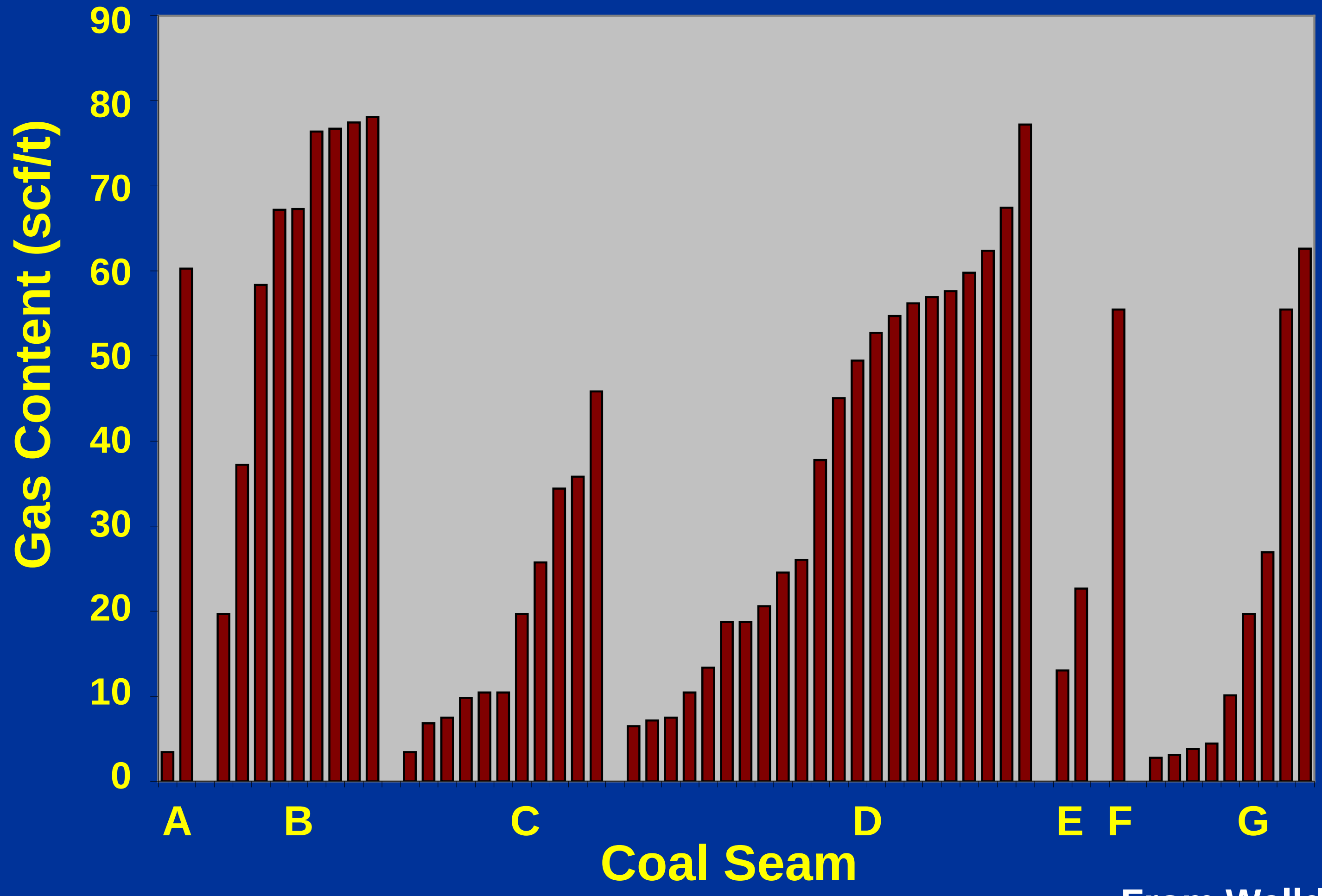
From Ayers and Ambrose, 1990



Coal Isochore Map
Hedong Basin, China
(coal thickness in meters)

Notes by Presenter: The second parameter, thickness, may vary greatly, with the thickest coals being located in certain sweet-spots. The map on the left shows a relatively large sweet-spot--in this case, the CBM fairway in the San Juan Basin where coals can be more than 30 meters thick. These large-scale maps can be misleading, however, because even within a basin sweet-spot, there may be significant variations in coal thickness. The map on the right comes from a sweet-spot in the Hedong Basin of China showing that over a distance of a few kilometers, it is not unusual for the cumulative coal thickness to vary by a factor of two or more.

Gas Content Variability



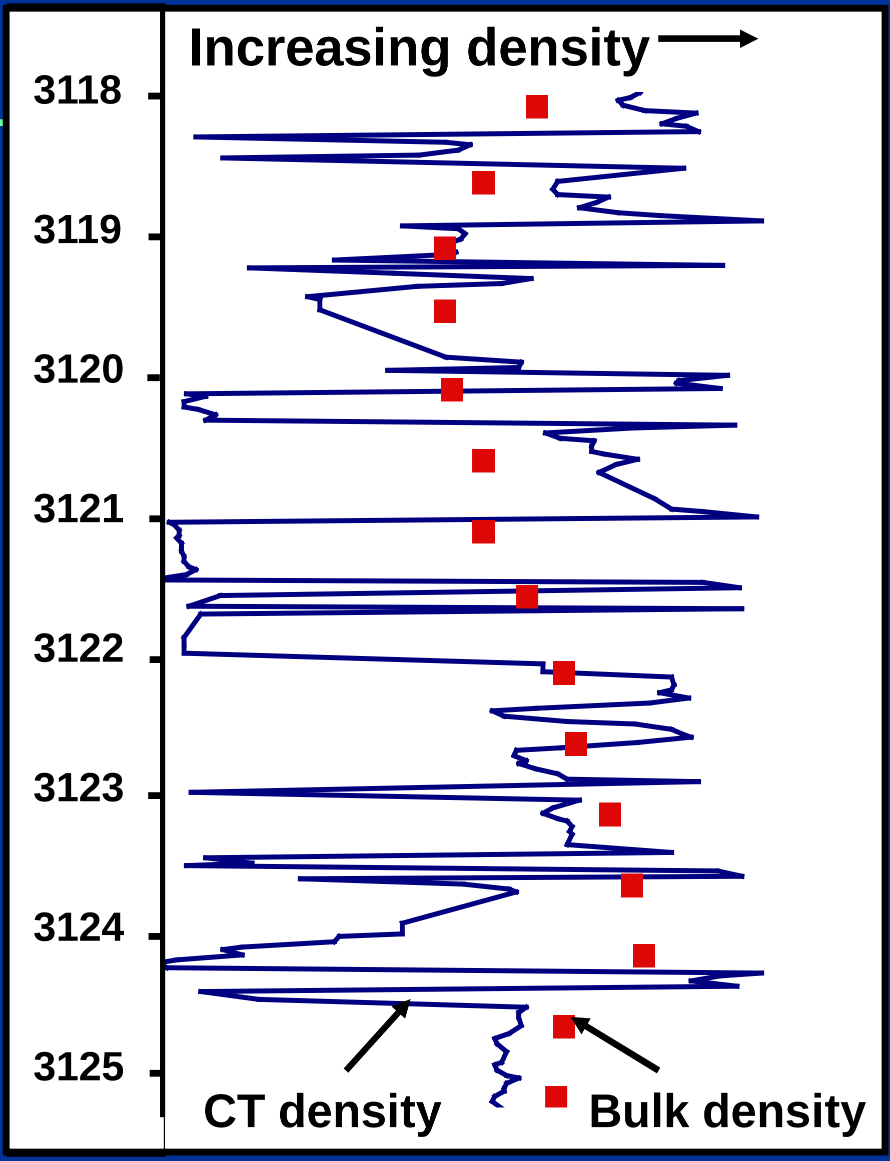
From Welldog, Inc

Notes by Presenter: The third parameter, gas content, can show tremendous variability, depending upon whether a seam is charged with thermogenic and/or biogenic gas, whether gas has been
stripped-out or added by ground water movement, and whether the coal seam has been buried to a shallow or deep depth.

The data on this slide, collected using a wireline-conveyed chemical sensing tool from a company called Welldog in the Powder River Basin, shows, for example, a 16-fold change in the gas content of Seam D, which ranges from about 5 to 80 scf/ton.

Density Variability

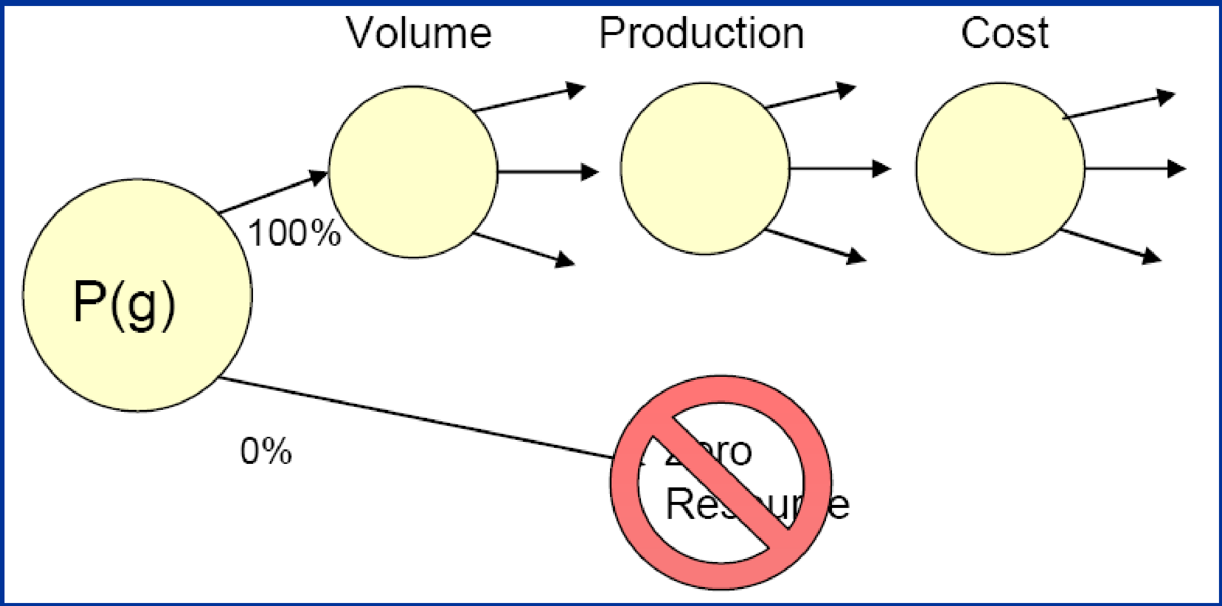
- Coal density heterogeneity is typically much finer than the resolution of conventional wireline logs



CT data courtesy of Walt Ring and Rusty Riese

Notes by Presenter: The fourth and final parameter, coal density, also varies greatly, but this is not something that is commonly reported in the literature because there are few comparisons between density values determined from coal cores and density values obtained from wireline logs. In the example shown here, the coal core, over a depth of 3118-3125 feet, has been subjected to a high-resolution, laboratory CT scan to determine its density variability. You can clearly see thin intervals of low and high density values from the CT scan that cannot be seen on the bulk density log whose measurements, which are made every half-foot, are shown here as a series of red squares. This phenomenon is one of the reasons why you hear people say there's no relationship between the productivity of my wells and the thickness of my coals. Because often times they're just counting all the intervals with a bulk density value of less than 1.75 g/cc as coal, and not considering how much of this interval consists of low density pure coals, which are likely to have the highest gas storage capacity and permeability.

Probabilistic Methods



From Haskett and Brown, SPE 96879

- Chance of geologic success (Pg) is 100%
  - Coal containing some gas is everywhere!
- Other resource parameters will have very wide ranges
  - Leads to large variability in gas-in-place volumes, gas production rates and costs

Notes by Presenter: Because of the variations that are so commonly seen from well to well in a CBM prospect, it makes more sense to use a probabilistic method to estimate the gas resource than a deterministic method that simply comes up with a single number. BUT applying this technique in a CBM reservoir is different than in a conventional reservoir. To begin with, the area in a CBM prospect is generally equivalent to the lease size because, as we've seen, the coal "package" is present everywhere. Therefore, any well that is drilled will produce some gas and will, by definition, be a "geologic success". That is, there will be virtually zero chance of having no resource. This is much different than a conventional gas prospect which typically has MUCH LESS than a 100% chance of geologic success. But the other resource parameters--thickness, gas content, and density--will likely have very wide ranges, and so the estimated resource volumes will have a wide range of uncertainty. This, combined with large uncertainties in gas saturation and permeability, will lead to large uncertainties in the estimated gas volumes, production rates, and project costs.

For example, if you don't know what the permeabilities are, you won't know whether big expensive frac jobs will be required to attain economic gas rates.

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An Example of Narrow Resource Ranges

Zone	Resources (Tcf)	Recovery (%)
Horseshoe Canyon	60-118	26-39
Mannville	239	21-38
Ardley	57	Unknown

Notes by Presenter: These wide gas resource ranges are often not reflected in presentations or the published literature. Here, for example, are some resource estimates that were provided in a talk on Alberta's CBM potential. I would argue that both the resource and recovery ranges presented here are quite narrow, and while it gives people an idea of what might be expected, it also does a disservice by implying that there is less uncertainty in these numbers than really exists.

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Key Pitfalls of CBM Resource Estimation

- Failure to capture the range of possible resource values
- Failure to consider the contribution of lithologies other than coal
- Failure to realize that resource estimates are a poor predictor of production potential
  - Anthracite coals
  - Undersaturated coals
  - Coals connected to large water volumes

Notes by Presenter: So some of the key pitfalls then in CBM resource estimation are, first of all, the failure to capture the range of possible resource values using probabilistic techniques.

A second key pitfall is the failure to consider the contribution of lithologies other than coals, such as tight gas sands and shales. In the Drunkard's Wash example I showed earlier, over half the gas-in-place in the field is contained in carbonaceous shales instead of coals.

A third key pitfall is the failure to realize that resource estimates are a poor predictor of production potential.

For example, anthracite coals, which are very mature, have tremendous gas content values that can approach 1000 cubic feet per ton. But these often have such low permeabilities that they will not be economic. Countries that have plenty of anthracite often boast of their huge gas resources without telling you that little of this will likely ever become reserves.

Similarly, undersaturated coals can have a high gas content, but it may not be economic to produce all the water necessary to reach the critical desorption pressure where gas will start to be produced.

I have also seen several cases of saturated coals with high gas contents that can't be produced because the coal is connected to natural fractures that can't be dewatered.

So you have to be very careful and NOT assume that just because you have a large gas resource that you're going to have commercial gas rates and significant reserves.

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CBM Reserves Estimation Techniques

- Numerical simulation modeling
  - Reservoir mechanisms, sensitivities
- Material balance
  - Requires gas production, water influx estimates
- Decline curve analysis
  - Requires data past gas production peak

Notes by Presenter: So let's turn now from estimating resources in CBM prospects to estimating reserves.

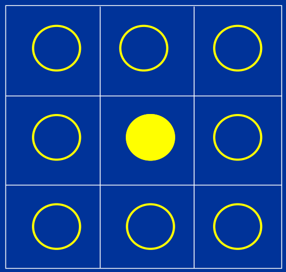
This slide shows a list of techniques that are commonly used to estimate CBM reserves including

(1) numerical simulation modeling,
(2) material balance calculations, and
(3) decline curve analyses.

The next few slides discuss each of these techniques in more detail.

Numerical Simulation Models

- Used for many purposes
- Provides a “best estimate” case for reserves
  - Closest reserves classification is usually the “Proven + Probable” or Median (P50) case
  - Model needs to be history-matched
- Requires modifications for SEC (proven) reserves
  - Values cannot exceed well control
  - Area limited to one offset spacing



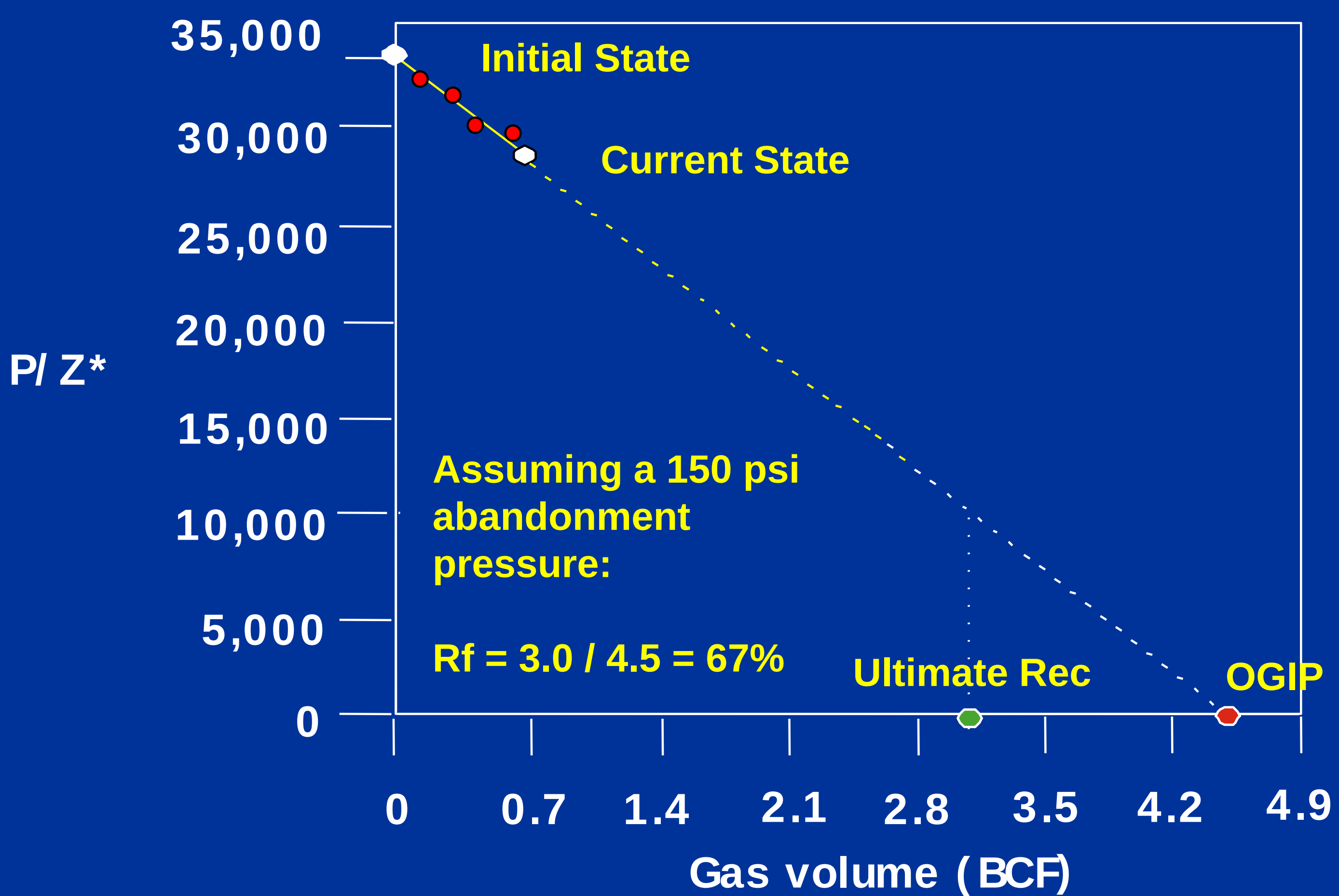
Notes by Presenter: Numerical simulation can be used for many purposes, including the optimization of pilot projects and assessing development well spacings and geometries.

If you're going to use numerical simulators for forecasting gas production and estimating reserves, the resulting reserves are generally considered to be a "best estimate".

That is, the reserves are usually categorized as "proven plus probable" or P50 reserves. But in order to use this to substantiate your estimates, the model needs to be history-matched to well performance.

In addition, if you're going to use these models to estimate SEC proven reserves, there are additional requirements beyond that of the PRMS. Parameter values in the model cannot exceed those values observed from the core, log, and well test data, and the area considered to contain undeveloped proven reserves around a producing well must be limited to one offset spacing. So, for example, in the diagram shown on this slide, the field is being developed using 9-spot patterns, so there can be up to eight proven undeveloped locations around a well producing at economic gas rates.

Material Balance



Z* from King, 1993

Notes by Presenter: Material balance can be used to estimate reserves in CBM reservoirs just like in conventional reservoirs, once significant gas production begins.

A plot is made of pressure divided by the z-factor on the Y-axis versus gas volume on the X-axis. Once sufficient gas has been produced to plot a series of points on the graph and these are fitted with a line, the line can be extrapolated to a P/Z value equivalent to the abandonment pressure. The corresponding gas volume, in this case about 3 BCF,
is equivalent to the reserves.

This biggest problem with the material balance technique is that if the reservoir permeability is low, producing wells will have to be shut-in for a very long time to get accurate static pressures, and what revenue-conscious manager would want to do that?

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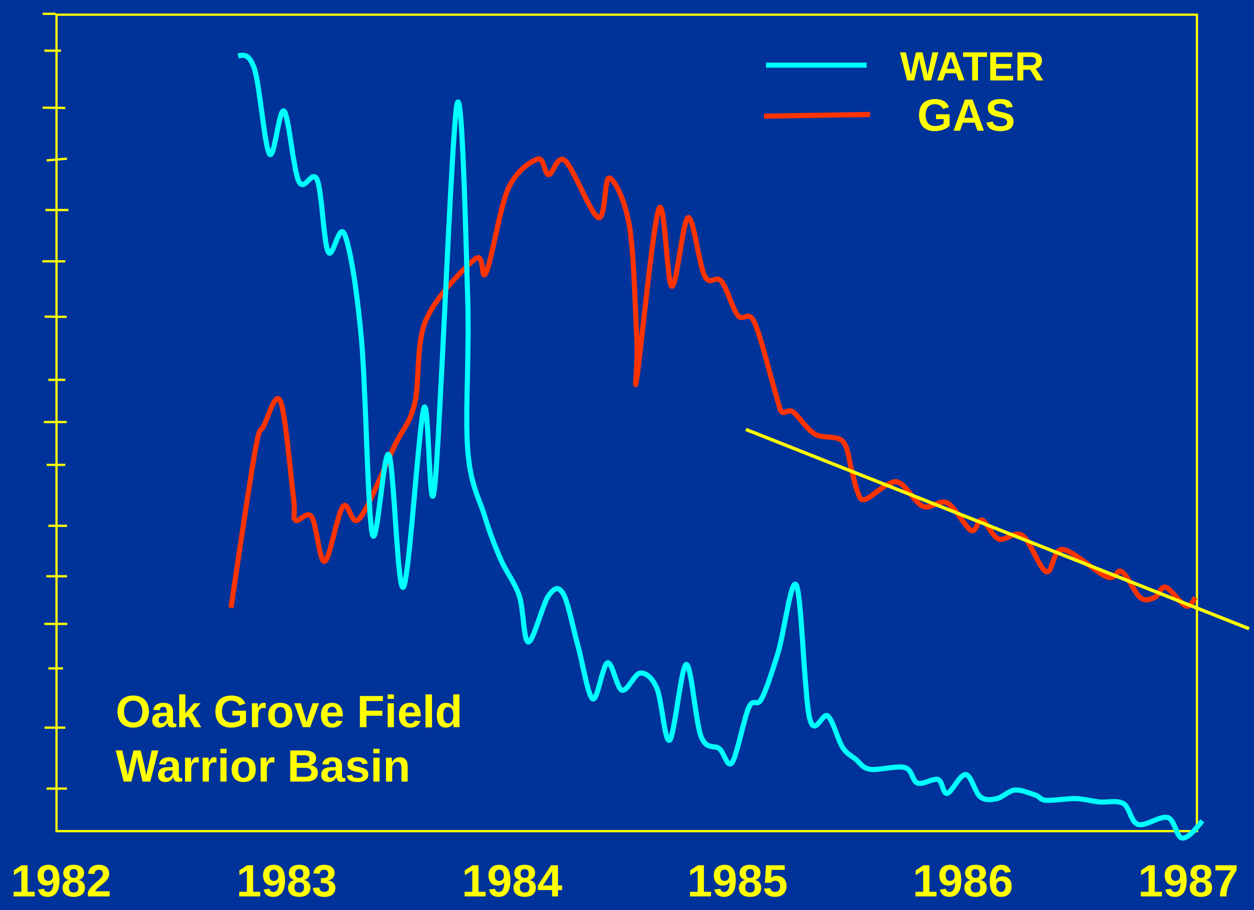
Decline Curve Analysis



Notes by Presenter: Prior to attaining peak production, material balance or numerical simulation are the best choices for forecasting rates and reserves.

Once peak gas production has been reached and the reservoir has been dewatered, CBM wells will begin to show a steady gas production decrease that can usually be fit with an exponential decline curve, just like conventional wells. However, in cases where the permeability is low or multiple seams are contributing, the decline may be very flat for many years, and then steepen later in field life.

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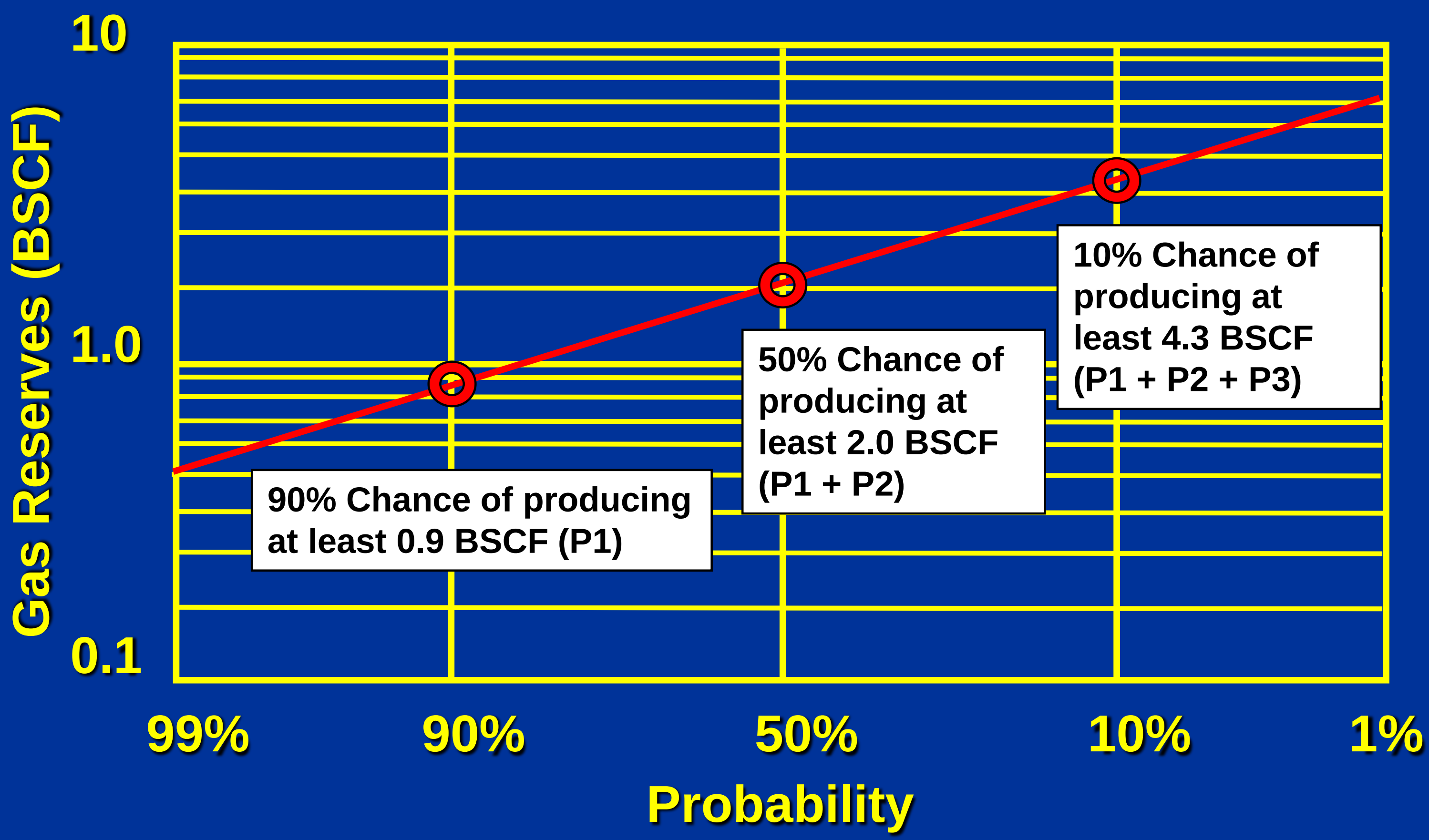
A Probabilistic Assessment of Reserves



Notes by Presenter: And, as was the case with resources, the uncertainty associated with the reserves estimate can be quantified using probabilistic techniques. In the example shown here, the P90 or proven reserves are 0.9 BCF, the proven plus probable reserves are 2.0 BCF, and the proven plus probable plus possible reserves are 4.3 BCF

Key Pitfalls of CBM Reserves Estimation

- Failure to collect, check, and use available data
- The use of optimistic decline curve projections, abandonment pressures, or recovery factors
- Failure to compare the results of two or more methods to estimate reserves
- The belief that good completions can salvage poor-quality reservoirs
- Making unrealistic assumptions as a substitute for missing data
- Working towards a desired number

Modified from A. Merryman, SPE 96776

Notes by Presenter: Now if you're doing reserves estimates, there are a number of technical pitfalls that you should keep in mind. These include:

1)The failure to collect, check, and use all the available data, and make sure that this data is consistent.

2)The use of optimistic decline curve projections, abandonment pressures, and/or recovery factors.

3)The failure to compare the results of two or more methods to estimate reserves, and this includes the failure to tie volumetrics to well performance.

4)The belief that good completions can salvage poor-quality reservoirs-I'm sure that none of you in this room has ever heard that one before.

5) Making unrealistic assumptions as a substitute for missing data, because you don't have sufficient information or experience.

6) Working towards a desired number, which is, of course, at least as big as last year's.

Project Stages and Resources/Reserves

- **Pre-appraisal drilling stage**
  - Collect data from mining coreholes, existing wells, analogs
  - Screening-level and parametric analyses
- **Prospective resources**
  - Are potentially recoverable
  - Based on the presence of coal, gas shows from drilling, coal mine methane, etc.
- **Undetermined contingent resources**
  - If it is clear that the coals produced gas from an existing well

Notes by Presenter: So that takes us through a brief discussion of some the practices and pitfalls of resource and reserves estimation, what I'd like to do now is to match these different techniques to the various project stages to help you better understand how this all fits together.

In the pre-appraisal drilling stage, which can also be thought of as a "project screening" stage, mining coreholes, existing well data, and data from analogs can be used to conduct screening-level and parametric analyses to estimate what the "prize" might be.

At this stage, it is likely that only prospective resources could be estimated, unless it was clear from a producing well test that the coals themselves did contribute gas. In this case, because you would then have a known accumulation of unknown economic potential, you would have undetermined contingent resources.

Project Stages and Resources/Reserves

- Appraisal drilling stage
  - Collect core, log and well test data
  - Conduct numerical simulation
- Contingent resources
  - If technically recoverable
  - Contingent upon dewatering, gas price, development costs, etc.
- Proven Reserves
  - If coal is dry and rates are economic

Notes by Presenter: In the appraisal drilling stage, the collected core, log and well test data from an individual well or wells can be used to estimate the gas-in-place, and a numerical simulator can be used to provide a first-pass estimate of projected gas rates and reserves, assuming that the coal can be dewatered.

At this stage, given that a known accumulation of gas is present and that it is technically recoverable, the project would have contingent resources. These could then be moved into the reserves category once the various contingencies that keep the project from being economic are removed.

If you are lucky enough to have a dry CBM reservoir, like the Horseshoe Canyon play in Alberta, it might be possible to assign proven and probable reserves at this stage, if you have a development plan and can show that the wells are economic.

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Project Stages and Resources/Reserves

- **Piloting stage**
  - **Collect producing and static pressures, water rates, gas rates**
  - **Refine the numerical simulation**
  - **Material balance and production decline curve analysis if coals are dry**
- **Proven reserves in individual wells or well clusters**

Notes by Presenter: In the piloting phase, collected water rates, gas rates, and pressure data can be used to history-match the numerical simulation model and generate both a production forecast and a reserves estimate. If gas production reaches commercial rates at this stage, proven reserves can be assigned to individual wells or clusters of wells. If the coal is dry, gas production should peak quickly and both material balance and decline curve analysis can be used to estimate reserves

Project Stages and Resources/Reserves

- Development
  - Additional dynamic data; refined drilling, completion, and production practices
  - Numerical simulation, material balance, decline curve analysis
  - Proven, probable and possible reserves

Notes by Presenter: Finally, assuming that the piloting phase results in commercial gas production and development proceeds, additional dynamic data will be collected and new techniques will likely be attempted, such as horizontal drilling or customized hydraulic fracturing that will affect reserves estimates.

Numerican simulation will continue to be the best way to estimate reserves until there is sufficient gas production to apply material balance and decline curve analysis techniques.

Summary

- Multiple methods exist for estimating resources and reserves in CBM reservoirs
- The choice of which to apply depends on
  - Project objectives
  - Stage of project development
  - Type and quality of the data
  - Experience and expertise of the evaluator
- Avoid common pitfalls
- Follow established definitions and guidelines

Notes by Presenter: So in summary, multiple methods exist for estimating resources and reserves in CBM reservoirs. The choice of which to apply depends on Project objectives Stage of project development Type and quality of the data Experience and expertise of the evaluator And my advice to you is, first of all, avoid some of the common pitfalls I've described, and secondly, follow the established definitions and guidelines in your work.

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What's Next??

- Establishment of guidelines over the next 1-2 years for applying the PRMS
  – A manual will be published
- Workshops are being conducted
  – To review proposed guidelines
  – To modify the definitions??
- In the meantime, consider using COGEH 3
  – Volume 3 of the Canadian Oil and Gas Evaluation Handbook, published by the Calgary Chapter of SPEE

Notes by Presenter: Which is easier said than done, because the guidelines don't exist yet for applying the PRMS definitions. The SPE is currently working to generate these and is holding workshops in various places around the world to review the proposed guidelines and possibly modify some of the current PRMS definitions.

In the meantime, you can get a copy of COGEH 3 to help you out. COGEH is the Canadian Oil and Gas Evaluation Handbook and Part 3 of this handbook, which was issued in draft form last summer, is titled "Guidelines for the Estimation and Classification of CBM Reserves and Resources". You can find COGEH 3 by doing a web search, or let me know and I'll send you a copy.

Thank you for your interest and attention, and I'll try to answer any questions you might have.

References

Ambrose, W.A., and W.B. Ayres, 1990, Geologic controls on occurrences and producibility of coal-bed methane resources in the Upper Cretaceous Fruitland Formation, San Juan Basin, Colorado and New Mexico: AAPG Bulletin, v. 74, p. 598.

Dharan, B.G., 2004, Improving the relevance and reliability of oil and gas reserves disclosures: Presented to U.S. House Committee on Financial Services July 21, 2004, http://www.ruf.rice.edu/~bala/projects.html

Ellis, M.S., et al., 1999, Sheridan Coalfield, Powder River Basin; Geology, coal quality, and coal resources: *in* Resource Assessment of Selected Tertiary Coal Beds and Zones in the Northern Rocky Mountains and Great Plains Region, U.S.G.S. Professional Paper 1625-A, version 1.2, p. PH1-PH56 on CD.

Harder, V.M., A.R. Papp, J.C. Hower and D.C. Peters, 1998, Atlas of Coal Geology: AAPG Studies in Geology no. 45, on CD.

Haskett, W.J., and P.J. Brown, 2005, Evaluation of unconventional resource plays: SPE Annual Technical Conference and Exhibition, Dallas, Texas, SPE 96879.

King, T., 1993, Flexibility is the key to opencast coalmining: New Zealand Mining, v. 11, p. 41-44.

Merryman, A., 2005, You cannot be ethical if you do not know the rules: SPE Annual Technical Conference and Exhibition, Dallas, Texas, SPE 96776.

Petroleum Resources Management System Report, 2007: SPE, AAPG, WPC and SPEE, http://www.spe.org/.

Society of Petroleum Evaluation Engineers (SPEE) Canada, 2007, CBM Reserves and Resources, International Properties, Bitumen and SAGD Reserves Resources, Part 3: *in* Canadian Oil and Gas Evaluation Handbook, SPEE.

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